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Nordic Perspectives on the Responsible Development of the Arctic: Pathways to Action

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To Marianne Røgeberg and Kyösti Lempa
who helped us along the pathway

Preface

Over the course of the past two decades it has been recognized that the Arctic is experiencing significant change. This has come in the form of environmental, economic, and social alterations to this once remote area. Today the Arctic is more connected to the rest of the globe than ever before and, as a result, increasingly subject to the impacts of globalization—both negative and positive. It is also, as we have learned, influencing other regions through climate change, the exploitation of its energy and other natural resources, and through the establishment of new communication and transportation networks. Within this change-focused setting, long-established ecological and societal communities of the North endeavor to continue to operate.

One of the less investigated regions of the Arctic, that of the Nordic North, has received new attention of late. The scientific inquiries which are the focus of this book have come about as a result of a new interest on the part of the Nordic states with respect to both the changing conditions found within their own northern territories and the ways these relate to the broader global community. Spurred onwards by a long-established tradition of Arctic exploration and scientific investigation, researchers from across the Nordic community have come together under the leadership of NordForsk to consider how change is affecting their northern waters, lands, and peoples and what should be the necessary and appropriate responses to such conditions. The research initiative, *Responsible Development of the Arctic: Pathways to Action*, has been a vehicle to their efforts and the focus of this volume.

Contained within its pages are descriptions and analysis of the work that has been conducted by the four Nordic Centres of Excellence on Arctic research as well as their rationales for undertaking such efforts. Like many other aspects of Nordic society, this scientific investigation is based not only on an awareness of a need to gather additional information about pressing concerns, but it is also pushed forward by a desire to develop new ideas and perspectives on how best to respond to them. Change in the North is steadily becoming a common awareness within the Nordic community. Deciding on what are the appropriate strategies and pathways for action to address this shared reality is of utmost importance. It is the hope of the contributors to this book that their collective efforts can assist in this effort.

This will not be an easy or short-term exercise. The type of research presented in this volume is broad, complex, and multi-disciplinary in character. Yet, this is the very kind of scientific investigation that is required to fully address the reality of the Arctic today. No longer is true headway in the region to be brought about by the efforts of a single explorer—no matter how bold or adventuresome. The current needs and aspirations of the region are too vast. Increasingly, the work that needs to be done must be a shared effort among teams of researchers who are willing to work collectively across disciplinary lines and to share new approaches, methods, and insights.

It will also require the continued support of research funders. Many of these types of research projects require dedicated commitment over several years from both the scientists who are directly involved and the funding agencies that provide the resources necessary for their inquiries. The NordForsk project shows how the pooling of research resources across national lines can be quite effective and result in added Nordic value. A new generation of Arctic researchers within the Nordic community also needs to be developed and encouraged. Their discoveries, some of which are contained in this volume, need to be supported and widely disseminated.

Such research undertakings must also rest on a strong relationship with the peoples who live within the northern areas being studied. They need to be part of the design and implementation of these research efforts and feel they are true co-participants in these endeavors. The co-production of knowledge which is highlighted in several chapters of this book needs to become more of an expected norm in research. Similarly, the results and findings of such inquiries need to be directly shared with northern residents, stakeholders, policymakers, as well as more traditional academic knowledge users. Only in this way can truly successful pathways to action be created and established.

Umeå, Sweden Douglas C. Nord

Acknowledgements

This volume, like the undertaking it chronicles, has been a collaborative effort. NordForsk's Joint Nordic Initiative on Arctic Research has witnessed more than one hundred scholars from across the Nordic states and the global community investing their time and knowledge in exploring the needs and aspirations of the Nordic North in an era of significant change. A quarter of these individuals have contributed their insights and research findings to this book. They represent both established research scholars of the region as well as new professionals just beginning their work in the North. To all, I extend my gratitude for your willingness to participate in this collective endeavor and for the distinct contributions that each of you have made to this work.

A special note of appreciation goes to the leaders of each of the Nordic Centers of Excellence (NCoEs) who helped envision the research plans that they and their colleagues have now implemented. They have advanced their agendas despite some unique challenges to the original plans that they first outlined. In so doing, they have demonstrated important qualities of listening, flexibility and leadership necessary within any collective effort. Throughout the course of this Arctic initiative they have been generous with their time, unflinching in their determination to go forward with the tasks before them, and good humored in their response to ongoing requests for information and details of their efforts. I am truly grateful for the efforts of Birgitta Evengård and Tomas Thierfelder from CLINF, Yongqi Gao and Astrid Ogilvie from ARCPATH, Sverker Sörlin and Dag Avango from REXSAC, and Øystein Holand from ReiGN.

My thanks go out as well to NordForsk and its research funders who provided the substantial and necessary support for such a broad and complex research effort. The Joint Nordic Initiative on Arctic Research represents one of the largest undertakings by the organization and a true example of how added value in research can be achieved from focused and collaborative effort among the Nordic states. The successive Directors of NordForsk during the project's conception and implementation, Gunnel Gustafsson and Arne Flåøyen, have provided the necessary inspiration and encouragement to advance this multi-front undertaking. Marianne Røgeberg and Kyosti Lempa as Senior Advisers have successively served as the day-to-day administrators of the project within NordForsk and have been of great assistance to all who have been involved with it. Their hard work, good counsel, and advice have been much appreciated. So too are the efforts of the Programme Committee whose members have taken an active interest in the project from the outset and provided excellent feedback and suggestions for the NCoEs. The same can be said for the members of the Scientific Advisory Board who have regularly reviewed and assessed the progress and achievements of the NCoEs.

The formulation of this volume has come from contributions from all the above. An effort has been to capture the essence of a broad and complex research project. The book provides a "snapshot in time" as each of the NCoE projects are still underway at the time of this writing. Their full impact and significance will not be known for some time as is always the case with such innovative scientific research. It was felt, however, that this "first bite at the apple" was a worthy undertaking in that it helps to underscore both the challenges and benefits arising from undertaking such groundbreaking work. It also provides a unique opportunity for researchers to share with the Nordic societies and the broader global community what can be accomplished when necessary resources are committed to helping to build necessary pathways for action in the North. Thanks also go to Lars Kullerud, Heather Nicol, Joël Plouffe, and Timo Koivurova who encouraged me to pursue the possibility of producing such an edited volume. Also, my appreciation is directed toward half a dozen colleagues who read the initial drafts of each of the chapters and offered suggestions and advice to the authors. To those individuals and the staff at Springer who helped with the book's final editing I am truly indebted. I thank you for your expertise, insight, and collaborative spirit. For any remaining limitations of the volume, I take full responsibility.

One of the clear messages contained within the book is that there is still much that needs to be done in investigating, documenting, and responding to the needs of the Nordic North in environmental, economic, social, and political terms. This initiative and the research findings and perspectives that it has brought forth are by no means the final word on any of these subjects. Instead they simply point us in some new directions from where we must continue our inquiries. Nor, should our mood be one of foreboding. As one of our colleagues has noted, there is lots of good news coming out of the North today that needs to be shared and publicized. Despite all the challenges, real accomplishments and goals are being achieved in the Nordic North as well as the broader circumpolar Arctic. Many of these have come about through expanded research efforts like the ones described here and the collaborative work among scientists, Indigenous peoples, and local residents of the region. This is a pathway to action that needs to be continued and supported.

Umeå, Sweden Douglas C. Nord

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About the Editor

Douglas C. Nord is an established scholar in the fields of international relations and comparative politics. His areas of specialty include the foreign and northern development policies of Canada, the Nordic states, Russia, as well as the USA. He has written extensively on the relations between the countries of the circumpolar north and on the emergence of the Arctic as a central concern of contemporary international politics. Professor Nord has taught and undertaken research inquiries at various educational institutions across the region. He presently conducts his studies of the North at Umeå University in Sweden where he is an Associate Research Professor at the Arctic Research Centre (ARCUM). Professor Nord has studied the Arctic Council for over 20 years and has published three volumes related to the organization and its work: *The Changing Arctic: Creating a Framework for Consensus Building within the Arctic Council* (2016); *The Arctic Council: Governance within the Far North* (2016); and *Leadership for the North: The Influence and Impact of Arctic Council Chairs* (2019). He presently serves as the Chair of the Scientific Advisory Board for NordForsk's Nordic Centres of Excellence in Arctic Research.

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Part I

Chapter 1
An Introduction

Douglas C. Nord

Abstract This chapter considers the current state of change within the Nordic Arctic and some of the challenges it presently confronts. It then moves on to examine the particular vision of the region that has developed within the Nordic community. It discusses some of the forces that have helped to create this Nordic vision of the Arctic and the ways in which many of these same forces continue to a fashion a distinctive Nordic attitude and approach to the area. The essay then addresses some of the leading concerns of the Nordic community regarding the future of the Arctic region. It also considers some of that community's efforts to collectively plan for the responsible development of its most northern areas. Special attention is given to the role played by the Joint Nordic Initiative on Arctic Research. It takes note of its overall guiding concerns and objectives and considers how the four Nordic Centers of Excellence in Arctic Research may help to build new pathways for scientific investigation in the region and needed policy development. The essay concludes with a brief summary of some of the research initiatives that have been part of the efforts of the Centers and which are explored in greater detail within the subsequent chapters of this volume.

Keywords Nordic region · Arctic research · NordForsk · Centers of excellence · Arctic

The past two decades have witnessed major changes within the Arctic. A variety of forces ranging from climate change to the continued exploitation of its natural resources have combined to alter the face of the region in a significant manner. Often the people who live within the contemporary circumpolar North feel at a loss as how best to respond to these altered conditions. The challenges of adaptation

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and building new resilience within their communities and environment can appear to be often daunting. The specific paths that they should follow toward a more predictable and sustainable future may not always appear that clear (Evengård et al. 2015).

This is certainly the case in the Nordic Arctic. This far northern edge of Europe provides a clear example of how northern communities have had to confront multifaceted change within their midst and to develop new strategies and approaches to deal with it. Although the region has, perhaps, received less attention than other areas of the circumpolar North, the challenges and opportunities found there are not that dissimilar from those seen in northern Alaska, Canada or Russia. What is distinctive about this particular northern community, however, is the manner in which its residents have sought to organize their thinking and actions regarding how change can be addressed and acted upon.

Central to this Nordic undertaking has been an effort to share analytical resources and apply scientific research to the challenges and opportunities arising from these changing Arctic conditions and circumstances. One of the best examples of this approach has been the establishment of a Joint Nordic Initiative on Arctic Research facilitated by NordForsk, the research arm of the Nordic Council of Ministers. Under its auspices four major Centers of Excellence have been created to examine pressing northern concerns and to facilitate policy discussions on such diverse topics as climate induced change, health security, natural resource utilization and community enhancement (NordForsk 2016).

The effort to create and implement an organized response to change in the Nordic Arctic is the focus of this volume. The work first considers a number of the more pressing needs of the region and then examines how research is being organized to respond to them. The work also examines some of the specific challenges and opportunities that arise in conducting scientific investigations across such a broad domain. It discusses the merits of utilizing both multidisciplinary teams of investigators and the application of specific research methods aimed at encouraging community engagement and benefit. Each of these undertakings represents an innovative step in Arctic research and, as such, worthy of careful analysis and consideration.

However, before moving in this direction, it might be profitable to begin this discussion by first considering the context for such efforts. This necessitates a brief view of the Nordic region, itself, and its dimensions. It also requires some consideration of the manner in which the Nordic community has traditionally viewed its own most northern lands. It is probably helpful, as well, to examine how Nordic policy toward the Arctic has been conceived and developed over time and what may appear to be the priority concerns of the region today. All of this can contribute to a better understanding of the distinctive Nordic perspectives on the Arctic that guide these current scientific research activities.

1.1 The Nordic Region

The Nordic community is composed of five countries—Denmark, Finland, Iceland, Norway and Sweden along with associated areas such as Greenland, the Faeroe Islands and Svalbard. Their total population is relatively small—some 27 million individuals who collectively represent less than 1% of the world's total. In geographic terms, the Nordic territory is somewhat larger—representing close to 3.4 million square kilometers and collectively forming the seventh largest region in the world (Fig. 1.1). As such, the Nordic area is a significant but relatively sparsely populated component of the globe (Nordic Council 2018).

It is also a region whose history and societal development are not particularly well known by those outside its borders. The Nordic region has not commanded the attention that other areas of the world have done so over the last few centuries. Nonetheless, the Nordic societies continue to play significant roles in the economic, social, political, cultural and scientific evolution of the global community. Its citizens have also assumed leading positions within a number of international organizations charged with the responsibility of promoting global peace, security and environmental protection.

As such, the Nordic region has been seen as providing an example of how "small states" or societies can exert influence far beyond their expected capacity to do so. In continually "punching above their weight" the Nordics have come to command the attention and admiration of observers from across any number of fields and endeavors (Ingebritsen 2006). The Nordic example or "model" is frequently referenced by those inside and outside of the region as a way of addressing and solving major societal needs and concerns in the contemporary era. One of its most frequently cited features is how Nordics tend to work together to address common needs and opportunities. This tradition of cooperation and the pooling of resources among neighbors can be seen across a variety of areas (Hilson 2008). The collective Nordic response to the challenges of the Arctic is but one of these and forms a connecting thematic thread within this volume and will be examined in a variety of contexts within its subsequent chapters.

1.2 The Nordics and the Arctic

The portion of each Nordic state that can be found within the Arctic varies from nation to nation. However, depending upon the definition of the Arctic utilized, fully a quarter to a third of each Nordic state's territory can be deemed to be located within this region. Most of these northern areas are sparsely settled with no more than 10% of each Nordic country's citizen's to be found there. Yet they represent a significant element of societal wealth that is rooted in the development and utilization of the natural resources found in these northern lands. Despite this fact, the North

Fig. 1.1 The Nordic region

has also experienced high levels of unemployment that are reflective of the periodic declines in its natural resource-based economies. The Nordic North has also witnessed regular outmigration from its more remote areas to both urban centers within the region as well as to communities located further south. In its wake, the region has suffered a variety of societal challenges including both outmoded transportation and communication networks and the inadequate provision of health and social services when compared to southern communities.

The Nordic Arctic is not generally well-known or understood by either its own fellow citizens or external observers. The northern areas of each country do not figure prominently in either their national histories or their society's day-to-day operations. It is an area that tends to be overlooked by government and the media. The "northern dimension" of these countries is not usually promoted or popularized by them to the same extent as can be seen in other circumpolar societies such as Canada, Russia or Alaska. Tourists and recreational enthusiasts spend time in the region, but most visitors—foreign or domestic—rarely see the Nordic Arctic as a place for permanent settlement, broad-scale economic investment or cultural enhancement. These northern communities face a regular challenge in promoting themselves and receiving adequate attention and resources from power centers situated in the south. Often, they are viewed as being too remote or too small in population to figure in the overall calculus of either key private or public sector decision-makers (Eriksson 2008).

Despite this lack of a prominent Arctic profile, the Nordic states have made significant contributions over time to the development of a true circumpolar community. They have contributed some of the most noteworthy of the early explorers who sought to map its lands and chart its waters. Names like Leif Ericsson, Vitus Bering, Adolf Erik Nordenskiöld and Fridtjof Nansen occupy positions of importance in such efforts. Similarly, Nordic scientists such as Carl Linnaeus, Harald Sverdrup, Hans Ahlmann and Kristian Birkeland all played prominent roles in developing the fields of Arctic biology, meteorology, glaciology and ecology. More recent Nordic researchers have also led the way in advancing new technologies of importance to the development of the Arctic including those related to transportation, communication and scientific observation and measurement (Sörlin 2013).

Nonetheless, much of any Arctic dimension of the Nordic countries tends to derived from the profile of its indigenous populations—the Sámi in Norway, Sweden and Finland and the Inuit in Greenland. These communities have figured prominently within most Nordic visions of their Arctic lands and in the development of a growing tourism industry within the region. Along with the iconic appeal of the reindeer, polar bear and the northern lights, the traditional cultures of these northern peoples have helped to provide a distinctive image of the region for both their domestic and external audiences (Müller 2015). However, like many other indigenous communities across the globe, this popular imagery can be at variance with reality. Both the Sámi and the Greenlandic Inuit societies face a number of challenges that make the continuation of their traditional lives in the Arctic ever more problematic over the coming years. Climate change, the steady over-exploitation of natural resources within their lands and the introduction of post-modern ways of life all pose significant problems. Likewise, the reluctance of government officials to recognize their traditional rights and the uneven treatment they have received from bureaucracies situated in the south remain a serious concern (Kuokkanen 2019).

On the whole then, the dominant Nordic view of the Arctic can be seen to be somewhat limited and uneven in character. Though significant portions of their own national territories are to be found in the region, there has been a tendency on the part of the Nordics to give only somewhat limited attention to the needs, concerns and interests of the lands and people found there. Frequently seen as a remote area "above the fold in the map" residents and policymakers from the rest of the Nordic area are only now becoming more fully aware of the challenges and opportunities that need to be addressed there.

1.3 The Nordics and Arctic Policy Development

The development of distinctive northern or Arctic policies has varied among the five Nordic countries especially in the domestic context. Some of the Nordic states like Finland and Norway have developed extensive efforts at northern regional development and promotion. Others like Sweden and Iceland have preferred to address the needs and challenges of their northern communities within the framework of overall national policies designed to encourage economic growth and the provision of necessary social services throughout their societies. Denmark's unique relationship with Greenland and the Faeroe Islands has resulted in very locally focused efforts undertaken in conjunction with the home rule administrations. As a consequence, no common "Nordic model" has emerged from such endeavors.

At an international level, however, there has been more of a shared perspective and approach to the concerns of the Arctic. As countries long-experienced in global diplomacy and international organization, the Nordics have acted largely in concert with one another in promoting a common agenda for action that includes protection of the environment, addressing climate change, encouraging sustainable development and providing adequate health, education and social services for the entire circumpolar community. They have also provided necessary leadership for the main coordinating and problem-solving bodies that have emerged within the area. The ideas behind the Rovaniemi Process and Barents Cooperation have their origins within the Nordic societies and can be seen as logical extensions of the previous efforts at cooperation and collaboration embodied by the Nordic Council (Young 1998).

Similarly, the Nordic states have played significant roles in the development and evolution of the Arctic Council. They have encouraged this key forum for Arctic enhancement to expand its efforts and increase its effectiveness (Nord 2016a). During their first terms as successive chairs of the body, Norway, Denmark and Sweden promoted a common Scandinavian agenda that sought to strike a balance between demands for environmental protection and sustainable development across the Arctic. They also worked together to bring new issues and participants to the decision-making table. This successful model of cooperation and innovation has continued during the subsequent chairmanships of Finland and Iceland (Koivurova 2019).

The one topic that has eluded a broad Arctic consensus among the Nordic states at the international level has been with respect to the provision of "hard security". Three of the countries (Denmark, Iceland and Norway) have been long-term members of the North Atlantic Treaty Organization (NATO) and have viewed the Arctic as a component of this mutual defense arrangement. They continue to maintain strong ties with the other Arctic NATO countries, Canada and the United States. The two other Nordics, Sweden and Finland, have elected not to join NATO and have pursued more non-aligned defense policies. With such distinct differences in approach with respect to defense planning, the Nordics have chosen to focus their collective efforts on "soft security" needs of the Arctic region including environmental monitoring, species protection and the furthering of community resilience in the wake of climate change (Eklund 2019).

Each of the Nordic states has also displayed differing approaches in outlining their overall Arctic policies and priorities. Some like Norway and Finland have been quite active and engaged in articulating their national perspectives on the region including an extensive consideration of both the domestic and external dimensions of their Arctic visions. Others like Denmark, Iceland and Sweden have been more hesitant and circumspect in such undertakings. Nonetheless, they have pursued a fairly consistent set of agendas during their chairmanships of the Arctic and Barents Councils focusing on items such as the effects of climate change, the need for economic diversification and the use of green technologies (Government of Finland 2017).

A commonly shared characteristic of the Nordic states in their approach to Arctic matters at both regional and international levels has been their offering of both focused attention and necessary funding to advance agreed upon new initiatives. Whether in the context of international climate negotiations or through their specific support and funding of Arctic Council and Barents Council initiatives, the Nordics have always been seen as strong and visible advocates for action to address growing matters of Arctic concern. They have always provided both scientific expertise and sufficient resources to support such efforts. As a consequence of this tradition of commitment, the Nordics as have been viewed as potential leaders in the effort to address some of the more pressing challenges faced by the Arctic today (Nord 2019).

1.4 What Are the Current Concerns of the Nordics with Respect to the Future of the Arctic?

Over the past decade, a number of assessments have been made of what are the priority concerns of the Nordic states with regard to changes in the Arctic—both from a sector and circumpolar perspective. National studies, regional investigations and plans for action by such bodies as the Arctic Council and Barents Councils provide good overviews of what contemporary Nordics are thinking (Government of Sweden 2018). In reviewing these documents, a consistent top-ten list of priority items tends to emerge. At the top of this list is environmental protection. From the issuance Environmental Protection Strategy in 1992 until the present day this has been the number one priority of the Nordic states with regard to the Arctic. The monitoring, defense and encouragement of healthy ecosystems within the region has been a consistent concern of the Nordic community (Keskitalo 2004).

Over the last decade this leading issue has been augmented by a second major concern—that of climate change. The Nordics have been in the forefront of nations asking for action in response growing alterations in the world's climate. They have led the way at international negotiations to impose restrictions on the production of greenhouses gases which are seen as primary contributors to climate change around the globe. They also have been at the forefront in drawing attention to the significant increases in temperature and ice-melt within the Arctic region and to the detrimental consequences that such developments have for both the immediate circumpolar community and the broader world (Hernes 2012).

A third commonly-held perspective of the Nordics with regard to the needs of the Arctic is a consequence of the two mentioned above. In highlighting the challenges and the need for action in the areas of environmental protection and climate change, the Nordics have been leaders in the promotion of such concepts as sustainability, adaptability and resilience. From the Brundtland Report in 1997 onwards, the Nordics have pioneered new thinking and approaches regarding how the modern world can respond in an effective manner to major socio-environmental challenges. They have stressed the need for humankind in its present and future evolution to live and work more in harmony with its natural setting, The Nordic countries have been in the vanguard of efforts to establish effective "green policy" practices and to share their ideas with the broader global community—including their fellow residents of the Arctic region (Government of Sweden 2017).

This concern for maintaining the environmental health of the globe has been advanced within the context of Nordic thinking with respect to the economic development of the Arctic. As noted above, the natural resources of the North have long been a central component to the economies of five Nordic states. All see their continued utilization to be important elements of their future economic growth and prosperity. The major change that has come in the last few decades, however, is the new emphasis given by the Nordics to the sustainable development and utilization of the resources of the region. This has become the fourth major focus for Nordic thinking with regard to the Arctic. Whether in the case of forestry, fishing, or energy production new focus has been placed by the Nordics on sustainability and the future development of these industries in harmony with their natural settings. Equally important, new attention has been given by the Nordics both to how threatened enterprises like reindeer herding and mining can be made more responsive to their communities and whether new economic initiatives such as tourism, recreation and those related to modern science can be developed in a sustainable manner in these areas (Sköld 2015).

A fifth focus of Nordic attention directed toward the Arctic relates to technology and research. The five Nordic countries have long been recognized as global leaders in scientific research and technological innovation. Increasingly these five countries have directed new thought to how such expertise can be applied to the challenges of living and working in their own Arctic lands. Over the last few decades, major initiatives have been undertaken by both private and governmental funders to promote investment in transportation, communication and cutting-edge scientific research within their northern communities with the goal of promoting them as new hubs of innovation. These initiatives have been augmented by other efforts to stimulate additional research and growth in more traditional technologies such as in ice breaking and snow removal, the production of specialized mining and forestry tools as well as in the creation of world-class winterized clothing and recreational equipment. The advancement of research and investment in such areas has been a priority for all of the Nordic states when they have headed such bodies as the Arctic Council and the Barents Council (Barents Regional Council 2013).

Health is a sixth significant interest of the Nordics with respect to the Arctic. Part of their concern relates their continued need to provide adequate health services within their own northern communities. This is supplemented by a real interest in the articulation of best health care practices that can be shared throughout the circumpolar world. Nordic concern in health matters in the North also includes a focus on the education and training of health care workers and the utilization of new approaches, methods and technologies there. Still another dimension of this Nordic focus on health matters in the Arctic is the community's stated desire to develop an effective response to the introduction of new pathogens into northern lands as a result of climate change (Parkinson et al. 2015). The effort to create additional monitoring and response capabilities to meet the challenges of these climate sensitive infections (CSIs) will be detailed in subsequent chapters of this book.

A similar Arctic challenge that has been identified by the Nordics relates to the offering of education and training in the region. This seventh overall area of focus arises from perceived need to provide new and enhanced educational opportunities for their citizens of the region. This comes as a response to continued higher levels of unemployment in northern areas and the need for local residents to adapt their capabilities to changing global economic conditions. Not only is there a requirement to provide new training options within established resource-based communities, but there is also a need to offer new educational programs that would allow residents to pursue careers in new high-tech and knowledge-based industries that are increasingly being introduced into the region. This requires the provision of an expanded menu of postsecondary programs into the Arctic by local colleges and universities as well as the delivery of technologically enhanced distance education programs from outside the area (Nord and Weller 2002).

Linked to this education-focused interest in the Arctic is also an increased Nordic attention to the challenges faced by young people in northern societies. The problems confronted by youth in these communities not only relate to the established issues of employment, health and education opportunities as noted above, but also can be seen to be linked to specific lifestyle concerns such as the excessive use of alcohol and drugs along with their participation in violence and crime. Added to this growing youth agenda of concern are additional problems related to the potential outmigration of young people from the area and need to ensure that both they and their elders have adequate connectivity to the outside world. These broad socio-cultural questions have become important priorities of Nordic concern for the Arctic and form a seventh focus of discussion and activity (Larson and Petrov 2015). Their impact will be considered in some of the chapters of this volume.

A related focus of concern—that of gender—forms a distinctive eighth area of Nordic interest in the contemporary Arctic. Here is included the perceived need to offer an adequate voice and set of opportunities for both women and men of the region. The vast majority of the Nordic community believes that both men and women should have clear options to pursue their lives and careers in the Arctic. Similarly, they desire to see any existing gender disparities in employment, education, health and social services removed from the region. Most importantly, they share a commitment to having both women and men have an opportunity to help design and shape both the features and futures of their northern communities. The traditional Nordic belief in furthering both gender equality and gender perspectives can be seen to be operative in these northern lands as well as in areas to the south. Several of the research projects detailed in this volume examine its imprint within the different communities of the Nordic North.

A ninth area of Nordic interest in the Arctic stems from similar roots. Democracy and public participation in regional decision-making processes are also seen by the Nordics as essential elements for the development of the Arctic. This includes local and indigenous populations having a voice and say in matters affecting their own communities. It requires that government and private firms take the affirmative step of consulting with indigenous peoples and local residents before they begin new undertakings in the area. It also means securing the necessary approval and "buy-in" from such groups before any such initiatives are commenced. Increasing number of Nordic observers of the Arctic also maintain that the traditional knowledge (TK) and expertise from both indigenous and local peoples need to be respected and incorporated into any decision-making process (Aylott 2014). This effort at beneficial participation and inclusion is examined within a number of the research projects detailed in this book.

A tenth major concern of the Nordics with regard to the Arctic's future relates to the need for broad engagement of all circumpolar parties in its design and implementation. As long-time proponents of international cooperation and multilateralism, the Nordics have championed the development of effective governance frameworks for the region. As noted above, they have been strong advocates for the creation such bodies as the Arctic Council and the Barents Councils and sought to enhance their mandates and scope of their operation. They have also consistently sought to encourage international cooperation in research and policy development aimed at addressing broad circumpolar needs. These efforts continue as a central feature of their desire to see the Arctic region function as an area of peace and collaboration and as a means to avoid any emergence of a new Cold War that might transform it into a zone of possible conflict (Nord 2016b).

1.5 Pathways to the Future

The Nordic perspective on the Arctic also contains within itself a distinctive element of looking to the future. The five Nordic states are known internationally as societies that are progressive and forward looking. They have produced over the decades many individuals and groups who have been in the forefront of cutting-edged science, artistic design and social reform. They are interested in emerging global patterns and trends along with the forces and factors that spur their development. As such, it is not surprising that the Nordic vision of the Arctic should embody an orientation toward forecasting and prediction (Government of Sweden 2011). Both are considered as essential elements in the process of building pathways to the future in the circumpolar region.

Embodied within this endeavor is a commitment to secure adequate data and information regarding the physical, biological and social dimensions of these northern lands and their residents. Such an initiative is no small undertaking and it has occupied a substantial element of Nordic investigations of the Arctic over the past century. Yet these data gathering exercises have always been linked in the minds of most Nordic explorers, scientists and researchers with how such findings can be best put to the service in preserving and enhancing the ecosystems of the region (Sörlin 2014). With this as background, one of the central elements of the Nordic approach to building pathways to the future in the Arctic has been that of using scientific investigation to assess the prospective needs and opportunities of the region. A number of these efforts are outlined in the subsequent chapters of this volume.

Another defining characteristic of the Nordic vision of the Arctic's future is an effort to foster and strengthen regional capabilities to respond to ongoing challenges. Whether this is in regard to creating greater resiliency in the face of ongoing climate change or offering new economic and educational opportunities for Arctic residents, all such endeavors require significant attention and investments by government and the private sector in the lands and peoples of the region (Arctic Council 2013). It necessitates, as well, a new awareness and thinking regarding what may be the most necessary environmental, health, education and business investments to be made in the area. In several of the chapters which follow, these undertakings to build and enhance Arctic capabilities and response by the Nordic community and its northern residents are outlined and discussed.

Effective efforts in all of these areas also require commitment and buy-in from the residents of the region. The long-practiced Nordic traditions of democracy and participation demand that this be secured. Yet this has not always been the case. Despite the good intentions of some policy planners and bureaucracies located in the south, indigenous peoples and other northern residents have often felt excluded from the process of designing and building an adequate pathway to the future within their own lands and traditions. New initiatives to establish confidence and trust and to incorporate the views of such individuals and groups need to be undertaken if a productive and harmonious future Nordic Arctic is to be secured (Berg and Klimenko

2016). Examples of some of the innovative efforts to encourage community engagement in knowledge production and policy development are presented and discussed in a number of the chapters within this book.

Finally, still another important element of the Nordic view of the future Arctic is one that calls for regular evaluation and assessment. The Nordic community has long believed in the importance of testing and measuring the impact of major investments of time, energy and resources. Before making such major commitments, the long-established practice has been to investigate the risks and benefits of such investment and to determine, as far as possible, the likely consequences. Careful analysis ahead of funding has been the hallmark of Nordic scientific research (Gustafsson and Røgeberg 2015). Not surprisingly then, both national and pan-Nordic investment in Arctic research over recent decades has followed this pattern. In this book an effort is made to explain why the initiative to create Nordic Centers of Excellence in Arctic research was deemed necessary at this time. Additionally, discussion is provided regarding how such an undertaking can be funded and evaluated over time. The precise processes for assessment and evaluation of this major Nordic research investment in Arctic research are also detailed in this book. Likewise, towards the end of the volume a focused discussion is offered regarding how future Arctic research of this type might be best designed and assessed.

1.6 Nature of the Volume

As noted earlier, the purpose of this volume is to investigate the Nordic community's perspectives on the Arctic and its views on how responsible development As of the region can be achieved. The specific framework in which this examination takes place is the current effort by NordForsk to establish and maintain four Nordic Centers of Excellence for Arctic Research. This initiative and the specific lines of inquiry that have arisen from it provide the basis for this book's consideration of how the needs and aspirations of the contemporary Nordic Arctic are being addressed by some of its leading researchers. Within this volume, there are four important questions or thematic lenses that help to focus and link their separate reporting of their work. The first of these is: How does the research presented provide new insights and understanding of the challenges and opportunities existing in the contemporary Nordic North? The second of these questions is: In what manner does the research discussed inform the process of developing an appropriate policy response? A third shared concern is: How can the use of interdisciplinary teams and methods help to enhance such research efforts? The fourth question that connects and frames the assembled research essays is: How can community engagement and participation become more central to such research inquiries? Each of the contributing authors to this book addresses one or more of these concerns in their individual essays.

The present volume itself is divided into six parts. The first part includes this introductory essay by the editor that seeks to provide an overview of the Nordic community, its traditional views of the Arctic, and some of the shared concerns of its citizens regarding the current needs of the region. It also touches upon some of the necessary requirements for constructing a pathway for action to meet them. This discussion is complemented by an accompanying chapter offered by Gunnel Gustafsson, the former Director of NordForsk, which looks at the circumstances that led to that body's decision to create a Joint Nordic Arctic Research Initiative. This essay also considers some of the research objectives and future policy discussions that NordForsk sought to encourage through such action. Together, the material contained in this first portion of the volume provides the context for the subsequent reporting of the specific research efforts by the four Nordic Centers of Excellence.

The second part of the book is devoted to the CLINF Center of Excellence. This multidisciplinary and multinational research effort is aimed at examining how climate change is having an impact on the health of animals and humans within a region stretching from Greenland to Siberia. The first chapter in this part is written by the co-directors of the Center, Birgitta Evengård of Umeå University and the Tomas Thierfelder of the Swedish University of Agricultural Sciences (SLU). Within their essay they provide both an overview of some of their specific research efforts and a discussion of their central goal of establishing a consortium of scientists to address the growing problem of climate sensitive infections (CSIs) in the Arctic. They also consider how the various research findings stemming from their work can be best communicated and shared with decision-makers and the public of the region.

The following chapter—also written by Professors Thierfelder and Evengård—offers a more detailed discussion of the methods utilized within the CLINF project to provide a synergetic assessment of CSIs in the Arctic. Here attention is directed toward the project's collation and dissemination of relevant data and the development of real-time surveillance programs for selected infectious diseases in the area. Consideration is also given to efforts to design CLINF as truly integrated research project with defined linkages between its several areas of concern and the sharing of information and data. It also explores some of the challenges associated with implementing an interdisciplinary science approach and creating a process of bilateral engagement with stakeholders and knowledge users at the local, national and international levels.

The third chapter in this part of the book picks up on this discussion of methods and highlights efforts by the CLINF team to advance new approaches at forecasting future aquatic and land-based environmental conditions that can lead to the development and spread of CSIs. Authored by a team of researchers led by Gia Destouni of Stockholm University and Shaun Quegan of Sheffield University, the chapter seeks to describe the available environmental models that could be utilized and the necessary data required to drive and test them. They also discuss new ways in which to quantify the uncertainty within these models so that they can be better utilized within the context of Arctic CSI prediction.

The final contribution to this part of the volume that focuses on the CLINF project is provided by a group of researchers led Grete Hovelsrud of Nord University in Norway, Camilla Risvoll from the Nordland Research Institute and Jan Åge Riseth of the Norwegian Research Institute (NORCE). In this jointly authored essay, the investigators describe their efforts within CLINF to examine how multiple stressors—including climate change and CSIs—are creating new challenges for Sámi reindeer herders in northern Norway. In their investigation, they focus their attention on how resource development and other human activities combine with climate change to necessitate adaptation strategies by the herders. They go on to discuss the necessary requirements for some of these. They also explore how local and traditional knowledge from the region may play a significant role in helping to develop the most effective of these approaches.

The third portion of this volume is devoted to the research efforts of the ARCPATH Arctic Centre of Excellence. In begins with an overview of the main objectives of the Centre. This essay is jointly authored by the lead coordinators of the Center, Astrid Ogilvie of the Stefansson Institute in Iceland and Yongqi Gao of the Nansen Environmental and Remote Sensing Centre in Norway, along with several of their fellow key investigators. The chapter focuses on the three central goals of ARCPATH: (1) to predict regional changes in Arctic climate over the coming decades; (2) to increase understanding and reduce uncertainties with regard to how climate change interacts with various societal factors; and (3) to utilize this combined knowledge to improve regional climate predictions and assist Arctic coastal communities in their efforts at adaptation. The several different work packages of the ARCPATH project are detailed as well as the necessary coordinating efforts to advance such multidisciplinary and integrative research that is aimed at building pathways to action.

The following chapter in this part of the book is focused on ARCPATH's development and utilization of sophisticated computer-based climate models. Shuting Yang of the Danish Meteorological Institute and some of her ARCPATH colleagues explain how these climate models seek to represent the known physics of the North Atlantic climate system, which includes the atmosphere, ocean, land surface and ice of the region. They then describe how these models can be utilized for a number of purposes including studying the dynamics, interactions and feedbacks within the climate system, examining climate variability in the past and present, and in predicting the dimensions of future climate change. The authors note that ARCPATH applies regional high-resolution climate models and decadal climate predictions to provide more accurate information of climate change in the Arctic and the Nordic seas over the coming years. This is vital knowledge for efforts focused on community resilience and adaptation within northern coastal areas.

The third essay in this ARCPATH focused part of the book looks specifically at such efforts. Laura Malinauskaite and her colleagues from the University of Iceland considers the cases of Andenes in Norway, Ilulissat in Greenland, and Húsavik in Iceland with regard the changing availability of marine mammals close to these communities. She applies the concept of Ecosystem Services (ES) to consider the multiple benefits derived from the presence of such marine mammals in these northern communities and endeavors to build an enhanced model of the interconnectedness of ecological and sociological processes that result in the enhancement of human wellbeing. In the essay, Malinauskaite and her research partners provide the reader with an expanded understanding of the underlying processes that enable Arctic coastal communities to benefit broadly from the presence of whales. They also identify key actions from each of the case studies that help to advance our awareness of the necessary requirements for sustainable management of whale resources in the Arctic.

The fourth chapter of this part of the book looks at ARCPATH's efforts to engage local northern communities in its research efforts. Catherine Chambers from the University Centre of the Westfjords and her ARCPATH research partners suggest that community engagement in the research process involves more than communication and outreach. They suggest it must also include the co-production of knowledge. Within this chapter Chambers and her colleagues sets forth what this entails. They argue that there is no single template that can be imposed from the outside in order to further such undertakings. Nonetheless, they take note some of the most effective strategies and best practices that have been advanced. They then explore their possible utilization within the Nordic North. Drawing from their experiences within the ARCPATH project, they advance the idea of a "sliding scale of community engagement" that can be utilized to conceptualize the definition of community engagement activities within in such a large research project and assist evaluators in measuring their effects.

The fourth part of this volume is rooted in the work of the ReiGN Nordic Centre of Excellence. Its first chapter is written by Øystein Holand from the Norwegian University of Life Sciences who is the lead investigator for the Center along with researchers associated with the project. Their essay discusses the major challenges faced by reindeer husbandry across the Nordic North and the need for new data and perspectives in order to create more effective management schemes. They suggest that a real opportunity for interdisciplinary and comparative research exists today within such endeavors. The researchers argue that by integrating both natural and social science perspectives, a more holistic and comprehensive vision can be achieved. They outline in this chapter some the major findings of the ReiGN Center of Excellence and suggests how they can assist in to promoting new societal responses and management methods that could help to create a more adaptive and viable reindeer husbandry in Fennoscandia.

The second chapter of this ReiGN focused part of the book considers one of the chief questions raised by the reindeer herding communities of the region. What are the factors and forces that have led to major fluctuations in reindeer populations in Fennoscandia over the last few decades? Here, Annti-Juhani Pekkainnen and Olli Tahvonen of Helsinki University and Jouko Tahvonen of the Natural Resources Institute of Finland seek to provide some answers to this important concern. They start by examining the different environmental, economic, sociological and regulatory drivers of contemporary reindeer herding. They then utilize bio-economic modeling to illustrate their individual and collective impacts. The authors proceed in their essay to illustrate how such modeling efforts can also be of great assistance in formulating responsive and effective regulatory and management schemes. The stated goal of their research effort is to provide a better understanding of how sustainable numbers of reindeer can be achieved by utilizing the best analytical approaches, methods and tools.

The next chapter in this part of the book presents another aspect of the ReiGN research project—how social science research methods can highlight other issues of concern to the reindeer herding communities of the Nordic North. The essay considers the difficult question of reindeer herders as “rights holders” versus “stakeholders” within the region. Here Simo Sarkki and Hannu Heikkinen from Oulu University and Annette Löf from the Centre for Sámi Research at Umeå University explore the complex relationship between the two perspectives from conceptual and methodological vantage points. They suggest that the idea of a “rights holder” is a preferable frame to utilize when considering the particular case of Sámi reindeer herders in Finland, Norway and Sweden and offer their reasoning. They argue that such an approach is both more sensitive to the realities of local histories and contributes to situating discussion of rights, stakes and relations within a broader indigenous research literature focusing on decolonizing and dependency. The authors provide illustrative examples of how this alternative perspective advances our understanding of the particular needs and challenges faced by such groups.

The fourth and final chapter of this part of this book addresses the issue of how community engagement in research on reindeer herding in the Nordic North can be accomplished. The co-production of knowledge by combining local insight and experience with traditional scientific methods has been increasingly viewed as a means of both democratizing science and empowering northern communities in the management of natural resources in their areas. In their jointly authored essay, Tim Horstkotte of the Swedish University of Agricultural Sciences (SLU), Élise Lépy of Oulu University and Camilla Risvoll of the Nordland Research Institute discuss the possibility of such an approach within the context of reindeer husbandry within Fennoscandia. In particular, they focus attention on its prospects for promoting regional and cross-national dialogue between herders and scientists on the question of supplementary feeding. They discuss in their chapter how mutual learning can take place and how its insights can be best communicated among both local practitioners and broader policy and management communities. This chapter also provides an excellent example of how researchers from different NCoEs (ReiGN, REXSAC and CLINF) have combined their research interests in the co-production of knowledge to produced significant findings on a collaborative basis and across disciplinary lines.

The fifth portion of the volume is devoted to a consideration of the REXSAC Center of Excellence. Its principal organizer, Sverker Sörlin of the Royal Institute of Technology in Stockholm (KTH), offers an introductory chapter which provides an overview of this multifaceted research initiative that focuses its research efforts on resource extractive industries and their impact on communities in the Nordic Arctic. He outlines in his essay the several lines of investigation that the project embodies and examines key theories of resource extraction and their relationship to ideas of economic development and sustainability in northern settings. He also considers some of the challenges of working with and applying such policy concepts as sustainability, assessment and “best practices” within such investigations.

The second chapter in this part of the book is written by Dag Avango from the Luleå University of Technology and Gunhild Rosqvist from Stockholm University. In their essay they describe some of the research efforts of REXSAC that examine how mining communities in the Nordic Arctic have dealt with the legacies of past mining operations and under what circumstances such legacies can ascribe new values after extraction has ended. They discuss how the REXSAC investigators have approached this research problem in an interdisciplinary manner combining methods and approaches from the humanities and social sciences in addition to those of the natural sciences. They also consider how this type of inquiry can generate new insights into three main post-extractive processes: environmental remediation, heritage making and re-economization.

The third chapter of this REXSAC-focused part of the book is co-authored by Kirsten Thisted and Frank Sejersted from the University of Copenhagen. In their essay they continue the examination of resource extraction industries in the Nordic North focusing on how emotions and affective response to such undertakings can be best considered. They note that that within the field of resource extraction there has been consensus among past researchers that emotions should be avoided in conducting their analysis. They question the utility of such an approach. The authors investigate how affect and emotion as cultural practices serve to empower discourses that connect—or disconnect—resource extraction efforts with broader undertakings such as community building and nation building. Their analysis is based on REXSAC supported studies and field work in Greenland and in the Sámi communities of northern Scandinavia.

The sixth and final part of this volume is centered on the challenges of research synthesis , evaluation and assessment. It features an initial chapter by Leslie King of Royal Roads University and Astrid Ogilvie of the Stefansson Arctic Institute that examines the need for collaborative research and the difficulties—and promise—of harvesting and integrating research findings across geographic and disciplinary divides. They discuss the challenge of such synergistic efforts within the context of the ARCPATH project. The second chapter of this final portion of the book is co-authored by Andre van Amstel of Wageningen University, Amy Lovecraft of the University of Alaska, Roberta Marinelli of Oregon State University and the editor of this volume, all of whom have served on the Scientific Advisory Board for NordForsk’s Joint Nordic Arctic Research Initiative. In their essay the authors explore how assessment and evaluation have been integral components of the overall project and some of the specific steps they have pursued in performing their important role in measuring the progress and accomplishments of the NCoEs. They discuss what have been some of the collective strengths and limitations of the four projects. The authors take a brief look at how other research bodies elsewhere in the world have promoted, developed and assessed similarly large and multidisciplinary research efforts. They also consider some of the specific challenges inherent in conducting such inquiries within the Arctic today.

This theme of evaluation is further advanced in the concluding chapter of the book. Here, Douglas Nord, the editor of the volume considers the overall impact of the Joint Nordic Arctic Research Initiative. He highlights what have been some of the most significant conceptual and methodological insights and innovations that have emerged from its sponsored inquiries. He describes how the Centers of Excellence have advanced the effort of conducting important scientific research utilizing multidisciplinary teams and perspectives. The author also considers how new efforts at knowledge building in the Nordic North can facilitate the construction of participatory bridges between researchers and residents of northern communities. He also argues that the NCoEs have also played critical roles in suggesting what may be appropriate directions for future policy formulation. Most of all, he suggests that the new Centers of Excellence in Arctic Research have encouraged a close examination of some of the major concerns of the Nordic communities regarding the Arctic and equipped them with the necessary analytical tools to construct new pathways to action.

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Chapter 2
NordForsk as a Facilitator of Integrated Research on the Arctic

Gunnel Gustafsson

Abstract This chapter presents a brief history of how NordForsk's research program the Responsible Development of the Arctic came to be launched. After 2011, when Nordic cooperation on Arctic issues was first raised, a range of preparatory and planning activities were organized by NordForsk. Four years later, these resulted in support for four Centres of Excellence with the highest budget so far allocated to a NordForsk research program. The chapter begins with an analysis of what was the state of science and society, both in the Nordic region and beyond, when the program was initiated. It then provides an overview of the essential features of the processes and organizational arrangements that led to the launch of the program. The analysis is focused on what made it possible for NordForsk to produce integrated knowledge of relevance that would provide a better understanding of the situation in the Arctic. It is argued that four cornerstones constituted the basis for accomplishing this. These were: (1) Key actors in the Nordic region and beyond who had started to realize that increased incentives for research cooperation across borders were needed; (2) There was dialogue and commitment to take joint action between policymakers in the Nordic research and political arenas; (3) Needs-driven and fundamental research started to be seen as two sides of the same coin rather than competing approaches; and (4) There was careful management of the processes from planning, to the production of new knowledge. Still another factor of critical importance was the work done by professional and dedicated people e.g. administrators, experts, advisors etc., who maintained pressure for reaching the goal of securing new knowledge of high scientific quality and relevance to change in and beyond the Arctic region.

Keywords NordForsk · Cross-disciplinarity · Global challenges · Arctic development

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During the first year of this century, the Commission of the European Union decided to establish the European Research Area (ERA). This was done in an attempt to strengthen the rather fragmented European research landscape (Ulnicane 2016). In the Nordic region, there were already two institutions that contributed significantly to enhancing political dialogue and co-operation across national borders. One was the Nordic Council (NC), established in 1952, which is composed of parliamentarians (Andersson 2000). The other was the Nordic Council of Ministers (NCM) established in 1971, which was organized separately for Ministries representing different sectors of the Nordic community e.g. the NCM for Higher Education and Research, for Energy, for Health etc. (Wiklund 2000). These two fora include members from the five Nordic countries, Denmark, Finland, Norway, Iceland and Sweden as well as from the three autonomous areas, the Faroe Islands, Greenland and the Åland Islands.[1]

The debates in the NC and NCM at the start of this century were highly influenced by the developments within the European Union (EU). The suggestion had been made in Brussels to establish a European Research Council (ERC). This resulted in a desire by the Nordic community to also extend cooperation in this area. It inspired the Nordic Ministry for Higher Education and Research (NMER) within the NCM to explore both the possibilities of increasing contributions to new timely knowledge within the Nordic region and for the Nordic region to play a leading role in Europe in certain research fields. In 2002, the NMER asked Professor Gustav Björkstrand, who had previously been Minister for Nordic Co-operation, to develop a White Paper for Nordic co-operation on research, PhD education and Innovation (Björkstrand 2004).

After consultations with research and business communities in the five Nordic countries, Björkstrand provided strong arguments for the establishment of a Nordic Research and Innovation Area (NORIA) organized along similar lines as the ERA, including a Nordic version of the ERC. In concrete terms this meant the establishment of a research and innovation institution with representatives from both fundamental scientific research and innovation-based research areas. This institution should fund research of the highest quality and at the same time be relevant in addressing global challenges such as climate change. In addition to being funded by the Nordic Council of Ministers, it should also secure co-funding from each of the national research and innovation agencies within the Nordic countries, and if possible, also from national ministries/sectors other than those representing research and Innovation. These main suggestions of the White Paper were soon implemented by the NCM and two new Nordic institutions were established in Oslo, Norway. These were the Nordic innovation Centre (NiCe),[2] set up in 2004, and NordForsk[3] set up in 2005.

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[1] The NC and the NCM are still organized in the same way. A comprehensive description of the development of Nordic cooperation is found in Sundelius and Wiklund 2000, and 2017.

[2] In 2011, The NiCe Board decided to change the name of the organisation to *Nordic Innovation.*

[3] The name NordForsk is in Scandinavian language referring to Nordic Research. (Nord is short for "nordisk" which translated to English means Nordic, and Forsk is short for "forskning" which

Since their establishment, both NiCe and NordForsk have had their headquarters in the same building as Nordic Energy Research – a NCM body which has existed since the 1980s. The three institutions are supposed to work closely together within this "Nordic Centre" with the aim to jointly accomplish cross-sectorial cooperation in order to produce new high-quality knowledge of relevance for the Nordic region in the twenty-first century. NordForsk is, by far, the largest of the three institutions and has since its establishment played an important role in the development of the NORIA by promoting free movement of knowledge in the Nordic region, the pooling of national resources and by creating critical mass for excellence in research.[4] Its specific mandate is to identify and respond to strategic priorities for Nordic research cooperation and thereby add value to national research efforts in the region. Decisions on how to accomplish this, should according to its statutes, be taken by a Board which at the time, 2013, was composed of nine members: five nominated by research councils, three by universities and one by industry in the Nordic region. In addition, there should be seven observers, without decision-making power, one from each of the three autonomous areas, one from NCM, NiCe, the Baltic states and the NordForsk personnel respectively.[5] It is of crucial importance to note that the establishment of both ERA and NORIA were embedded within a broader discussion and debate over science and society which emerged around the year 2000. This was focused on the ongoing globalization processes and the many complex consequences arising from them such as climate change. A book with great impact on this discussion was *Runaway World* published by the well-known British scholar, Professor Anthony Giddens and later translated to many languages including some from the Nordic region. In that volume, Giddens argues that the ongoing globalization, which he perceives to be far from clearly defined, is closely related to digitalization and a historical transition with the potential to fundamentally change the lives of human beings (Giddens 1999).

Another publication that especially influenced the Nordic debate was *Hot Topic – Cold Comfort; Climate Change and Attitude Change*. It was published by the Norwegian Professor of Sociology and former Minister of Higher Education and Research, Gudmund Hernes. He argues that there have been several events during the last hundred years which, when taken together, are creating what he calls an "ecological revolution" in our way to thinking about the interaction between human beings and nature. As an example, he suggests that we, in the past, perceived the

translated to English means Research.) Thus, the name denotes that NordForsk's mission is to fund Nordic research cooperation.

[4] The suggestion, in 2000, for establishing ERC was an inspiration for setting up NordForsk in 2005, but ERC actually became established later than NordForsk in 2007.

[5] In 2014, the number of members and observers were reduced and the Board is now composed of six members; one from each of the five research councils and one from the universities. The observers are four; one from NCM and one from each of the autonomous areas. Like other Nordic institutions NordForsk receives a yearly grant from the NCM and reports to the NCM for Research and Higher Education regarding how funds have been spent. The amount of co-funding from national research financiers has increased over time and is nowadays at least double the amount from NCM.

Earth to be invincible, but now we are increasingly aware that it is fragile and in danger of irreversible damage. Hernes believes that politicians must be willing to think and plan along new lines and set up new institutions in order to combat the sometimes gradual and sometimes sudden shifts in how human beings are confronted with change. (Hernes 2011, 2012).

Also, highly relevant for the emerging globalization debate was a book with the title *Governing the Commons – The Evolution of Institutions for Collective Action*. It was written by Nobel prize winner Elinor Ostrom who was a forerunner in pointing to environmental issues as crucially important for future life on this planet. Her work and theorizing have greatly impacted how we study and govern common environmental assets and, on our attempts, to preserve nature. It has influenced the studies and research of many Nordic scholars (Ostrom 1990).

2.1 European and Nordic Efforts to Re-think the Character of Research in an Era of Change

In the spring of 2009, when Sweden was chairing the EU Presidency, it was considered timely to start planning for what would come after the 7th Framework Programme that was aimed at supporting research within the ERA.[6] Several reports and documents had laid the ground for this discussion of what type of research should be conducted in the future in the wake of rapid globalization and global system changes.[7] The Swedish Chairmanship volunteered to lead a discussion of how the EU could respond to environmental, social and other challenges through its research efforts. The purpose of such a discussion would be to strengthen Europe's position in the world based on research and innovation (Vis 2011). To prepare for this, four workshops were arranged with the aim of providing ideas and insights for discussions of which actions should be taken in order to accomplish this goal. Participants were invited from all EU member states and EU-associated countries, like Norway, and also from counties outside Europe. The seminars would cover different topics, but were bound together by a common somewhat provocative theme, based on the assumption that challenges and even "shocks" could be turned into opportunities and progress. Four workshops were held during February and March of 2009 in Brussels, Berlin, Tallinn and Alcalá de Henares outside of Madrid. They

[6] Framework Programmes are funding initiatives created by the European Commission to support and foster research in the European Research Area (ERA). The specific goals and actions vary between funding periods. The 6th Framework programme (2002–2006) had a relatively modest budget of 16.3 billion Euros. In the 7th Framework Programme (2007–2013) funding was increased to 53.2 billion Euros, and the 8th Framework Programme (2014–2020) – which is called Horizon 2020 – has a budget 77 billion Euros.

[7] Some of the more important of these were the Aho Report "Creating an Innovative Europe" in 2006; the European Commission Green Paper "The European Research Area: New Perspectives" in 2007 and the Evaluation of the 6th Framework Programme 2002–2006 (Arnold 2009).

were focused, on “Nature Shocks – as Opportunity, “Business Shocks – as Opportunity”, “Social and Cultural Shocks – as Opportunity” and finally “European Decline – as Opportunity” (Lund Declaration; Background Material 2009).

The discussions during these meetings provided food for thought and debate during the Swedish EU Presidency Conference held in Lund in July 2009. The Lund Declaration, launched during this conference was entitled “New Worlds New Solutions: Research and Innovation as a Basis for Developing Europe in a Global Context”. It emphasized the need for new knowledge in response to grand challenges. The most urgent of these challenges were perceived to be climate change, energy and water supplies, the ageing of populations and changes in the world economy. The Lund Declaration underlined the point that unwanted, and sometimes, unexpected developments and even “shocks”, seemed to demand both a new type of knowledge resulting from cross-disciplinary research and a new risk-tolerant and trust-based approach in funding such research (Lund Declaration; Final Report 2009). The theme of the Lund Declaration was followed by actions at the EU-level along with the publication of two additionally important reports.[8]

The Danish Presidency of the European Union, in first half of 2012, provided input of crucial importance regarding how to implement these reports (Smits 2015). The subsequent result was the 8th Framework Programme, Horizon 2020, which not only gave new direction to European research initiatives, but also included substantial funding for research responding to grand challenges.

The discussion over European research priorities and approaches was pursued in a variety of settings.[9] One of these was within the EuroScience Open Forum (ESOF). ESOF holds a biennial conference on research and research policy in Europe. This was started in 2004 and soon became an arena for discussion that attracted large numbers of senior and junior research participants from Europe and beyond. At the 2010 ESOF meeting in Turin Italy, there were two workshops in which NordForsk was directly involved. These were entitled “The Nordic Top-level Research Initiative : A Model for Europe? “, and “Europe 2014 and Onwards: A New Deal between the Member States and the European Commission”. The point of departure for the first workshop was the Nordic Prime Minister’s globalization agenda outlined in the Riksgränsen Declaration. The second workshop was organized in response to the specific suggestions of the Lund Declaration.

Several of those who attended these seminars were critical of the new suggested approaches to European research policy. They foresaw that investments in “grand challenges responding research” would, in practice, undermine investments in basic research and might lead to inadequate research quality. They strongly argued that traditional disciplinary research initiated by individual researchers and research

[8] The first was the *European 2020 Flagship Initiative – Innovation Union* (2010) which was followed by a report from the Commission soon thereafter “*Grand Challenge, design and societal impact of Horizon 2020*” (2010).

[9] Further information on Nordic efforts to re-think the character of research during the current era of globalization and change is provided in Gustafsson 2014 and 2017, Langer 2011, Titelstad 2015 and in Anniversary insert in the NordForsk Magazine 2015.

communities alone would not only come up with solutions to contemporary global challenges and problems but guarantee the high quality of research. At the same time, however, another group advanced the opposite opinion. They argued that "strategic" research has the same potential as "fundamental" research to result in high quality. It also had the additional benefit of allowing researchers to focus their efforts on pressing global concerns.[10]

The controversy continued and the different arguments were repeated over and over again without much dialogue between the two groups. Those who listened carefully, however, could note that some of the conflicting views were based on misperceptions of terms like "grand" and "strategic" and were used rhetorically as catchwords for a number of different phenomena. Then the well-known and highly respected Professor of Physics, Jerzy Langer, took the floor in an attempt to clarify the situation. He emphasized that "grand challenges responding research" has the same potential as "basic research" to result in the very highest scientific quality, but that a necessary precondition for such research is that it be carried out by highly qualified researchers. He also added that research of low quality is of no use for those decision-makers who want to take knowledge-based action.

Langer's way of reasoning made the critical voices become more nuanced, but the competing opinions expressed during these workshops are still recurring within research communities in Europe today. The tensions, misunderstandings and fears for new approaches to research have, however, over time diminished considerably and it is now rather commonly agreed that "strategic research" of high quality is needed and useful for addressing the contemporary complex challenges with which the world is presently confronted (National Strategies and Roadmaps for International Cooperation in R&I 2020).

2.2 The Nordics Look Northward

The International Polar Years (IPY), which lasted from March 2007 to March 2009, brought world-wide attention to climate change and its consequences for the polar regions and beyond. During these years state of the art of knowledge about change in the Arctic was at the fore and much research was carried out in that region as well as the Antarctic. However, it also became increasingly clear that further inquiries would be necessary to document the speed and extent of climate alterations in the Arctic. This was of crucial importance as many of the indicators of climate change in the region would suggest some of the challenges that both Northern and more distant ecosystems might face in the future. The reason for this was that the effects of climate change were noticeable earlier in the High North than elsewhere on Earth. In this respect the Arctic can be perceived to be a global laboratory and

[10] The information in this paragraph and the forthcoming one is based on notes from the ESOF meeting and on communication with Jerzy Langer regarding the accuracy of these.

knowledge about what is happening there of crucial importance for the resilience of our planet in the current era of climate change.

The scientific work initiated by the IPY put a spotlight on the need to address the remaining huge knowledge gaps on development and change in the Nordic area. It was one of the factors that triggered the Nordic Prime Ministers, Geir H. Haarde (Iceland), Jens Stoltenberg (Norway), Anders Fogh Rasmussen (Denmark), Fredrik Reinfeldt (Sweden) and Matti Vanhanen (Finland), to formulate the Punkaharju Declaration when they met in Finland in the summer of 2007. The document included a suggestion that the countries should initiate a "Nordic globalization agenda for a more knowledgeable, visible and prosperous Nordic region". Earlier informal discussions with representatives of the Nordic research communities who had past experience in Nordic cooperation convinced them that the Nordic region was in a position to pioneer efforts to combat climate change and that the "Nordic model" could be expected to demonstrate its potential for combining reduced emissions with economic growth. The Prime Ministers now sent a request to the Nordic Council of Ministers asking them to formulate a plan for research and innovation on climate changes and its consequences. When the same Prime Ministers met again, in April 2008, at the Riksgränsen ski resort in Sweden, they approved the Riksgränsen Declaration which laid the foundation for a very large joint Nordic venture focusing on such concerns and labelled as the Top-level Research Initiative (TRI).

This program was elaborated and planned jointly by NordForsk, NiCe and Nordic Energy Research. When the call for research proposals was launched it included six themes: (1) Interactions between Climate change and the Cryosphere; (2) Effect Studies and Adaptations to Climate Change; (3) Energy Efficiency and Nanotechnology; (4) Integration of large-scale wind power; (5) Sustainable biofuels; and finally, (6) CO2- Capture and storage (Solving the Climate Crisis – A Nordic Contribution 2015 and Final report from the evaluation of the top-level research initiative 2014). After a thorough peer review process this call resulted in support for a number of projects and several Centers of Excellence, but only two of these were explicitly focused on the Arctic.[11] Change in the Arctic region was, however, a cross-cutting theme in all TRI activities and deemed of great relevance for developments in the Nordic countries.

NordForsk started to consider the merits of an integrated research program on the Arctic within the above context. The desire to advance a cooperative Nordic approach to address pressing environmental and development issues was very much in the forefront. So too was the goal of seeking to bridge the gap that had emerged between "strategic" and more traditional researchers and funders. When the idea to initiate the Responsible Development of the Arctic emerged, another important factor was that there were a number of Nordic researchers who were both willing and able to participate if such an opportunity should arise. Many had played significant

[11] These were the Nordic of Excellence on "Stability and Variations of the Arctic Land Ice" and the Nordic Centre of Excellence on "Cryosphere Interactions in a Changing Arctic Climate"

roles within the IPY. Another important factor was the long-existing trust-based relationships between actors in the research and the political communities within and among the Nordic countries. These were further strengthened by the recent TRI experiences. Finally, the fact that Sweden and Denmark had worked to promote "grand challenges responding research" at the EU level was of crucial importance for the attempts to initiate a larger-scale Nordic research and innovation program focusing on change in the Arctic (Annerberg 2015; Stafström 2012).

2.3 From the First Idea to Preparatory Activities

The overall goal of NordForsk was, according to its 2011–2014 strategy document to "make the Nordic region strong and influential both within the European Research Area and globally." During this time period, it was important for the organization to make itself known and respected within the Nordic region as a "funder of research judged to have considerable potential to result in long-term knowledge-based progress" (NordForsk Strategy 2011). In order to accomplish this, NordForsk had the ambition to also become a visible and important player within the European and global research funding arenas.[12] When an invitation came, in 2011, for NordForsk to visit the National Science Foundation (NSF) in the US and present its activities, it was most welcomed. The agenda for the meeting called for an exchange of information and the identification of possibilities for co-operation between NSF and NordForsk.

At the meeting, which took place in December 2011, the Director of NordForsk gave an overview of ongoing research. This included the newly started program on climate, energy and the environment within the Top-level Research Initiative (TRI), and the cross-cutting theme Arctic was mentioned. During the discussions, where among others the Director and Vice Director of the NSF Office for Polar Programs were participating, it was jointly agreed that one of the areas for co-operation between the two organizations worth exploring further were issues connected to the developments in the Arctic region. It should be noted that the meeting happened at a time when Sweden, in 2011, had just started its 2 year-long Chairmanship of the Arctic Council, after the previous Norwegian and Danish and the forthcoming Canadian and the US chairmanships. Against this background and because of the positive experiences of the TRI, the NordForsk Director considered Arctic studies to be a timely and interesting theme. A seed was planted which later led to integrated research within the NordForsk program on the Responsible Development of the Arctic.

The dialogue, that was started at the meeting between NSF and NordForsk, continued during the final IPY Conference, "From Knowledge to Action" that was held

[12] In this section, when references are not given in the text, the information is derived from the minutes of NordForsk's Board meetings. In addition, information and analyses regarding first ideas and preparatory actions is found in Gustafsson and Røgeberg (2015).

in Montreal Canada during April of 2012.[13] This conference attracted more than 2000 participants and was the largest gathering on polar matters that had ever taken place. One of the events during the Montreal meeting was a seminar organized by NordForsk. It concerned the potential for cross-national collaboration within joint research programs that would address the challenges and opportunities of the Arctic region. Invited stakeholders and researchers from seven of the eight Arctic countries, i.e. the five Nordic, US and Canada, participated in this side-event which was well attended.

During the seminar, it was concluded that continued cross-national collaboration focused on addressing remaining knowledge gaps in Arctic issues would be of great importance. There was broad interest in participating in such an initiative. Support for the idea came from the US via the NSF, as well as from some of the funding agencies in Canada. The invitees from Russia sent a message saying that they were interested in being kept informed about the results of the seminar and would also consider participating in such an endeavor.[14]

In order to explore the possibilities of turning this idea into action, the NordForsk Secretariat started informal consultations with funding agencies within the five Nordic countries. The purpose was to find out if they were willing co-fund research on developments in the Arctic and, if so, ask for their suggestions regarding a thematic focus. These preparatory activities revealed that a majority of the Nordic countries were positively disposed toward such a research initiative. They also considered it to be a good idea to include interested parties from all countries within the circumpolar North. It was noted, that the Nordic Council of Ministers had earlier set aside a special budget-pot for cooperation between Russia and the Nordic countries. However, it was at this stage not clear whether it could be used for this purpose and, if so, how the co-operation between Russia and the Nordic countries in Arctic research should be organized.[15]

According to the agreed procedures of NordForsk, before any new research initiative can be launched, there is a requirement that at least three of the five Nordic countries indicate that they are positively disposed to the establishment of such a research program. As previously discussed, informal consultations regarding research on the Arctic had resulted in such indications of support. The next step was to formulate a Program Memorandum that would describe the overarching objectives, thematic framework and focus areas of such an undertaking. Within NordForsk, this task is usually carried out by a network of people appointed by the financiers of the Nordic Research and Innovation Area (NORIA). These so-called NORIA-nets are given the mandate to co-ordinate input from the national funders, NordForsk and policy-makers in the Nordic region. The main guiding principle during such a

[13] Information on the Montreal Conference is provided at: http://www.jpy.2012montrealca/

[14] Russian funders of research in this field had been invited, but were unable to attend the meeting in Montreal.

[15] A Nordic-Russian program in Higher Education and Research was started and is still ongoing. It is a now administered by NordForsk, and all the four Centres of Excellence within Responsible Development of the Arctic have collaboration with Russian researchers.

planning processes is "added value by Nordic co-operation", which means that more should be accomplished by working together than would have been possibly achieved if the individual countries had been working on their own.

A proposal to establish a NORIA-net on the Arctic was now formulated and this suggestion was presented to the NordForsk Board at their meeting in Nuuk Greenland in June 2012. The NordForsk Board members thought that the preparations made so far constituted a thorough basis for the establishment of a NORIA-net on Arctic research. However, they considered it to be too early to invite others than the Nordic countries to take part in the planning and formulation of the Program Memorandum (PM) that would make it possible for them to decide if to start such a joint Nordic research program. At the same time, they emphasized the importance of listening to interested voices from outside the NORIA-net's own circle e.g. to business, civil society organizations, research funding and performing organizations etc., both within and outside the Nordic region.

The NORIA-net Arctic was given the mandate to assess the potential for added value emerging from a larger-scale joint Nordic research initiative that would respond to the multiple societal challenges and new opportunities of the Arctic region. Based on this assessment, a PM should be formulated. This was to include an elaborated plan for research focus and joint funding to be discussed and decided upon later by the NordForsk Board. It was expected that the NORIA-net process would consider as its point of departure the challenges related to climate change and aim to produce suggestions for research that would be relevant to policy-makers and others regarding smart adaptation. Other guidelines included recommendations that research should incorporate a multidisciplinary approach and facilitate cooperation with relevant stakeholders working on Arctic issues. It would also facilitate international research cooperation, in particular, between the Nordics and other states of the Arctic Council e.g. the United States, Canada and Russia.

It was also decided that input to the NORIA-net process should be provided by three expert groups. These were to be in the fields of "health and medicine", "social sciences and humanities" as well as in "science and technology". These expert groups should identify research needs within their respective areas of competence and, in addition, jointly suggest inter-disciplinary topics. It was foreseen that knowledge from different research fields was needed in the analysis of the complex developments in the Arctic. In addition, a reference group should be given the opportunity to provide input to a preliminary Program Memorandum. Broad groups of stakeholders such as researchers, representatives of the indigenous populations in the Arctic region, policy-makers, industry, the University of the Arctic and others should be invited to participate at this meeting.

NordForsk Board member, Sven Stafström, Secretary General for Natural and Engineering Sciences at the Swedish Research Council, was appointed Chair of this NORIA-net. It was to finalize its work in time for a presentation of suggested further actions, at the NordForsk Board meeting in June 2013. In an interview, published in *NordForsk Magazine* soon after his appointment, he promised to work hard to keep to this time table, and emphasized that there are researchers, especially climate scientists, who are keen to contribute to a coordinated research effort in the

Nordic region. He also noted that a multi-disciplinary approach would be of great importance for securing new relevant knowledge on the developments in the Arctic. At the end interview he said that "coordinating Arctic research within the Nordic region may lead to a wider global effort in the future, with potential initiatives that include other countries" (Stafström 2012).

He was right. Already in 2015, NordForsk had participated in a Belmont Forum call on Arctic research together with many other national financiers. In an interview conducted at that time, Kelly K. Falkner, Division Director of the NSF said: "It was useful to have NordForsk identify and represent collective Nordic interests in the area of sustainability. The strong community response to the Belmont Forum call on *Arctic Observing and Research for Sustainability* confirmed the interest in and readiness for transdisciplinary research on this issue" (Falkner 2015).

2.4 Planning and the Decision to Launch the Initiative

After the decision by the NordForsk Board to start planning for a research program on developments in the Arctic, the financiers in each of the Nordic countries nominated the following members to the NORIA-net: Arja Kallio (Finland), Christine Daae Olseng (Norway), Þorsteinn Gunnarson (Iceland), and Kirsten Thisted (Denmark).[16] Together with its Chair, Sven Stafström of Sweden, they formed a group that would be expected to provide the best possible assessment of the potential for Nordic added value as well as having the capability to plan for a large-scale joint Nordic research initiative. This was because all of the members had long experience in establishing such program and could also speak to the different areas of research needed in this context.

The work of the NORIA-net was stated by the Chair in the beginning of September 2012, and the expert groups became operative around the same time. The NORIA-net members along with the members and chairs of the expert groups worked independently,[17] but were supported by the NordForsk Secretariat in such areas like the recording of their discussions and provision of documents. NordForsk also hired Professor Sverker Sörlin of Sweden, long-experienced in Arctic studies, to help co-ordinate the various actions that were then initiated. At an early stage the NORIA-net asked for an overview of Arctic strategies and research in the Nordic

[16] This section is, when references are not given in the text, built on decisions made by the NordForsk Board or by the Director of NordForsk, and on minutes from the NORIA-net meetings and the reference group meeting. Both Senior advisor Marianne Røgeberg and the Director of NordForsk Gunnel Gustafsson took part in all NORIA-net meetings and in the reference group meeting. In addition, there were informal contacts between the Chairs of the expert groups and Gunnel Gustafsson and/or Marianne Røgeberg. The analysis is also based on observations during the meetings of the Chairs and on informal contacts with the Chairs of the expert groups.

[17] The Chairs of the expert groups were: Professor Birgitta Evengård for health and medicine, Professor Joan Nymand Larsen for social science and humanities, and Doctor Øyvind Paasche for natural science and technology.

countries and the Secretariat started to produce such a document which was to constitute background material for the suggestions to the NordForsk Board.

Each of expert groups met a couple of times in September and during early October of 2012. After a while, they organized their individual meetings in the same place in order to provide opportunities for discussions regarding possible joint activities. To start with, it turned out to be difficult for members to communicate effectively with one another. There were misunderstandings caused by different concepts and traditions within the different academic disciplines which resulted in heated debates and underlined a lack of common views regarding what kind of research could contribute most to an improved understanding the nature of change in the Arctic. The discussions escalated to a point where it was questioned if it really was worthwhile to attempt to suggest initiating any multi-disciplinary research activities.

The debates continued at a meeting held in Stockholm on October 15, 2012 where the NORIA-net members and the chairs of the separate expert groups met for the first time, and where Professor Sverker Sörlin was also present. The fact that the NORIA-net was composed of people from different research backgrounds was a critical factor in the dialogue regarding multi-disciplinary research needs. The previously identified difficulties of researchers being unable to fully communicate with one another turned out to reflect a more general limitation on their ability to fully understand those who had been trained inside a less familiar area of competence. Thus, some NORIA-net members had difficulties in fully appreciating the importance of knowledge developed within research fields that were not well-known to them. Professor Sörlin attempted to “translate” the differing arguments and opinions in order to overcome misinterpretations and everybody around the table aimed to reach a more coordinated view on how to move forward. After several rounds of discussions, there was improved respect and open-mindedness, and it became possible for all the participants to start to listen and learn from each other.

The next meeting took place a month later, on November 15th of 2012, at the Abisko Scientific Research Station in northern Sweden in conjunction with an Arctic Council meeting of Senior Arctic Officials, who were now informed about the plans for a joint Nordic Arctic research initiative.[18] Each of the expert groups had prepared overviews of key issues and relevant literature from their respective fields. Building on these, they also provided input to the NORIA-net on knowledge gaps and suggestions for collaboration across disciplines. Shared ambitions and respectful discussions emerged, and everybody, acknowledged the need to work within a framework where all the three groups and the members of the NORIA-net could make important contributions. They, thereby, laying the groundwork for the creation of new and much-needed knowledge on development in the Arctic.[19] The

[18] The Arctic Council meeting of Senior Arctic Officials was held in Haparanda in northern Sweden November 14–15, 2012.

[19] In 2015, the chairs of the expert groups co-edited a book which reflected their deepened insights of the importance of integrated contributions from different areas of competence; Evengård, Nymand Larsen and Paasche (eds.). This is an indication of unexpected insights that can come as

Chairs of the expert groups concluded that they should further develop their overviews and suggestions and present these at a meeting with the NORIA-net before the end of the year.

When they gathered again, in Stockholm on December 10th, the main item on the agenda was a discussion of the content of the Program Memorandum to be delivered to the NordForsk Board. It started with a presentation of a draft overview of Arctic Strategies and Research in the Nordic countries. The NORIA-net members were pleased with the preliminary suggestions and some of them volunteered to provide the NordForsk Secretariat with updated information on a number of ongoing projects that could be included in the final version of the PM. Other information of relevance for the future Policy Memorandum was provided by the Secretariat. It included a brief description of newly started preparations for a Nordic Research Program on Societal Security which could be expected to contribute to a better understanding of developments in the Arctic.[20] There was broad agreement on the importance of creating synergies with already ongoing research programs at national and Nordic levels and the importance of avoiding duplication.

Then, the preliminary content of the forthcoming Program Memorandum was discussed. The expert groups presented their views and suggestions regarding knowledge gaps and multi-disciplinary research needs. These included what they considered as distinct vertical thematic headings such as: resource development, health and well-being, Nordic countries in Arctic affairs, modes of communication as well as arts, and languages. Their interconnecting, horizontal issue headings were also numerous including: data and monitoring, legal issues, vulnerability and resilience, technology, gender, age, indigeneity and ethnicity.

Additional information and a range of views on these research suggestions were put forward by the participants. The most important was that the NORIA-net members requested a prioritization of the various suggestions. In response to that, the chairs of the expert groups promised to revise their documents. Further discussion concerning participation in the upcoming reference group meeting to develop the Program Memorandum resulted in a decision to invite a broad range of key stakeholders that would include policy-makers, NGOs, the University of the Arctic, indigenous peoples, representatives of business, IPY stakeholders, individual researchers as well as NordForsk Board members and others who were directly involved in the formulation of the program.

The Chair of the NORIA-net, Professor Sven Stafström, summarized the discussions, and emphasized that existing knowledge gaps, Nordic added value and national priorities should be noted as important points of departure for the selection

a result of, often rather time-consuming deep-going discussions, between scholars who have the ambition to improve their understanding of what researchers from fields other than their own can contribute within grand challenges responding research.

[20] This was based on a presentation by Professor Bengt Sundelius regarding the forthcoming Policy Paper on Societal Security in the Nordic Countries (2013), and a research program with this focus was started already in 2013. Further information regarding Nordic co-operation on Societal Security is provided by Bailes and Sandö (2017), and in Sundelius (2011).

of topics in the forthcoming Program Memorandum. He also underlined the point that the reference group should be provided with suggestions regarding the content of the planned initiative. These would be elaborated upon after input from the reference group and then would be sent to the NordForsk Board in time for their meeting in June 2013.

A strict timeline for the work ahead was therefore needed, and the Chairs of the expert groups promised to provide a document to be included in the Program Memorandum before the end of the 2012. The NORIA-net members said that they, hereafter, would produce and circulate a draft PM for comments from members of the expert groups. A minimum of two more joint meetings between the Chairs of the expert groups and the NORIA-net were foreseen. One was to be held before, and at least one after, the Reference Group meeting in March. The first took place in Copenhagen from January 31–February 1, in 2013. The members of the NORIA-net and the chairs of the expert groups now discussed and agreed upon documents to be sent to the reference group participants. These included information on the background, rationale, aim and focus of the planned Nordic Arctic research initiative as well as the now finalized document on Arctic strategies and Arctic research with focus on the Nordic countries (January 2013). The reference group meeting, which was organized for March 11 of 2013 in Oslo attracted many participants from a broad group of key stakeholders.

The draft Program Memorandum of February 2013 had emphasized that the main challenges for the Arctic were simultaneously emerging from both nature and society. Those originating from nature were perceived to be climate change and its implications for the rise of sea levels, ice coverage and permafrost. Those challenges coming from society were seen as appearing in response to economic and geopolitical forces which manifest themselves in many ways including the extraction of oil and gas, the decline in natural resource-based economies and new patterns with regard to tourism. The comments offered by the Reference Group included many examples of knowledge gaps as well as more general suggestions on what focus future research should have in order to better understand the developments in the Arctic both in the short and long run. This input provided lots of food for thought regarding how to prioritize between the many complex and important research topics.

In conjunction with the Arctic Science Summit Week in Krakow Poland in April of 2013, members of the NORIA-net and the Chairs of the Expert Group met to discuss these and other matters. On April 19th, the preliminary Program Memorandum was revised in light of input from the reference group and from the discussions that had taken place during the Arctic Science Summit Week. It was also agreed then that the Program Memorandum should be further developed before it would be ready to be sent to the NordForsk Board.

A decision was also made for NordForsk representatives to attend a seminar on Arctic research organized in Kiruna on May 14th and then afterwards decide on the final shape of the PM. This seminar was organized by the Swedish Chairmanship of the Nordic Council of Ministers in cooperation with NordForsk and the Swedish Polar Institute and held in conjunction with the final session of the Swedish

Chairmanship of the Arctic Council. The NORIA-net members, the Chairs of the expert groups and several members all participated in the seminar. The Chairs of the expert groups came well prepared for their meeting with the NORIA- net as a week earlier they had held a preparatory meeting at which they had agreed on suggestions and priorities. As a result, a final draft of the Program Memorandum was approved after some language checks, and on 29th of May forwarded to the NordForsk Board for its consideration at the meeting of June 14, 2013.

The six-page long Program Memorandum was entitled: Responsible Development of the Arctic. Its subtitle, Opportunities and Challenges – Pathways to Action, spoke of the desire of its authors that the sponsored research have policy consequences (Program Memorandum June 2013). Within this PM three key thematic areas of research were identified. These included: (1) Drivers of Change -Interactions and Impacts; (2) Arctic Resource Development in a Global Context; and (3) Waters, Ecologies and Life Environments. It was stated in the Program Memorandum that the program should be cross-disciplinary in character and be built on integrated research efforts in the areas of public health and medicine, humanities and social sciences, and natural sciences and technology. The initiative should also support international cooperation at the highest level among Arctic as well as non-Arctic countries. In addition, it should integrate and monitor data collection and support the joint use of existing archives, scientific collections or other research infrastructures.

In the finalized PM, it was stated that the overall purpose of the effort was "to produce integrative new knowledge of past and current change, and projections for future change that can inform societal discourse on probable or desirable directions of change in the Arctic" (PM, page 1). It was also suggested that the initiative should create "pathways to action" by strengthening the knowledge base for political decision-making, education, industrial and human development. The latter should be accomplished by inviting the full range of stakeholder communities, including politicians, industrial actors, public sector officials, educators, NGOs and local communities, to take active part in the creation of new integrative knowledge within the Nordic initiative to be launched.

It was suggested that a key approach within the "Drivers of Change – Interactions and Impacts" prioritized research area, there should be a combination of economic and climate modelling. The second prioritized area "Arctic Resource Development in a Global Context", should include studies of the traditional economic base of the North including agriculture, fishing and hunting as well as the needs of the industrial economy. Attention would also be given to renewable energies including wind, geothermal power, hydroelectricity, and non-renewables such as oil, gas and mining. The third area of suggested inquiry "Waters, Ecologies and Life Environment" would consider how the hydrological cycle in the Arctic is changing and how this is having an impact on the ecosystems, the development of business, human health and well-being within the Nordic North. It would also consider related issues such as migration, ethnic relations and gender.

The Program Memorandum, as briefly described above, was presented to and approved of by the NordForsk Board when they met in Helsinki in June 2013. The decision was also made to allocate money from the NordForsk budget, which together with the financial contributions from the five Nordic countries, should make it possible to carry out a larger-scale research program on the Arctic.[21] The contribution from the NordForsk budget was 112 Million NOK and each of the Nordic Centers of Excellence were granted 28 Million NOK.

2.5 Implementation of the Initiative

Soon after the decision of the NordForsk Board, a Program Committee (PC) comprised of representatives from the participating countries was established with the aim of assisting the NordForsk Secretariat in the process of taking the content of the Program Memorandum and formalizing it into a call for proposals. Decisions had to be made with respect to the choice of financing instrument to be utilized and whether these should be research projects or Nordic Centers of Excellence. A decision had also to be made whether to launch the call in one or two stages. Likewise, identifying key aims of the initiative and the criteria for eligibility and evaluation had to be determined. Similarly, additional decisions had to be made regarding the best means for identifying international peers with expertise in the field and how the peer review process would take place. Future contingencies including the possibility of securing additional funding for remaining knowledge gaps had also to be considered.[22] The NordForsk Board appointed the Director of the Finnish Environmental Institute Mari Walls, to act as Chair of this PC. The other members were appointed by the main financiers in the respective Nordic countries.[23] All of them had the relevant

[21] The NordForsk Board decided to allocate 49 Million NOK from its own budget. After the transfers of money from the co-funding agencies to NordForsk's "common pot", this end up being more than double the sum provided by NordForsk. As each of the Nordic countries have their own currency and because the currency rates fluctuate a lot, the final contributions depended on at what point in time money are being transferred to NordForsk and when they are paid out from NordForsk to the grantees. NordForsk's common pot was therefore at this point in time not exact, but estimated to be 116 Million NOK. The following financiers contributed to the NordForsk common pot: The Research Council of Norway, the Swedish Research Council, the Academy of Finland, the Danish Ministry of Higher Education and Science, and the Islandic Centre for Research (RANNIS). It should be noted that there was a requirement that any NCoE, in addition to receiving grants from NordForsk, should contribute some of its own funding either as cash or in kind. The University of Greenland volunteered to provide in kind funding for two PhD students working within the Responsible Development of the Arctic.

[22] In this section, when specific references are not given in the text, the discussion is derived from decisions made by the NordForsk Board, by the Director of NordForsk or by the Program Committee. These are documented in minutes from PC meetings, the texts of research calls, applications etc. Senior Advisor Marianne Røgeberg and sometimes also the Director of NordForsk Gunnel Gustafsson took part in these meetings.

[23] The other members were: Christine Daae Olseng (Norway), Frej Sorento Dichman (Denmark), Þorsteinn Gunnarson (Iceland), and Lize-Marié van der Watt (Sweden). Currently, only those appointed by Denmark and Iceland are still members of the PC. The other members are now: Anna

knowledge and experience needed to deal with the many important issues to be handled during the forthcoming process.

At its first meeting in September 2013, the PC decided to use NordForsk's main financing instrument i.e. Nordic Centers of Excellence (NCoEs). This is a structure based on a single- or multisite research environment or consortium with a joint research agenda and joint management. It allows for international mobility of researchers and PhD candidates as well as their full participation in the research infrastructure.

The PC also decided to use a "real common pot" with no "juste retour". This means that the funding would be granted to the most qualified researchers regardless of their nationality. There would be no guarantee that researchers from the countries that had supported the program financially would be funded. Such a competition has proven to be a quality driver and therefore utilized within most research cooperation facilitated by NordForsk. When the Chair of the PC, Director Mari Walls was asked about the choice of funding instrument she said: "We aim high with the NCoEs. The challenge – and reward – is to generate true interdisciplinary excellence that changes the way we look at Arctic issues. NCoEs bring together professionals with diverse backgrounds for fresh thinking and collaborative research efforts. It is people who are the critical element here and we therefore hope to see researcher mobility and coordinated efforts in using research facilities and infrastructure" (Walls 2014).

At the same meeting, the PC decided to announce a call for seed money to be used for establishing consortia and for preparatory activities. This action was taken in order to allow all interested parties resources to produce a well-conceived and through research plan. It was, however, emphasized by the PC that this would not create a two-step call for proposals as applications for such planning grants were not to be mandatory for participation in the main call for proposals. The announcement of the availability of such seed grants was made immediately after the meeting with a deadline for submission of some 6 months afterwards. The main call for NCoE proposals was announced in the spring of 2014 with a deadline for submission being in early March of 2015. Interestingly, it turned out, that of those who submitted NCoE proposals, only a few had applied for seed grant money. Nonetheless the announcement of such an opportunity was considered useful because it not only gave some the opportunity to gather their thoughts but to consider the timelines involved in the main application process.

The main call for proposals in 2015 for the Nordic Centers of Excellence (NCoE) related to Arctic research outlined several eligibility criteria. These included requirements that the formal applicant should be a research institution, that the leader(s) of the NCoE should be a senior researcher based in one of the Nordic countries, that all consortia should include researchers from at least three Nordic countries and, if possible, also contain investigators from nations outside the Nordic region.

Kaijser (Sweden), Jon L. Fuglestad (Norway), Tine Pars (University of Greenland), Tuula Aarnio (Finland), and the Chair is now Rauna Kuokkanen (Finland).

Additional requirements mandated that: (1) Each Arctic NCoE consortia should contribute some of its own funding to the initiative either cash or in kind; (2) All NCoEs would provide plans for how they would ensure open access to research results; (3) Information on the legal and ethical frameworks for the research conducted would to be detailed; (4) that gender aspects of research and consortium organization be incorporated; and that finally (5) "The NCoE must have a cross-disciplinary focus, integrating excellent research within health and medicine, humanities and social sciences, and natural sciences and technology" (Nordic Centres of Excellence in Arctic Research 'Responsible Development of the Arctic: Opportunities and Challenges – Pathways to Action– announcement text 2014).

This fifth requirement – a commitment to cross-disciplinary research – might initially have appeared controversial given the existing tensions in the research communities between fundamental and strategic research. It was, however, already given a priority status during the earlier consultations with potential co-funding agencies in the Nordic countries. There were several reasons for their willingness to support a cross-disciplinary approach. One was that bottom-up initiated research of high quality and relevance already was available in each of the countries. Another was that it was considered to be added value in combining the existing different research profiles in the Nordic countries in order to accomplish even higher research quality and new knowledge of relevance for the developments in the Arctic. It was also mentioned during the consultation processes that some of the Nordic funding agencies were unable or inexperienced in financing multidisciplinary research. They considered NordForsk to be a suitable platform for doing this. The focus on "challenge-driven" research was also seen as highly relevant by members of the NordForsk Board and by the Nordic Council of Ministers. Thus, the criteria included in the call for NCoEs were firmly anchored among all those who supported the program.

Thirty-four applications were received by NordForsk by the March 2015 deadline and then sent on to an international peer review committee for evaluation. This body was to judge the quality of proposals with regard to "standard criteria" such as the track record of the applicants, their plans for reaching excellence in the main fields of research, the offering of realistic plans for implementation and also other eligibility criteria listed in the text of the call. It turned out that the most difficult criteria for the review committee to apply were with regard to cross-disciplinarity and the integration of new knowledge as a result of cooperation between different "traditionally" defined research fields. The evaluation of these aspects of the applications required several rounds of discussions as well as recruitment of additional peer reviewers with experience in judging the quality of plans for research integration from different areas. There were many proposals which received high marks using traditional "standard criteria", but which received weaker assessments when judged on the basis of their efforts at cross-disciplinarity and the integration of new knowledge and methods. In the final evaluation of the applications, it turned out that these latter concerns were critical and decisive factors in the minds of the assessors. In the end, there was agreement on how to prioritize the applications and a consensus regarding which of the proposed NCoEs should be granted funding. These recommendations were forwarded to the NordForsk Board for its consideration.

The NordForsk Board members were impressed by the thorough process that led to the suggested priorities for the program and the assessment of each of the proposals received. It was noted that the program had attracted many very qualified consortia. At their meeting, December 18 2015, they decided to provide funding for four of the proposed NCoEs with an amount of 28 million NOK each. The selected Arctic NCoEs included: (1) Climate-change Effects on the Epidemiology of Infectious Diseases (CLINF) led by Professor Birgitta Evengård from Sweden; (2) Reindeer Husbandry in a Globalizing North (ReiGN) led by Professor Øystein Holand from Norway; (3) Arctic Climate Predictions (ARCPATH) led by Research Director Yongai Gao from Norway, and (4) Resource Extraction and Sustainable Arctic Communities (REXSAC) led by Professor Sverker Sörlin from Sweden. Although the four leaders of the NCoEs were based in either Norway and Sweden all of the new Arctic NCoEs included researchers from at least three of the Nordic countries, and several had participants from outside the Nordic region. All of the new Nordic Arctic Research Centers included participants with documented multidisciplinary experiences and the capabilities of integrating contributions provided from many different perspectives and knowledge fields.

Work within each of these Centers is still ongoing and so is the monitoring of their progress which is handled by a highly competent Scientific Advisory Board (SAB).[24] The SAB's mandate is to contribute to the further strengthening of the NCOEs' work through a combination of suggestions for improvement in their undertakings and advice regarding the next steps in their efforts. Progress by the NCoEs is evaluated by the SAB with respect to a range of criteria. The most important of these are: research performed to date, cross-disciplinary accomplishments, the effective management and use of research infrastructures, the opportunity for knowledge-user involvement, the dissemination of research findings, contributions to Nordic added value, the offering of researcher training and mobility, the organization and administration of the Centre and the articulation of future plans and directions. Every year, each of the Nordic Centres of Excellence summarize what it has accomplished during the previous year and sends this documentation to the SAB. Then, a yearly gathering of SAB members and members of the NCoEs takes place at which this information is discussed and assessed. Members of the Programme Committee are also invited to participate during some of the sessions. Based on written input from the Centres as well as on information provided during this gathering, a report on the accomplishments and future plans of each NCoE is sent by the SAB to the NordForsk Secretariat which, in turn, provides this

[24] Professor Douglas Nord is the Chair of the SAB, and the other members are: Amy Lauren Lovecraft (University of Alaska), Roberta Marinelli (Oregon State University), Andre van Amstel (Wageningen University) and Antti Oksanen (Finnish Food Authority), who from 2019 has replaced Steven Cummins (London School of Hygiene and Tropical Medicine).

information to the Programme Committee and to the NordForsk Board. (See Chap. 19 of this volume).

These yearly meetings have turned out to be important mutual learning exercises that have helped to create useful synergies between the different Nordic Centres of Excellence. They have also provided opportunities for collaboration between researchers who belong to different consortia. (See Chap. 14 in this volume) This platform for face-to-face exchange of information and dialogue also fulfils a much-needed bridge-building function as it makes research results better understood and more visible across countries and research fields.

In sum, the accomplishments so far within *Responsible Development of the Arctic* suggest that this initiative is likely to reach its dual goals of producing new knowledge on past and present change in the Arctic furthering the debate both in science and society about the region's future. The research information and methods that it is facilitating will contribute to the ongoing attempts to inform about and fight the negative consequences of climate change with the help of this relevant, even though still incomplete, "knowledge compass".

2.6 Some Lessons Learned

A review of the steps that made it possible for NordForsk to initiate and fund the Responsible Development of the Arctic initiative shows that four main factors or cornerstones were of crucial importance. The first was the fact that around the year 2000 key actors in different countries, not least in the Nordic region and in Europe, started to realize that they needed increased incentives for research cooperation across borders because societies were confronted with major global challenges. Thus, a policy-window was at least half open when the idea to initiate research on the Arctic was "born". The second cornerstone was the established tradition of dialogue and commitment to joint action between policymakers within the Nordic research and political arenas. This manifested itself in the cooperation between the five Prime Ministers of the Nordic countries and representatives of Nordic research communities that led to the Top-level Research Initiative on Climate, Energy and the Environment (TRI). The Lund Declaration followed by the 8th Framework Programme Horizon 2020 reflects a growing acknowledgement within the research communities of the Nordic region and the rest of Europe that needs-driven and fundamental research might not be competing approaches, but rather two sides of the same coin. This realization constituted the third factor of critical importance in successfully caring out this initiative. The fourth cornerstone was the planned organizational arrangements for the careful management of the processes from research planning to production of new knowledge. This was built on agreements and regulations regarding the distribution of power and responsibility between the NordForsk Board, the Nordic Council of Ministers and the NordForsk Secretariat. It was also sustained by the Secretariat providing clear mandates to NORIA-nets, the Programme Committees and the Scientific Advisory Boards.

All these circumstances were of great importance in making it possible for NordForsk to facilitate research on the Arctic. However, they are not sufficient, in themselves, to fully understand what are the necessary preconditions for establishing a large-scale research program like the one analyzed in this chapter. An additional lesson learned is the critical importance of having the necessary professional and dedicated people in place to begin such an undertaking. Having the optimal mix of highly qualified and informed administrators, politicians, researchers and policy advisors within the Nordic countries and, specifically, within the Nordic Council of Ministers was, also, a critical factor leading to success of the endeavor. The necessary support and funding for integrated research on the Arctic could not have been accomplished without the organizational skills and strategic intelligence of the leaders involved during the process. Likewise, the strong organizational abilities of the NordForsk Secretariat in handling the administrative, technical and economic aspects of the program was another contributing factor to the success of the initiative especially given the relatively long period from the initial program planning to the start of actual research activities.

The highly qualified members and experts who took part in the work of the NORIA-net also paved the way for the establishment of a large-scale Nordic research program on Arctic issues. Similarly, the time-consuming and demanding effort carried out by the Programme Committee members before the actual call for proposals was of great importance to the ultimate success of the undertaking. So too was the difficult work undertaken by research peers during the evaluation of the proposals. The provision of guiding feedback during the implementation process, currently undertaken by the members of the Scientific Advisory Board and the Programme Committee, have also been important in facilitating new knowledge based on the integration of research from different fields.

A key lesson learned from the launch of this innovative research initiative is the importance of dedicated professionals in ensuring that all the links of a rather complicated chain of action worked smoothly. Because of the excellent contributions made by those involved throughout the initiation, planning, and implementation processes of this undertaking a positive result has been brought about. Without knowledgeable and dedicated people, it would not have been possible to keep the project focused on its goal of providing new knowledge of high scientific quality and relevance for the Nordic community and the broader world.

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Part II

Chapter 3
CLINF: Climate-Change Effects on the Epidemiology of Infectious Diseases, and the Associated Impacts on Northern Societies

Birgitta Evengård and Tomas Thierfelder

Abstract The research initiative CLINF addresses a central issue in planning for the responsible development of the North: an understanding of the impact of climate change on the geographic distribution and epidemiology of climate sensitive infectious diseases (CSIs), and their associated consequences for Arctic health, economic growth, and societal prosperity. Changes in infectious diseases transmission patterns are a likely consequence of changing climates, a neglected problem that is likely to have a profound effect on northern societies, including indigenous cultures. There is an urgent need to learn more about the complex underlying dynamic relationships, and apply this information to the prediction of future CSI impacts, using more complete, better validated, and integrated data and models. This chapter provides an overview of the thoughts behind the CLINF NCoE (Nordic Centre of Excellence), and the integrative context expressed therein. The most recent findings regarding climate change in the Arctic, as published by IPCC and other global networks, are presented. In the international CLINF consortium of researchers, nine human and 18 animal husbandry diseases have been selected for study due to their potential for being climate sensitive. The human infections were selected by an international consortium of researchers, to represent fundamentally different transmission processes. The main CLINF objectives are the construction of practical tools for the decision-makers who are responsible for the development of northern societies. By contributing to the development of an early warning system for increased risks for CSIs to spread at the local level effective policy responses may

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be formulated. The overall aim of CLINF is to support the sustainability of Arctic development.

Keywords Climate change · Infectious diseases · Ecosystems · Homo sapiens · One Health

CLINF represents one of four Nordic Centres of Excellence (NCoE) that were established in conjunction with NordForsk's support of a broad scientific inquiry into "the responsible development of the Arctic." Each NCoE was proposed with the clear objective of providing "pathways for action" to meet the existing and anticipated needs of the region. In the case of CLINF its focus of attention has been on addressing the health requirements of the Far North—specifically those associated with the emergence of new diseases and pathogens resulting from significant changes in climate now seen in that region. This essay begins by considering the historical legacy of scientific inquiry on which such an investigation is based. It then moves to consider how this tradition of inquiry helped to inspire the CLINF project. From there an overview of the nature and extent of climate change and species migration is presented. The growing threat of infectious disease transmission (especially between animals and human) is then discussed within this context. From such an introductory discussion, the goals and objectives of the CLINF project are presented. This is followed up by a reporting of results from one of its major efforts: the creation of a CSI data base encompassing the area from Greenland through Siberia.

3.1 Building Upon a Historical Legacy of Inquiry

The views of climate, transitioning landscapes, and ecosystem functionality that underpin CLINF and much of today's science, do have an inspiring history that link back to the explorative scientific era of the late eighteenth and early nineteenth centuries. In 1802, as Alexander von Humboldt (1769–1859) looked out from a plateau, having almost reached the top of the volcano Chimborazo in Ecuador, he experienced an "on the road to Damascus" moment. He realized that vegetation zones vary with regional climates. This "resemblance which we trace in climates [can be] the most distant from each other. Nature is a force and a web of life". (Wulf 2011).

With this view of nature, combined with unprecedented communication skills, von Humboldt became a modern geographer, naturalist, and explorer. Like his friend and mentor Goethe, he was driven by a sense of wonder for nature: "Close your eyes, prick your ears, and from the softest sound to the wildest noise, from the simplest tone to the highest harmony, from the most violent, passionate scream to the gentlest words of sweet reason, it is by Nature who speaks, revealing her being, her power, her life, and her relatedness so that a blind person, to whom the infinitely visible world is denied, can grasp an infinite vitality in what can be heard" (Von Goethe, 1885 preface of The Theory of Colours) von Humboldt argued that we need to use our imagination to understand nature. His holistic view included art, history, poetry, and politics, while science was the foundation. This German investigator became the founder of "ecosystem sciences" (Wulf 2011), which constitutes a concept for science that very much applies to the CLINF NCoE.

As science has developed into more and more specific fields, such a holistic embrace of science has become viewed as outmoded by some. Nonetheless von Humboldt's beliefs in the free exchange of information, today called Open Access, continue to direct the course of scientific research. Similarly, his vision of uniting scientists across disciplines, today called multidisciplinarity, directs much of contemporary cutting-edge research. Finally, his constant urge for communication between scientists, and also with the general public, today is called for by all science funding organizations. These views represent pillars of current scientific research, and most probably of that of tomorrow's as well. Von Humboldt's ideas about how social, economic, and political issues are closely tied to ecological problems, are necessary considerations also for CLINF in its work.

The visions developed and shared by von Humboldt were transformed into something that all humans, today take for granted. Nonetheless, they were quite revolutionary at the time. Religion or God were never mentioned in his immensely popular book *Cosmos* (Von Humboldt 2010). However, "the web of life" was central to his concerns. He stressed that the world is characterized not by balance and stability, but by dynamic change. During his Russian expedition in 1829, where he crossed river Ob after having passed through a landscape plagued by an enormous anthrax outbreak von Humboldt listed three ways humans were then affecting climate: through deforestation, ruthless irrigation, and the usage of steam and gas for industrial purposes. What foresight!

Alexander von Humboldt was the first scientist to talk about harmful human-induced climate change, first in 1800 and then again in 1831! His fame rose, and he was elected to many scientific societies around the world including to the Royal Swedish Academy of Science in 1810. According to one anecdote, he was much inspired by the poem "The Loves of Plants" in which nature and imagination were combined. The poem was written by the grandfather of Charles Darwin, and during the latter's voyage around the globe he read it over and over again, along with the seven volumes of von Humboldt's *Personal Narrative*. (Wulf 2011) Darwin collected scientific data, and also information about the indigenous peoples along his way, and came to incorporate von Humboldt's ideas regarding "the web of life" into his famous theory regarding natural selection as the origin of species. Darwin was standing on the shoulders of Alexander von Humboldt, and so is the CLINF science initiative linked to them.

Our present undertaking is also indebted to other keen scientific minds. The Swedish scientist Svante Arrhenius (1859–1927), a leading physicist and chemist, advanced in his book *Worlds in the Making* the so called "hot-house" theory of the atmosphere. He was also the first to describe the advent of the Anthropocene era.

Based on information from his colleague Arvid Högbom, he was the first to predict that carbon dioxide emissions released from the burning of fossil fuels would cause global warming. However, he thought it would take thousands of years (Swedish National Encyclopaedia). When James Watt improved the steam-engine in 1769, the same year Alexander von Humboldt was born, he did not realize the effect it would have in dynamic interaction with the transition from an agricultural society, into the industrial society starting with English textile industry. Svante Arrhenius would further develop von Humboldt's reflections concerning a possible emergence of an Anthropocene era as a consequence of the industrial revolution.

On reflection, what we see is a succession of brilliantly open minds, utilising each other's observations and reflections to advance the cause of scientific inquiry. A descendent of Svante Arrhenius, Greta Thunberg, is today engaging in the climate debate at the global level. She is correcting her ancestor's mistaken idea that it would take thousands of years for CO2 emissions to reach critical levels. In fact, it is occurring here and now. With this historic perspective on how science is transferred and developed through generations, we would like to think that CLINF also rests on the shoulders of all of these scientists.

3.2 The Specific Origins of the CLINF NCoE

When the research call for investigations of the "Responsible Development of the Arctic" was announced by Nordforsk in 2015, the present authors were immediately attracted and inspired by its research priorities. We had just met with other Arctic scientists during a workshop concerning the effects of climate change on the Arctic and found common ground in these discussions and shared concerns as to future developments in the region. Birgitta, a Professor of Infectious Diseases, with a broad interest in human health, had been one of the pioneers at Umeå University in the creation of a Swedish Arctic Centre. She had also been working with human health in the context of climate change for a number of years. Tomas, a Mathematician and Earth Scientists with an interest for interdisciplinary science designs, had been involved with the work of INTERACT, an international monitoring system (www.eu-interact.org) over several years and was familiar with the efforts to create practical administrative tools in response to the effects of climate-change in the Arctic (www.interact-gis.org).

With the NordForsk initiative being profoundly interdisciplinary, encompassing both human and animal health as well as natural and social sciences, we were very excited, and immediately started to formulate our proposal. In the broadest possible context, the three themes of the NordForsk initiative were: (1) Drivers of Arctic change; (2) Arctic resource development in a global context; and (3) Arctic waters, ecologies, and life environments. With infectious diseases being carried by "waters and ecologies", and affecting "life environments", it was the third theme of the announced research call that particularly caught our attention. This theme called for new empirical work, like the procurement of new relevant data, along with interdisciplinary collaborative assessment of such data in order to produce practical tools in "bilaterally inclusive support of stakeholder decision-making and administration". With our combined expertise regarding Northern infectious diseases, data-driven interdisciplinary assessment, and the agile development of supportive infrastructures, we organized our proposal. It would adopt a grand-style approach to the emerging threat and changing exposures to human and husbandry-animal infectious diseases in the North. It would include both biological and associated societal effects of such developments. The proposed interdisciplinary design of the initiative would rest on the very holistic view of health called One Health, which definitively reflects the views of von Humboldt and Goethe and the other pioneering researchers noted above. One Health takes a holistic approach to health risks and risk mitigation for humans, animals, plants and the environment with the understanding that human health and welfare is dependent on ecosystem health.

3.3 Climate Change in the Arctic

The winters of 2016 and 2018 were extremely warm across the Arctic, with record lows in the extent of winter sea-ice (NSIDC 2018, 2019; Overland et al. 2018). According to the Intergovernmental Panel on Climate Change (IPCC reports from 2014 and 2018), the Arctic is warming at a speed more than double the rate in the rest of the world. The effects of climate change are clearly felt in northern communities of the Arctic where people, animals, and the environment, in general are affected (Rosen 1984; Diffenbaugh and Field 2013; Kemp et al. 2015; Chen et al. 2011; Poloczanska et al. 2013; CAFF 2013). This Arctic warming is also an important driver for climate change in the rest of the world (Collins et al. 2013).

Some of the most ancient of Arctic permafrost has warmed by more than 0.5 °C since 2007 (AMAP 2017). The snow-cover season is becoming ever shorter. Between 1982 and 2011, the period of snow-cover in the Eurasian Arctic decreased by 12.6 days/year on average, while Arctic North America lost 6.2 days of snow-cover duration per year during the same period of time These changes affect ecosystems and local human populations in a significant fashion (Bokhorst et al. 2016). Since 1880, there has been an average global surface warming of 0.85 °C (IPCC 2014). A higher rate of Arctic warming, called Arctic Amplification, is caused by feedback loops that are unique to the Far North. When sea ice melts in the Arctic summer, for example, the maritime waters will absorb more of the heat from the sun, thus speeding up the melting of the ice. The same kind of dynamic processes, related to loss of albedo, also have an impact on snow-melting, bare-soil absorption of sunlight energy, and the associated thawing of permafrost (Dai et al. 2019).

Permafrost is defined as ground that remains frozen for two or more years. It occupies approximately 22% of the Earth's surface (NSIDC 2018). The current area of permafrost in the northern hemisphere is approximately 15 million km^2. This is predicted to decrease to 12 million km^2 by 2040, followed by a rapid decrease to 5 to eight million km^2 by 2080 (AMAP 2017). Thawing permafrost leads to unstable mountain slopes, coastal erosion, and seriously threatens human settlements, infrastructure and examples of cultural heritage. (Hovelsrud et al. 2011and Hollesen et al. 2018).

Across the globe, frozen grounds hold an estimated 1500 billion tons of carbon – double the amount of carbon now in the atmosphere (Schuur et al. 2015) – and half the world's total soil carbon (AMAP 2017). This permafrost carbon reservoir is stable as long as the ground stays frozen. However, as the permafrost melts, we can expect more carbon emissions. These, in turn, will result in more frequent forest and tundra fires and the loss of terrestrial and aquatic habitats. Such losses will cause species to move into new and more favourable territories, carrying with them zoonotic infections.

Studies show that as near-surface permafrost continues to warm, a broad range of new lifeforms are attracted to the transforming landscapes. A central hypothesis of the CLINF inquiry claims that some of these lifeforms carry new infectious pathogens into the Arctic (See Chap. 4 of this volume). This thawing trend appears to be irreversible. Under an IPCC high-emissions greenhouse-gas scenario, stabile permafrost will most likely remain only in the Canadian Arctic Archipelago, along the Russian Arctic coast, and in the East Siberian uplands (AMAP 2017).

Most current climate models, predict that at the present rate of atmospheric CO2 increase, the Arctic will be free of summer-ice in the 2030s (Jahn et al. 2016; AMAP 2017). Less Arctic sea-ice means an extended duration of open waters, which, in turn, can attract additional economic activities such as fisheries, energy production, mining exploration, and increased shipping along "the northern Arctic route". The warming of the Arctic Ocean, and its freshening and dilution from the thawing of glaciers and sea ice, as well as from increased riverine inputs, affects ocean circulation. It decreases the formation of cold, relatively dense, deep-strata water, which, in turn, may weaken the Gulf Stream of the Atlantic Ocean. This may have further feed-back implications for the global weather systems. As observed, the frequency of intense hurricanes, heat waves, and wildfires, are now increasing in the northern hemisphere (Samenow 2018; Schiermeier 2018).

In the Arctic, the effects of such change have long been felt by people living in the region. Climate adaption has already become part of their ordinary lives for a long period of time (Bokhorst et al. 2016; Hovelsrud et al. 2011). Indigenous peoples throughout the CLINF study region, from western Greenland to Pacific Russia, such as the Inuit of Greenland, the Sami in Sápmi, and the Nenets, Evenki, Tjuktji in Russian Siberia, have all developed adaptations to their changing environments. Their local, traditional and indigenous knowledge, is of inestimable value, and is utilised by CLINF researchers as they conduct their inquiries. Another focus of CLINF's work has been to incorporate a gender perspective. An authentic study of the societal effects of climate-change cannot be undertaken without giving due consideration to gender, age and social status variables.

3.4 Species on the Move

While climate-change is denied by some, we nonetheless believe that we are witnessing one of the largest climate-driven global redistribution of species since the last glacial maximum. While the traditional geographic range of species can fluctuate dynamically in space and time, recent climate changes can cause a systematic translation of species populations. If "cold species" cannot adapt to warming local conditions, they will seek new habitat towards the poles, higher up the mountains, or deeper down in the oceans (Pecl et al. 2017). Meta-analyses show that, on average, terrestrial taxa move poleward by 17 km per decade (Chen et al. 2011), and marine taxa by 72 km per decade (Poloczanska et al. 2013; Sorte et al. 2010). Just as terrestrial species on mountainsides are moving upslope to escape warming lowlands (Chen et al. 2009), some fish species are now driven deeper as the sea-surface is warming (Dulvy et al. 2008).

With different species responding to climate change at different rates and to varying degrees, new interactions across species may also occur (Parkinson and Evengard 2009). New ecological communities are established, and rapid changes in ecosystem functioning may also have an impact on human societies (Hoberg and Brooks 2015, Björkman et al. 2009). Although difficult to overlook, the resulting biological/ecological chain-reaction must, be considered and included in all local, regional, and global decision-making regarding climate-change countermeasures and planning. Although this redistribution of the planet's living organisms introduces a substantial challenge for human society, the consideration of such effects has often been absent in most mitigation and adaptation strategies. This includes the United Nation's Sustainable Development Goals, where the applicability of a number of objectives not are adequate for usage in the changing Arctic. To date, most key international discussions and agreements regarding climate change have focused on the direct socioeconomic implications of emissions reduction, and on funding mechanisms. Shifting natural ecosystems have yet been largely absent from the agenda (Pecl et al. 2017).

Persistent responses to climate change usually demand long-term data collection, in order to assess pre- and post-climate change trends at the level of species and ecosystems (Brown et al. 2016). Such long-term datasets covering biological/ecological systems are rare. Recent trends of declining funding in some nations undermine the viability of the monitoring programs required to document and respond to climate change. Fortunately, for many years, there have been research and monitoring stations operating all around the Arctic. Today organized under the EU infrastructure project called INTERACT (International Network for Terrestrial Research and Monitoring in the Arctic). INTERACT aims to provide a geographically comprehensive and an excellent state-of-the-art terrestrial research infrastructure throughout the Arctic and adjoining forest and alpine regions. It seeks to identify environmental change, to facilitate understanding and prediction of future change and to inform decision makers about societally-relevant impacts. INTERACT is the fundamental building block and a one-stop-shop for EU and international projects, programmes and organisations requiring access to northern lands, data and services, and includes a rapid response capability to potential hazards. INTERACT is pan-Arctic, multidisciplinary and crosses all EU domains by linking to forest, coastal, marine and atmospheric communities.

Climate change supports the spread of microorganism also in many other ways. For thousands of years, as humans have migrated across lands and explored the oceans, they have carried species with them from one part of the world to another, intentionally as well as unintentionally. Around 480,000 invasive species are estimated to have been introduced around the world by humans (Pimentel et al. 2001). At a global scale, invasive species are the second greatest threat to biodiversity after habitat destruction (Bellard et al. 2016). Invasive species are introduced through the unintended transportation of insects, algae, and crustaceans "hitch-hiking" with airfreight, shipping containers, on the hulls of ships, and in their ballast waters. As trade volumes rise and globalization expands, the likelihood of an increasing number of invasive species also rises (Seebens et al. 2017). A major concern along these lines is the expected increase in shipping within and across the Arctic in the coming decades. An ice-free Northern Ocean Route offers major advantages for shipping between Europe and Asia (Melia et al. 2016; Smith and Stephenson 2013). This is an important development, since it is likely to bring new marine species into the Arctic and the Northern Hemisphere (Miller and Ruiz 2014).

3.5 Without Healthy Ecosystems, No Human Health

The emergence of early humans was most likely conditioned by their capacity to switch between preys and diets as changing climatic conditions made new resources available (Compton 2011; Harari 2014; Berg 2007, 2011; Evengard et al. 2015). With climate-change serving as an important driver through the development of Homo sapiens, the difference now as compared with earlier eras is the rate at which it is occurring. In the present era of rapid change, human societies have come to rely increasingly on technological and behavioural innovations in order to meet changing species distribution patterns. The indirect effects of changing species distributions may be dramatic. Decreasing food security is a current problem for many Arctic residents, due to climate-induced changes to habitats and wildlife. Other effects include worsening travel conditions due to the thawing of tundra and the decrease in use of ice-roads along frozen rivers due to the lack of thick enough ice. This impacts their ability to reach important hunting and reindeer-herding regions.

Declines in some species will most likely also have cultural impacts. Within the Arctic, the integrity of ecosystems and the sustainability of communities are being challenged, affecting people's lives and livelihoods (AMAP 2017). In the East Siberian tundra, for example, faced with melting permafrost, the Chukchi people are struggling to maintain their traditional nomadic reindeer-herding practices (Mustonen 2015; West 2010). The encouragement of citizen-recording of climate-induced changes as a complement to assessments based on scientific sampling and remote sensing, may form part of a strategy to maintain traditional practices.

Human health is also likely to be seriously affected by changes in the distribution and virulence of animal-borne pathogens. These already account for more than 70% of all emerging infections (Jones et al. 2008; Wu et al. 2016; Allen et al. 2017). Geographic transmission of mosquito and tick populations, in response to global warming in the North, is a threat to health in many societies where the number of known and potentially new diseases is predicted to increase. The winners and losers arising from the redistributions of species will reshape patterns of human well-being across regions and sectors of industry and communities (Weatherdon et al. 2016). With living conditions changing so rapidly throughout the Arctic, the mental health of northern populations will most likely also be affected.

3.6 Zoonoses: Diseases Transmitting from Animals to Humans

Global pandemics occur when a new disease suddenly appears against which humans have no immunity. They are often caused by a virus or other pathogens "jumping" from animals to humans. These transfers from animals to humans are called zoonoses and include infections or infectious diseases caused by viruses, bacteria, parasites, fungi and prions (proteins linked to several fatal neurodegenerative diseases). Zoonoses are transmitted in many ways, including through direct contact between animals and humans, biting insects, intake of food and water contaminated with parasites and through the air (de la Rocque et al. 2008). The Spanish flu of 1918, caused by the Influenza A virus found naturally in wild aquatic birds, claimed between 30 and 50 million lives (Taubenberger and Morens 2006) and is perhaps the best-known – and deadliest – example. The rabies virus and recent emerging diseases, such as the Ebola, the Zika and the SARS-CoV-2 viruses, are other examples.

The frequency of contagious diseases observed in Arctic species has increased in recent years. These include avian cholera outbreaks in marine birds in the northern Bering Sea and in the Canadian Arctic Archipelago as well as mortalities within seal and walrus populations found in the US Arctic (CAFF 2017). The increased thawing permafrost may also have the potential of releasing highly resistant spores of anthrax as was seen in a 2018 occurrence in Yamal within the Russian Arctic. This outbreak was widely covered in the media, and resulted in the death of a 12-year-old boy, the hospitalization of around 100 people, and the death of 2300 reindeer (Goudarzi 2016). There is also a risk of ancient microorganisms re-emerging with the thaw of permafrost, releasing long-time buried pathogens (Parkinson et al., 2011, 2014; Callaghan et al. 2011). Migratory birds also have the potential to transmit ticks across long distances (see Fig. 3.1 below) as well as antibiotic resistant genes.

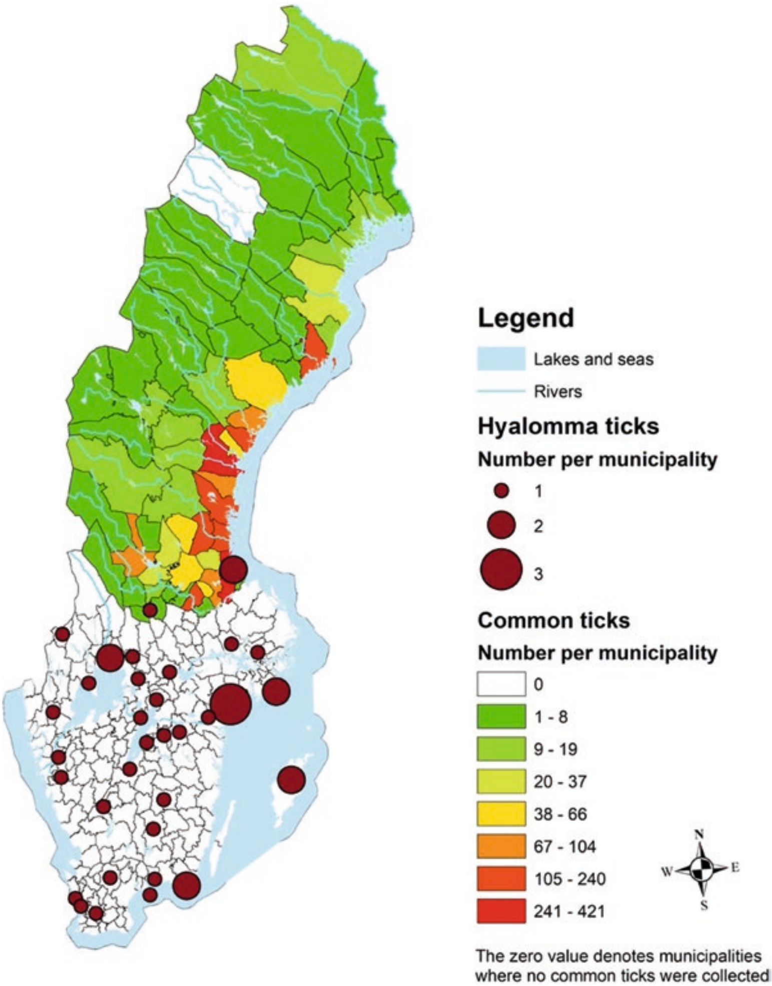

Fig. 3.1 CLINF ticks survey conducted via a campaign of citizen science during 2018
As a result, the first ever observation of adult Hyalomma ticks was made in Sweden
CLINF data collected by SVA, cartographer: Tomas Thierfelder, SLU-ET

3.7 The CLINF Nordic Centre of Excellence (NCoE)

The CLINF NCoE has consisted of an international interdisciplinary team of natural and social scientists (climatologists, ecologists, veterinarians, animal scientists, experts on human health, biologists, anthropologists, sociologists and social philosophers, experts on gender and traditional knowledge) brought together to address a key objective: **to clarify the impacts of climate change on humans and animals among animal husbandry households, which are particularly exposed and sensitive to such changes, through the changed geographical distribution and epidemiology**

of CSI. The additional aim has been to turn this new understanding into practical tools for decision-makers responsible for the development of northern societies, both by providing relevant data in an accessible form, and by contributing to the development of an early warning system for increased risk of spread of CSI at the local level.

Zoonotic infections that may be transferred between humans and animals are particularly central (Hueffer et al. 2013; Omazic et al. 2019a) to this inquiry. As mentioned above, more than 70% of current human infections are zoonotic, as are many of the emerging infections in the North (Wolfe et al. 2007). In-depth case studies within the CLINF project address how the CSIs may pose not only a threat to both humans and their reindeer and sheep, but also offer direct and indirect challenges and opportunities to the economy and culture of northern societies. The CLINF project has the following logical structure:

- To gather information on the prevalence and incidence of CSIs in humans and animals in the north;
- To characterize the environmental envelopes under which terrestrial and aquatic disease vectors can thrive and propagate;
- To develop statistical and biophysical models that can represent the environmental conditions, and use the models to predict relevant environmental changes under climate change;
- To relate these changes to the likely spread of CSI and the associated risks to health and Nordic economies and culture; and
- To provide data and tools allowing this knowledge to be exploited by societies and individuals to make informed choices.

3.8 CLINF and Human Diseases

The nine human infections considered within the CLINF NCoE were selected by an international committee including scientists from Russia and Greenland. Their selection was based on how these separate infections represented different modes of transmission involving different ecosystems. They also considered whether they had the potential of becoming an emerging infection if not already being one. As climate change will have specific consequences in different ecosystems, microorganisms involving, air, dust, water, soil and permafrost sources were considered and their modes of transmissions are described below in detail:

Anthrax is caused by Bacillus anthracis, a bacterium found in soils and mammals, that may be part of normal bacterial flora. Humans become accidentally infected via contact with infected animals or animal products.

1. Cutaneous anthrax with ulcer is the most common form, with case fatality-rate < 1% with antibiotic therapy, untreated up to 20%.
2. Inhalation anthrax originates from the inhalation of B anthracis spores when working with animal products, or by intentional release at occasions of bioterrorism, and has the highest mortality rate.

3. Gastrointestinal anthrax is caused by eating undercooked infected meat from animals with anthrax.

Veterinary vaccines are used worldwide.

Brucellosis is a zoonotic infection, transmitted to humans via contact with fluids from infected animals (sheep, cattle, etc), or derived from food products such as unpasteurized milk and cheese. Brucellosis occurs worldwide, endemically in the Mediterranean region. Brucella spp. are small intracellular bacilli, and Brucellosis may hence be prevented via vaccination of animals or by pasteurization of milk.

Borreliosis, also known as Lyme disease, is a tick-transmitted bacterial infection caused by spirochetes Borrelia burgdorferi sensu lato. It is transmitted to humans by the bite of infected ticks, and can be found mainly in Europe, North America, and temperate Asia. Neuroborreliosis is the main complication which may be found in approximately 10% of all cases.

Ticks become infected when they feed on birds or mammals that carry the bacterium in their blood. Usually smaller mammals are preferred for the larva and nymphs to feed on, while adult ticks feed of larger mammals like deer. Optimal habitats are e.g. mixed woodlands, heathland, open grassy meadows, and urban parklands.

Cryptosporidiosis (short Crypto) is a disease caused by the parasite *Cryptosporidium*. It lives in the intestines of infected humans or animals, and may be found in soil, food, water, or at surfaces that have been contaminated with the faeces from infected humans or animals.

Several community-wide outbreaks of cryptosporidiosis have been linked to contaminated municipal drinking or recreational waters.

Hantavirus is carried and transmitted by rodents, and occur by seasonal outbreaks. Humans are infected via aerosols of rodent excreta, i.e. urine or saliva. Two different, severely acute febrile illnesses may be distinguished:

Haemorrhagic fever with renal syndrome (HFRS; Old World viruses) and Hantavirus cardiopulmonary syndrome (HCPS, New World viruses).

In Europe and Russia HF with renal syndrome is common. Case fatality-rates range from <1% for Puumala (nephropathia epidemica), to 2–10% for Hantaan or Dobrava.

Leptospirosis is a zoonosis caused by spirochetes and is distributed worldwide. The organism infects mammals, especially rodents, which may either develop asymptomatic or clinical infections. Reservoir animals shed the organism with their urine, and contaminate the environment. Humans may be infected after exposure to soils contaminated with urine.

Q-fever occurs worldwide, and is caused by the bacteria *Coxiella burnetii*. It affects humans and cattle, sheep and goats all serve as reservoirs. Human infection usually occurs by inhalation of contaminated air and from tick bites, from drinking unpasteurized milk or other dairy products, and at rare occasions via human-to-human transmission.

Tularaemia is a disease of animals and humans caused by the bacterium *Francisella tularensis*, with Sweden, Finland, and Turkey having reported the highest incidences (Desvars-Larrive et al. 2017). Rabbits, hares, and rodents seem to be especially susceptible, and often die by large numbers during outbreaks. Humans can become infected through several routes, including:

- Tick, mosquito, or deer-fly bites
- Skin-contact with infected animals, i.e. when handling infected animal tissue, skinning rabbits after hunt, etc.
- Ingestion of contaminated water
- Inhalation of contaminated aerosols or agricultural dusts
- Laboratory exposure

In addition, humans could be exposed as a result of bioterrorism.

TBE is a human viral infectious disease that affects the central nervous system, and may result in long-term neurological symptoms, and even death. The virus is transmitted by the bite of infected ticks, with reservoir hosts being mainly small rodents (voles, mice), but also birds and small carnivore mammals. There are three subtypes:

1. European subtype; transmitted by Ixodes ricinus ticks, endemic in rural and forested areas of central, eastern, and northern Europe.
2. Far-eastern subtype; transmitted mainly by Ixodes persulcatus, endemic in far-eastern Russia and in forested regions of China and Japan.
3. Siberian subtype; transmitted by Ixodes persulcatus, endemic in the Ural region of Russia, Siberia, and far-eastern Russia and recently found also in some areas of north-eastern Europe.

TBE can cause an influenza-like illness, but also neurological symptoms since it may infect the central nervous system and cause meningitis/encephalitis. Tick activity and life-cycle depend on climatic factors such as temperature, soil moisture, and relative humidity (Tokarevich et al. 2017), where wet summers in combination with mild winters tend to increase tick population density. A vaccine is available in some regions of endemic disease.

A detailed account of a CLINF animal disease research initiative is provided in Chap. 6 of this volume.

3.9 Specific Undertakings of the CLINF NCoE with Regard to CSI in the North

The ClINF NCoE has been organized around six work packages (WP). The focus of each is briefly detailed below:

WP1 gathers information on the prevalence and incidence of climate-sensitive infections (CSI's) in humans and animals in northern Scandinavia, north-western Russia and the North Atlantic islands. One major objective has been to provide an alert system for CSI at local level, by identifying ecological changes of importance for emerging diseases.

WP2 has been focused on the acquisition and integration of the in situ and satellite-based environmental data needed to assess the potential spread of CSIs under high latitude change. It seeks to use these data in model projections of environmental change relevant to the viability and propagation of disease vectors.

WP3 combines disease prevalence data from WP1 with present and projected scenarios of landscape change from WP2, in order to analyze how present populations of selected diseases will change in a thawing North. Using the current geographic distribution of diseases as a baseline, the potential for migration of disease is analyzed as a function of projected landscape and hydrological change and depicted with a time-series of thematic maps.

The aim of **WP4** has been to understand how the spread of climate sensitive infections (CSIs) will affect societal and individual well-being, ontological security, and adaptive capacity in the North. Ontological security is defined here as: The sense of security of individuals and communities about the potential to preserve and develop identity and tools for understanding and controlling their social and material environment.

Climate change has different impacts on the well-being of different groups of people in Northern communities. These different impacts are assessed in **WP 5**. Indigenous people, the elderly, women and children are particularly vulnerable in the Arctic (SLICA; AHDR, 2004, 2014). Within this work package traditional knowledge, (TK) has been defined as knowledge and beliefs regarding relations between living beings and their environment.

WP6 acts as a central node for CLINF. It provides a novel decision-support system for storage and sharing of intermediate CLINF data, as well as for disseminating data products intended for end-user decision-support on the infectious hazards associated with climate change. This web-based infrastructure seeks to support an environmentally friendly project culture.

Further research of the type described above is needed to better understand the distribution and spread of climate-sensitive infectious diseases in Arctic ecosystems and societies. Such studies can assist in the development of an early warning system and other preventive measures. These needs were pointed to and underscored within the context of the original CLINF proposal that was made to NordForsk. The resulting CLINF Nordic Centre of Excellence (NCoE) was designed to research these and other health related concerns of the Arctic. The full dimensions of some of these inquiries are covered in Chap. 4 of this volume. The specific focus and operation CLINF climate modelling efforts are captured in Chap. 5. Similarly, CLINF's study of the societal impact of Climate Sensitive Infections is offered in Chap. 6 of this book. The remainder of this chapter provides an account of one of the major initiatives by CLINF to capture human and animal diseases data which have been used by all components of the NCoE.

3.10 The CLINF Database

The procurement, inventory and assessment of reference disease, weather and landscape data is fundamental to the CLINF integrated design. The provision of continuously refined data products has utilised as an integrative agent when communicated within the consortium. This is further passed on to the stakeholders and the broader society as described further in Chap. 4 of this volume. With CLINF data and data products disseminated via a cloud-based repository called CLINF GIS, the repository covers four sets of harmonised data, which are discussed below. They include: (1) historical human data regarding nine tentative CSI's; (2) historical animal data regarding 18 tentative CSI's including human zoonoses; (3) climate/weather data related to the areas of study; and (4) landscape data covering the same regions.

As noted earlier, most of the diseases addressed by CLINF are zoonotic in character--they may be transmitted from animals to humans. The term "human CSI" indicates that the corresponding diseases have been provided through human diseases reporting systems. The CLINF repository contains data regarding borreliosis, brucellosis, cryptosporidiosis, leptospirosis, haemorrhagic fever with renal syndrome, Q-fever, tick-borne encephalitis, and tularaemia. Since human diseases data are reported on case by case basis, information regarding gender and age of the patient was also secured. CLINF produced a data set showing the variability of such diseases by country and over time as illustrated in Table 3.1 (Omazic et al. 2019b).

Human diseases data for the CLINF initiative was either reported clinically or via laboratories, in written form or via digital report systems. This introduces a potential of overlay error since single cases of diseases may be reported twice, and since older written reporting systems may overlap with the implementation of

Table 3.1 Coverage of supplementary information concerning gender and age per nation and disease

Nation	BOR	BRU	CRY	LEP	PUU	QFE	TBE	TUL
Finland	1995–2016	1995–2014	1995–2016	1995–2016	1995–2016	1998–2016	1995–2016	1995–2016
Greenland	n/a	n/a	n/a	n/a	n/a	2007–2007*	n/a	n/a
Iceland	n/a	n/a	–	n/a	n/a	n/a	n/a	n/a
Norway	1990–2016	2004–2016	2012–2016	n/a	1991–2016	n/a	1998–2016	1985–2016
Russia	–	–	n/a	–	–	–	–	–
Sweden	–	–	2004–2016	–	1985–2016	–	1978–2016	1969–2016

Where not applicable (n/a), the diseases have not been reported. A bar (–) annotates the lack of supplementary information despite reported diseases. *BOR* borreliosis, *BRU* brucellosis, *CRY* cryptosporidiosis, *LEP* leptospirosis, *PUU* haemorrhagic fever with renal syndrome/Puumala virus infection, *QFE* Q fever, *TBE* tick-borne encephalitis, *TUL* tularaemia. * = A single case of QFE reported in Greenland 2007 digital systems. CLINF has spent much effort on reducing such sources of error to their minimum.

"Animal CSI" data refers to mainly zoonotic diseases reported via animal diseases reporting systems, and are generally more scattered in space and time than human diseases data. In contrast to the human data, the animal data assembled by CLINF originated from many different species of vector and reservoir organisms, and are therefore were more difficult to inventory and procure. As for human data, animal diseases may be reported clinically or via laboratories, and different generations of reporting systems and routines certainly overlap. Again, CLINF devoted much effort in minimising the associated errors.

Complementary serological data were procured from Greenland, northern Sweden, and Russia, for laboratory analysis in Copenhagen, Denmark. The collection of sera, either via primary sampling or indirect via sera banks, require ethical approval. In addition, the transportation of sera materials across national borders are due to customs administration. One lesson learnt in the process is to never underestimate the time required for these procedures, particularly when sampling is performed in Russia. Human sera were predominantly sampled from national sera banks, whereas animal sera were collected in-field at reindeer slaughter occasions, and both types were analysed for the presence of infectious agents by a number of methods such as PCR and Next Generation Sequencing.

The CLINF diseases data comprise empirical observations concerning individual cases reported to authorities in Finland, Greenland, Iceland, Norway, Russia and Sweden. The national administration of reported diseases is managed per reporting district, where the typical size of a reporting district approximates the size of counties everywhere except in Russia, where diseases mainly are reported per oblast, republic, or autonomous region (See also Chap. 4). As a result, the smallest possible spatial resolution of CLINF diseases data is "reporting district". In Greenland and Iceland, the entire nations constitute one reporting district, although confined to their respective coastal regions.

In parallel with acquiring disease data, CLINF also procured weather, hydrography, and landscape data for all nations from western Greenland to the Russian Pacific, through the current 30-year climate reference period. In total, 3.5 TB of satellite data were retrieved to cover a total of 30 primary variables including:

- Greening, chlorophyll, biomass, evaporation, and phenology
- Temperatures, radiation, precipitation, humidity, soil moisture, and surface water
- Snow cover, land cover, topography, soils, and plant functional types
- Length of vegetation period, duration of soil freeze, and duration of snow cover
- Extremes of temperatures and precipitation, etc.

Apart from assessing the primary CLINF weather and landscape reference data, they were also used to calculate many different derived expressions of climate and landscape characteristics. The primary CLINF satellite data were retrieved in raster format with varying spatial ground resolutions, down to arc-seconds, and upscaled to the scale of the diseases reporting districts whereupon diseases data are reported.

The CLINF goal of covering the current thirty-year climate reference period with data was fairly successful, although fundamentally affected by national differences regarding the inclusion of different diseases in their respective lists of communicable diseases, *i.e.* diseases that need to be reported by law. Therefore, the time period covered by human CSI data varies with disease and nation as depicted in Table 3.2 below. Animal diseases are much more scattered in time than human diseases, but principally dispositioned just like human diseases data.

With human and animal diseases reported case-by-case, every single case is now made available in the CLINF diseases database. This temporal case-by-case resolution may be upscaled to any interval, such as monthly or annual accumulation of cases. The temporal CLINF standard resolution of human diseases data was set to *the number of cases per 100,000 report district inhabitants and year*, which defines "the CLINF incidence of human diseases". Since the number of animals inhabiting the animal diseases reporting districts is generally unknown, the temporal standard resolution of animal diseases data was defined as *the number of cases per reporting district and year*. The temporal resolution of the weather and landscape data varies from one satellite product to another, down to four observations per month for a few variables. These data were transformed into different temporal periods, such as monthly, annual, and thirty-year reference scenarios. For each of these periods, the average variable value was complemented with standard deviations, minimas and maximas.

For purposes such as map production and spatiotemporal statistical inference (see *Chap. 4 in this volume*), a basic GIS vector skeleton of disease reporting districts was produced and added to CLINF GIS for the benefit of other GIS-workers. In addition, the average thirty-year incidence of diseases was depicted with formal maps, and the year-to-year variation of incidences with an animation of such maps. These two map products may be considered as defining a "*diseases climate*", as observed from Western Greenland to Eastern Siberia, particularly in the case of

Table 3.2: Temporal coverage of CLINF human CSI data per nation and disease

Nation	BOR	BRU	CRY	LEP	PUU	QFE	TBE	TUL
Finland	1995–2016	1995–2014	1995–2016	1995–2016	1995–2016	1998–2016	1995–2016	1995–2016
Greenland	n/a	n/a	n/a	*n/a*	n/a	2007–2007*	n/a	n/a
Iceland	n/a	n/a	2013–2016	n/a	n/a	n/a	n/a	n/a
Norway	1990–2016	2004–2016	2012–2016	n/a	1991–2016	n/a	1998–2016	1985–2016
Russia	1992–2015	1970–2015	n/a	1975–2015	1975–2015	1998–2015	1969–2015	1970–2015
Sweden	1985–1994	2011–2013	2004–2016	1972–2013	1985–2016	2007–2013	1978–2016	1969–2016

Where not applicable (n/a), the diseases have not been reported. * = A single case of QFE reported in Greenland 2007 human diseases where the generic incidences are fairly covered with data. The CLINF diseases database was further supplemented with findings from ongoing studies of historical records, and from interview studies with indigenous peoples. On the basis of tree-ring data as far back as the sixteenth century, and of old academic literature, CLINF investigated also the correlation between warm, dry weather and major disease outbreaks in reindeer. Together with modern day information from indigenous peoples, such results will be helpful for the projection of diseases geographies into the future, which is a topic that will be further discussed in Chaps. 4 and 5 of this volume.

CLINF has chosen tularaemia as a case study for detailed analysis of climate sensitivity and model testing for future geographic disease distribution. The overall objective of this case study is to develop strategies and methods that may be applied to other tentative CSI's, with respect to how they are regulated by abiotic and biotic characteristics of the landscape that support their existence.

3.11 Data Procurement via Citizen Science

As signs of changing ecosystems are noticed relatively early by individuals living in close contact with nature, like many indigenous peoples do, the involvement of citizens in an integrated science design should be encouraged. An inspiring work has been done in the Alaskan LEO (Local Environmental Observer) network (www.leonetwork.org), where local observations are rapidly managed and disseminated at central levels of environmental surveillance. In CLINF, a citizen-based surveillance was performed in 2018, where the CLINF partner SVA (Swedish National Veterinary Institute) received around 4500 ticks found on animals or humans in the northern half of Sweden (approximately lat. 61 to 69 degrees North) see Fig. 3.1. In the resulting sample, 35 specimens of adult *Hyalomma* were identified (*H. marginatum* and *H. rufipes*) (Grandi et al. 2020). These are very big two-host ticks (20 mm after feeding), that usually are associated with the Mediterranean area. *Hyalomma* had previously been found in Sweden as nymphs on migratory birds and, in one case, as an adult on an imported horse, but adult ticks on non- imported animals had never before been observed in Sweden. These ticks are vectors for a range of pathogens, including Crimean-Congo-Haemorrhagic Fever virus, and various rickettsia, that hence seem to be potentially carried into the North by new vector organisms. The Taiga tick has also been found in the county of Jämtland, being able to transmit the Russian form of TBE.

3.12 In Conclusion

Throughout the history of Homo sapiens humans have experienced the occurrence of epidemics. The balance of living in nature surrounded by microorganisms is a delicate balance. As species exist in different niches of nature and of ecosystems it is when this balance is shifted by different causes and humans get in closer contacts with previously virgin areas that diseases can be the result. As climate change in this moment in time is indisputably occurring species are on the move and this at a speed not previously recorded. An improved international surveillance of infectious disease is much needed.

We have in this chapter described the thoughts behind the design of the CLINF NCoE and some of the results so far achieved. We have shown there is an obvious need of well-functioning international collaboration in surveillance and data collection and we point at the need for involvement of local communities in such efforts. We have shown the possibility of constructing a database to be used by specialists from different fields as the complexities of rapidly occurring problems related to CSI need a multidisciplinary approach in handling. Microorganisms and species do not respect borders and to achieve optimal control of infectious diseases we need a trustful international collaboration and harmonisation of data collected. If not, there might be chaos.

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Chapter 4
CLINF: An Integrated Project Design

Tomas Thierfelder and Birgitta Evengård

Abstract As introduced in the preceding chapter of this book, the CLINF Nordic Centre of Excellence (NCoE) addresses the broad scenario of warming northern landscapes transforming into warmer biomes, that may attract vector organisms such as ticks, mosquitoes, and rodents. These have the potential of carrying new zoonotic infections onto humans and husbandry animals of the North. With Far-North societies being generally dependent on their husbandry animals, i.e. by terms of economy, status, and tradition, an altered exposure towards infectious diseases may strike at the very heart of northern cultures. When added to other direct or indirect societal effects of climate change, such as the direct effects of altered human exposure, the resulting holistic approach to health is called OneHealth. CLINF is devoted to inquiring into the OneHealth effects of a warming North. Addressing such a broad topic requires an interdisciplinary science approach, in combination with an elaborative plan for how to engage bilaterally with stakeholders at scales ranging from the local to the international. The following chapter outlines the CLINF endeavour, from typical OneHealth problem identification and formulation, through principles of integrated projects design into the outlines of the finally implemented NCoE, and further on to the resulting discoveries and lessons learned. The chapter may be perceived as a case-study of integrated projects design, and as an example to study for others that find themselves in the situation of designing a large integrated science project.

Keywords Northern · OneHealth · Integrated research · Project design

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4.1 Introduction

With climate-change, the landscapes of the Far North are generally transforming into warmer biomes at a greater speed and magnitude than elsewhere (IPCC 2014). This change may be depicted as a geographically translating climate gradient, that moves in the direction of the gradient itself. Rather than generally pointing towards the North, the geographic direction of regional climate gradients is regulated by the balance between continental and maritime climates, not seldomly interrupted by the presence of mountain chains. Regardless of the resultant regional direction of climate translation, it may be decomposed into latitudinal and longitudinal components, and the resulting warming of the North should, by principle, be perceived as a process capable of pointing into any direction (AMAP 2004; Callaghan et al. 2013).

A climate gradient may be characterised by the succession of biomes that reside along the gradient, connecting warmer landscapes with colder. With a climate gradient characterised by terms of connected biomes, warming may be defined as the translation of biomes, and by the resulting transformation of landscapes into new different biomes. And most importantly in the CLINF context, by the resulting potential for species to migrate along the climate gradient. Such species migration may expand existing populations, but also diminish others by competition. In addition, species adapted to cold biomes face the possibility of dilution or extinction when migrating into a transforming dead-end landscape (Oechel and Vourlitis 2014).

One particular group, that are subject to potential migration, are the vector- and reservoir organisms that carry infectious pathogens through the landscape (Hoberg and Brooks 2015). Examples of such organisms are the ticks, midges, mosquitoes, and rodents that may transfer a range of zoonotic infections, such as tularaemia and borrelia, onto humans and their husbandry animals (Wolfe et al. 2007; Hueffer et al. 2013; Parkinson et al. 2014; de la Roche et al. 2008). As the biological interrelation across infectious pathogens and their respective vector and reservoir organisms may be dynamically complex (Albihn et al. 2012; Berggren et al. 2009), the fabric of ecological support required for pathogen existence may be referred to as "the vector process". Hence, in principle, the entire vector process needs to be supported and/or attracted by the geographic translation of biomes in order to potentially migrate (Rydén et al. 2012). If this is the case, the infection is per definition climate sensitive (CSI: climate sensitive infection), otherwise it is geographically stationary in relation to the landscape effects introduced by climate-change (Omazic et al. 2019a).

In the above context, and at the population scale, climate sensitive infections have a mass, a density, and a geographic distribution. Furthermore, as discussed above, they have a potential of migrating which includes the possibility of expanding their global population mass. Since the probability of annihilating any climate sensitive infection principally is a function of its total population mass (Daley and Gani 2005), the potential expansion of CSI populations is a climate-change effect of serious global concern.

With CLINF working across the vast northern realms of the globe, from western Greenland to the Russian Pacific, and from approximately 55 to 80 degrees North, Siberia more or less dwarfs the rest of its study region. It is difficult for the untrained mind to grasp the vastness of these lands, where the two respective districts of Krasnoyarsk and Sacha alone approximate the size of India. The sheer size of Siberia, not to mention its solitude, makes it difficult to monitor with respect to the climate-change transition of landscapes, and to the associated composition of infectious pathogen's and/or vector processes. In addition, since diseases are generally reported via human and animal diseases report systems, reportable diseases may persist unobserved through such vast regions of low human population densities (Malkhazova et al. 2017).

The climate gradients of Siberia are correspondingly vast, connecting relatively warm continental and maritime climates with the extremely cold. As a consequence, Siberia holds a worrying CSI potential which is largely unobserved and capable of providing CSI expansion-territory enough for a red-alert global warning. These worries, together with other concerns addressed later in the chapter, suggests why CLINF has been able to supplement its original funding with a budget particularly allocated for CSI studies performed in bilateral collaboration with Russian peers (NordForsk 2016).

CSI populations may translate geographically, while societal infrastructures tend to remain stationary. As a result, northern societal CSI exposure is potentially changing as an effect of climate change. If novel CSIs appear, and the exposed population of humans and their husbandry animals hence is immunologically naïve, CSI outbreaks may have catastrophic consequences. Since many northern cultures holistically depend on their husbandry animals, i.e. by terms of economy, status, and tradition (West 2010; Hovelsrud et al. 2011), changing societal CSI exposure potentially may strike at the heart of Far-North cultures (Evengård et al. 2015; UNESCO 2009). When the effects of altered societal CSI exposure are added to other environmental consequences of climate change, the cumulative effects require a holistic approach to health called OneHealth[1] (WHO 2017). CLINF is devoted to inquiring into the OneHealth effects of a warming North, which may include the young Sami men that lose faith in their traditional ways of life, becoming depressed and suicidal, and leaving the North for city-jobs. The latter example illustrates the fundamental fact that OneHealth effects typically depend on factors such as gender, age, and societal status (AHDR 2007; Rasmussen 2009; Riseth et al. 2011).

There are also political dimensions to the OneHealth concerns for the North. As already mentioned, the CSI potential of a thawing Siberia should be considered as constituting a potential OneHealth threat of global concern, despite insufficient CSI monitoring and adequate response protocols. Similar insufficiencies apply to the entire CLINF study-region, particularly in the case of animal diseases (Omazic et al. 2019a). The diseases reporting systems that have been an important part of national health strategies for centuries, continue to differ substantially by design and administration when compared across nations. Although international

[1] The OneHealth concept recognizes that human, animal, and ecosystem health is holistically interrelated and interdependent. It represents the intuitive world view of indigenous people everywhere.

homogenisation of national health report systems is promoted within the European Union, the contrast with otherwise excellent Russian report systems (Malkhazova et al. 2017) is striking. These incompatibilities constrain the possibilities of overlooking the international CSI scenario, and of collating empirically reported diseases data across nations. There is an urgent need for international standardisation of diseases report systems (Omazic et al. 2019b), of seamless administration across human and animal diseases data, and of repositories wherefrom such combined data may become internationally disseminated. All of this requires coordinated political action and political will at all levels.

The CLINF research initiative has set out to study the above scenario regarding OneHealth climate-change effects in the north, including the forecasting of OneHealth risk scenarios into the future. This undertaking requires an interdisciplinary study-design that connects with stakeholders throughout the study region, while maintaining a hypothetic-deductive approach to scientific inquiry at its core. In the following pages, the design of this initiative is outlined for the eventual benefit of others that may approach similar scenarios, using similar methods.

4.2 Objectives of Work, and Their Integrative Powers

It is possible to condense the above OneHealth scenario into functional thematic constituents that are able to address, with formal hypothetic-deductive science methodology, the core of CLINF research. This condensation may be expressed as follows: The notion of migrating diseases must be considered as being merely hypothetical until properly tested. Since such a test would require empirical observations regarding the incidences of diseases, the procurement of such data is fundamental. Since the process of diseases migration may occupy a spatiotemporal domain of considerable size, such data should reflect diseases incidences across a vast geographic expanse through a considerable interval of time. In addition, the worrying OneHealth potentials of Russia should, if possible, be covered with empirical data.

In accordance with these presumptions, CLINF procured more or less all human diseases data that has been officially reported from western Greenland to the Russian Pacific through the era of national digital reporting systems, and further back into the respective national paper archives. Since different diseases are reportable in different nations through different periods of time, the resulting dataset covers roughly the past 30-year climate reference period with rather heterogenous diseases data. The same applies to animal diseases, although these are much more scattered and hard-to-come-by than typical human diseases data (Omazic et al. 2019b).

If, hypothetically, geographically translatable landscape and weather characteristics attract vector and reservoir organisms that carry infectious diseases, there must exist a significant correlation across such characteristics and the geographic location and incidence rate of diseases. This called for empirical diseases data to be complemented with weather and landscape data observed in parallel with diseases data. Thus, all possible sources of remotely sensed information regarding weather, hydrography, landcover, and greening (etc.) were inventoried, and the associated data procured across roughly the same spatiotemporal domain as in the case of diseases data.

Since diseases data typically are reported at the spatial scale of counties everywhere in the CLINF study area except in Russia,[2] the relatively high resolutions of remotely sensed data were upscaled to the level of diseases reporting districts. Diseases incidences were cumulated on an annual basis, and the resulting operative spatiotemporal scale hence became “annual assessment per diseases report district”. With data generally procured through the 30-year climate reference period, and across approximately 60 diseases report districts, a theoretic maximum of 1800 observations per diseases variable were attained.

Based on the combined diseases and weather/landscape data, the geographic distribution and eventual translation of diseases populations could be studied trough the 30-year climate reference period, and depicted by terms of maps and map-like animations. Utilising the geographic centre of diseases reporting districts (i.e. their centroid latitudes and longitudes), the eventual geographic translation of diseases, on a year-by-year basis over the course of the 30-year reference period, could be statistically tested at high level of precision. If diseases proved to be stationary despite climate-related transitions in the supporting landscape, they were deemed as not being “climate sensitive”. If, on the other hand, significant linear relationships linked the variation of diseases incidences to variations in weather/landscape characteristics, this would indicate climate sensitivity. For every climate sensitive disease identified by CLINF, the best subset regressor base of weather/landscape variables was identified.

In parallel with inventorying diseases and weather/landscape data, and establishing the associated database, CLINF engaged societal scientists to “inventory” how the people of the Far North have experienced climate change in terms of their eventually changing exposure to human and husbandry-animal diseases. Since Far-North cultures may be “stratified” with respect to gender, age, and societal status (etc.), it was important to include such factors in the CLINF designs of interview questionnaires, bilaterally arranged workshops, and alike (West 2010).

Since the future OneHealth prospects of these Northern peoples and cultures are central to CLINF, the forecasting of future CSI scenarios has been another fundamental constituent of the CLINF research initiative. Hence, the landscape/weather regressor bases discussed above, identified via regression models that were fitted to data procured through the 30-year climate reference period, were forecasted 30 and 50 years into the future. These forecasted regressor-base variables were then inserted back into the reference models with which they were identified, under the assumption that these models represent also future CSI processes. With the forecasts made in accordance with four different IPCC emission scenarios (IPCC 2000), four different future geographic CSI distributions were predicted. Since these distributions depict the approximate change of CSI exposure that will be experienced by

[2] Oblasts and autonomous republics most often constitute Russian diseases report districts.

Far-North societies in the future, they enabled CLINF societal scientists to predict also future OneHealth scenarios.

Collecting, processing, and depicting spatiotemporal data such as that discussed above is rather unique in the history of northern epidemiology, particularly when this is made across such a vast domain. Since CLINF strongly advocates OPEN principles (The Eight Principles of OPEN Government Data) whenever possible, the OPEN sharing of these data was seen as an important legacy of the CLINF NCoE. Someday, if complemented with compatible data covering Canada and Alaska, a true circumpolar diseases database could be established.

In order to develop a disseminative digital data infrastructure, CLINF inventoried its stakeholder community as part of specifying and designing the system (Böhme 2017). The resulting data repository was called CLINF GIS (www.clinf.org, see bullet 6 further down this chapter), and is used to share all CLINF data products within the NCoE as well as with its external stakeholder community. One particular feature of the CLINF GIS is its ability to communicate in local languages, at least at the level of operative systems and user interfaces (leaving CLINF metadata in the English language).

The specific CSI OneHealth research objectives that have been advanced by CLINF, may be expressed as a list of six intersecting scientific themes. Each of these are outlined below with the particular focus of inquiry, along with a means or method to advance knowledge in that area, noted. They were:

1. Procuring human and animal diseases data across northern Eurasia

   Allocation of human and animal diseases data across the CLINF study region, reported through the past 30-year climate reference period, with particular emphasis on Russia.

2. Climate change across northern Eurasia

   Procuring weather and landscape data across the CLINF study region, as observed through the past 30-year climate reference period, and modelling future climate scenarios.

3. Inferring the climate sensitivity of human and animal diseases

   Using procured reference data to infer how weather and landscape characteristics have regulated the observed spatiotemporal CSI variation across the CLINF study region, through the past 30-year climate reference period.

   Feeding the thus identified inferential models with weather and landscape data projected into future climate scenarios, in order to predict future CSI scenarios.

4. Climate sensitive infections: Societal impacts and adaptation needs

   Assess the societal CSI impacts and adaptation needs of selected reference cases, and extrapolate societal CSI risks and adaptive strategies onto predicted future CSI scenarios.

5. Climate sensitive infections: Traditional knowledge, gender, age, and local agency

   Assess how local CSI adaptation strategies depend on different traditions of knowledge and agency, and different societal roles across categories of gender and age.

6. The CLINF geographic information system – CLINF GIS (www.clinf.org)

Providing a (digital) communicative infrastructure for information exchange inwards CLINF as well as towards stakeholder organisations, facilitating bilateral connective interaction.

Particularly important products of the CLINF GIS are the maps and map-like animations designed to pedagogically convey information regarding where OneHealth risks have been geographically present through the past 30-year period of time, and how they are moving in relation to a warming North.

In order to facilitate integration across the CLINF scientific themes, an "integrating agent" is required. Since all themes are designed to procure and process primary empirical data, one useful aspect of project integration is the exchange of the increasingly refined data products that are "handed over" from one theme to another at pre-defined occasions. This timely flow of increasingly refined data products, from primary data to diseases maps and projected OneHealth risk scenarios, defines the temporal propagation of CLINF at large, and provides an integrative agent that may be utilised for regular project control (Lyall et al. 2011). When the flow is utilised for outlining the integrated design of the CLINF NCoE, the following applies: Theme 1 and Theme 2 procure primary diseases and landscape/weather data through the past 30-year climate reference period, while Theme 6 develops CLINF GIS for the necessary communication of CLINF data and data products. The latter includes the identification of CLINF stakeholder organisations throughout the study region, there are hundreds, and an analysis to learn how they are administratively and communicatively interrelated (Böhme 2017).

Further along the CLINF flow of data and data products, Theme 3 combines the data received from Themes 1 and 2 into the central CLINF database, which is hosted at CLINF GIS. Based on these data, the following two basic CLINF hypotheses were statistically inferred: (*1*) the observed populations of diseases have translated and/or expanded geographically through the current climate reference period, and (*2*) these eventual translations/expansions may be explained by changing landscape and/or weather characteristics. As part of inferring hypothesis *i*), the average geographic distributions of diseases incidences were depicted with maps that illustrate the CLINF notion of a "diseases climate" (Fig. 4.1 a and b). Correspondingly, while inferring hypothesis *ii*), the diseases that significantly correlate with changing weather and landscape characteristics are defined as being climate sensitive (Fig. 4.2 a and b).

In parallel with the work of Themes 1, 2, and 3, researchers associated with Themes 4 and 5 undertook case studies regarding local adaptive strategies by northern communities facing the OneHealth effects of climate-change in their everyday existence. Since such effects are complexly dependent of age, gender, and societal status (etc.), CLINF placed particular emphasis on such factors. Whenever possible, these case-study results are presented with data products, such as maps, that may be further disseminated via CLINF GIS.

After undertaking the initial work outlined above, Theme 3 researchers engaged in inferring the weather and landscape "mechanisms" that have regulated the

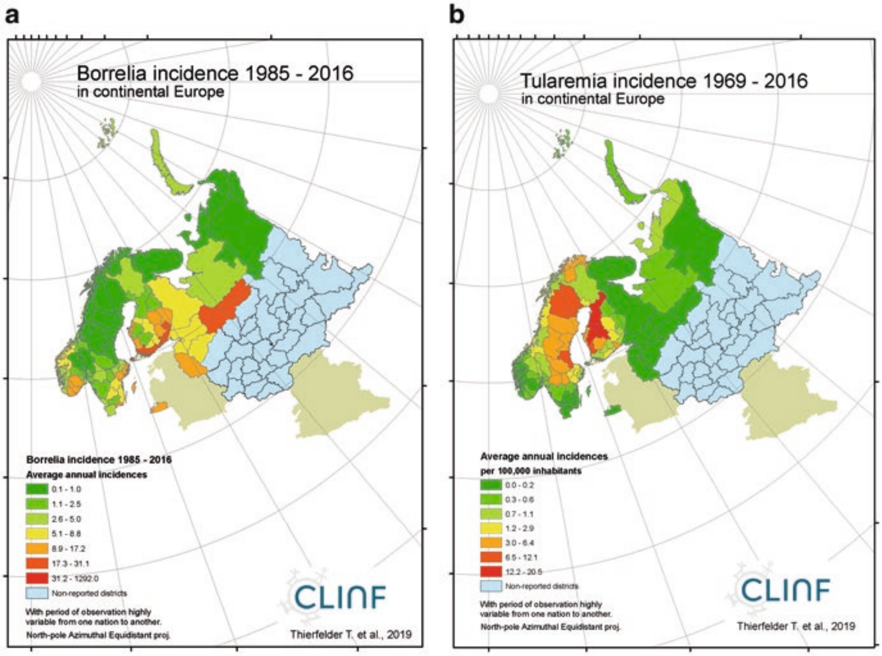

Fig. 4.1 (**a**) and (**b**) Average incidences of borrelia and tularaemia respectively, through the 30-year climate reference period. The maps hence depict the "diseases climate" of two potential CSIs

spatiotemporal variation of diseases through the 30-year climate reference period. As a result, a list of regulating variables was presented to Theme 2 researchers, who engaged in projecting these variables onto future CSI climates as described above. One important constituent of this work was the estimation of the resulting projection errors.

These projections of future geographic CSI distributions importantly revealed societal infrastructures in the way of migrating CSIs. This information was also disseminated via CLINF GIS, back to the researchers associated with Themes 4 and 5. They used it for their subsequent assessment of societal CSI risks and local adaptation strategies. The resulting products, such as scientific publications and recommendations to stakeholder societies, may be considered as being the final core-products of CLINF. In addition to these core products, several secondary products of some significance also emerged from the process. These will be discussed later in this chapter.

In the integrated project design described above, the bilateral exchange of information, internally within CLINF as well as externally with its stakeholder organisations, serves as the integrative constituent that connects its different themes. In integrated project design (Lyall et al. 2011) it is most important to identify such an integrative constituent, and to actively use it for interdisciplinary integration across the project.

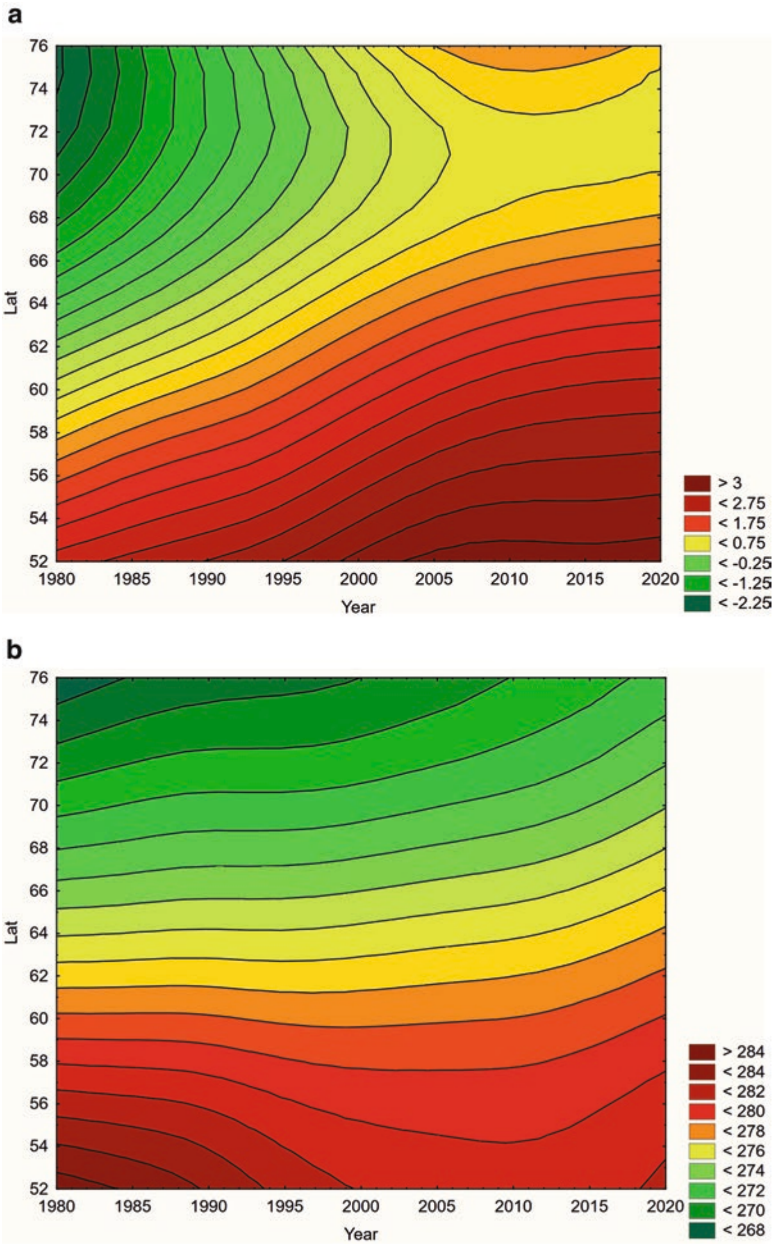

Fig. 4.2 (**a**) and (**b**) Through the CLINF study region depicted in Fig. 4.1, borrelia (left: incidence per 100,000 inhabitants) and average annual surface temperature (right: Kelvin degrees) have translated significantly towards the north through the 30-year climate reference period. Spline interpolated surfaces, including interpolation artefacts (like negative incidences)

4.3 Integrated Project Design

In parallel with turning the themes listed above into an actual integrated project design, project coordination was added as a seventh thematic area of the design. The members of the coordination team were hence given the task of developing a consensus regarding project objectives, approaches, and designs, and eventually came into the position of allocating the necessary project resources. As a result, the CLINF coordination team allocated personnel from traditional science disciplines such as climatology, biology, ecology, earth sciences, systems sciences, mathematical statistics, veterinary medicine, human medicine, economy, anthropology, sociology, and social philosophy. During the allocation of resources, the implementation of gender, child, and ethical perspectives was used as an integrative factor cutting across disciplines (a transdisciplinary factor). In addition, the provision of adequate administrative support throughout the entire project process has proved to be invaluable. The allocation of resources led to the establishment of a CLINF consortium, which was incited into collaborative work. As a result, the original science themes were combined into integrated work-packages (WPs) for a collective assessment of the key CLINF objectives outlined above.

In order to further refine the features of the project design, and to prepare for formal project management and control (Lyall et al. 2011), the CLINF consortium engaged in the creation of interdisciplinary integrative work-packages. The classic supportive platform for this process is the GANTT project management platform, where "some connective agent" is anticipated to connect and bring forward the parallel strains of research that normally constitute an integrated project plan. In CLINF, the successive collaborative development of data and data products provided this crucial connective agent, and the above themes provided the parallel strains of research. When rearranged into parallel and integrative crosscutting work-packages, each of the overarching themes were finally resolved into sub-WP tasks, and a succession of temporally planned deliverables that was depicted in a GANTT diagram. (see Fig. 4.3 below). With the successive collaborative processing of data hence keeping the project design together, CLINF deliverables may be perceived as data products successively leaving the project for the intended audience.

4.4 Construction of Work-Packages

As a result of the integrative allocation of project resources described above, and utilized in accordance with standard principles for interdisciplinary research designs (Lyall et al. 2011), the resulting CLINF consortium was provided with the width of knowledge and experience required for its interdisciplinary enterprise. The relatively strong integration of the CLINF project introduced certain dependencies into the project, where individual WPs awaited the timely deliverance of data products from other WPs. These dependency structures are schematically depicted in Fig. 4.3

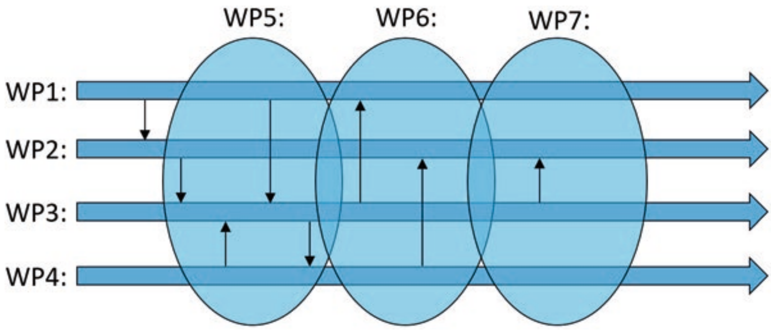

Fig. 4.3 CLINF integrative project outline, where WPs 1–4 engage in parallel science assessment while exchanging and developing data products, and where WPs 5–7 have cross-cutting roles such as monitoring and supervising activities with respect to ethics, gender, communication, and project control. The thin black arrows schematically represent integrative data exchange

below where the CLINF project design has been presented as having four parallel research work-packages (Themes 1–4) and three cross-cutting integrative WPs (Themes 5, 6, and 7: project management).

When described at an intermediate level of detail, the following work-packages and their sub-tasks can be distinguished as follows:

CLINF WP1: Human and Animal Diseases in the Nordic Region: Retrospective Data Processing and Modelling of Future Scenarios for Locally Applicable CSI Alert Systems

WP1 sought information regarding the prevalence and incidence of climate-sensitive infections (CSIs), covering human and animal diseases from western Greenland to pacific Russia. One of its major objectives was to provide a CSI alert system at the local level, by identifying ecological changes of importance for emerging diseases. WP1 was sub-divided into four sub-WPs that provided primary CSI data (WP1.1), that generated serological baseline CSI data across the study region (WP1.2), that provided in-depth epidemiological data regarding human tularaemia (WP1.3), and that identified important health problems with relevance for future sheep and reindeer herding in the North (WP 1.4). Also included in WP 1.4 was a pilot study, to test DNA deep-sequencing as a method of providing surveillance of animal CSI pathogens. The sub-WPs are:

WP1.1: Procurement of official CSI data regarding the prevalence and incidence of relevant CSIs, “from Nuuk to Yakutsk

Objectives: To provide an overview of CSI across the CLINF study region.

WP1.2: Generating serological CSI baseline data across the study region.

Objectives: The CSI sero-prevalence, for which assays are available, will be determined by analysing sera procured from existing serum banks, covering pregnant women in northern Sweden and mixed individuals in Greenland.

WP1.3: Procurement of in-depth epidemiological data regarding human tularaemia.

Objectives: Modelling the future geographic distribution of tularaemia.
WP1.4: Changing geographic CSI distribution, and the associated effects on future enterprises of sheep and reindeer herding.
Objectives: Collect information regarding climate-change CSI effects relevant to future enterprises of sheep and reindeer herding in the North, and use the information to develop models for projecting the associated effects onto future socio-economic scenarios. Apply DNA deep-sequencing and bioinformatics tools to survey known and unknown CSI pathogens in animal faeces.

CLINF WP2: Climate Change in the Nordic Region: Procuring Data and Modelling Future Climate Scenarios
WP2 sought to acquire and integrate the in-situ and satellite-based environmental data needed to assess the potential spread of CSIs under high latitude change, and use these data in model projections of environmental change relevant to the viability and propagation of disease vectors. WP2 was constituted by the inclusion of sub-WPs that address landscape-scale terrestrial processes (WP2.1), landscape-scale aquatic processes (WP2.2), and biological/ecological processes (WP2.3). WP 2.1 also dealt with the coupling of terrestrial and aquatic process models, in order to provide consistent predictions. The sub-WPs are:

WP2.1: Landscape-scale terrestrial processes.
Objectives: 1. Provide stand-alone and coupled hydrological and dynamic vegetation models capable of accurately simulating the variables identified in WPs 1 and 3, as relevant to the viability and spread of disease vectors, and validate the models against satellite, in-situ, and disease vector data, from the last two decades. 2. Use the coupled models to predict environmental changes in the Northern region to year 2050, under a range of climate scenarios, in a form suitable for assessing changes in the occurrence and spread of disease vectors.
WP2.2*:* Water-borne CSI-spreading pathways and hydro-climatic change.
Objectives: 1. Synthesise controls on disease vectors (from WP1) that pertain to pathways in water. 2. Investigate changes to these pathways due to changes in climate and hydrological conditions in the boreal and Arctic regions, using a suite of land cover and climate scenarios, projecting changes out to 2050. 3. Integrate results from modelled changes to the water system, with corresponding results from landscape transition modelling (in conjunction with WP2.1).
WP2.3: Biological/ecological vector processes.
Objectives: 1. To bridge from landscape-scale model output, to the scale where vector carriers of infectious pathogens migrate. 2. Identify ecologically adequate combinations of disease case-studies addressed in WP1, and input data used for modelling in WP2, to facilitate statistical assessment of proxy relations across the scales available in CLINF diseases, weather, and landscape data.

CLINF WP3: Depicting the Geographic Spread of Climate Sensitive Infectious Disease (CSIs) in Northern Eurasia

WP3 endeavoured to combine disease prevalence data from WP1 with present and projected scenarios of landscape change from WP2, in order to analyse how present populations of selected diseases will change in a thawing North. Using the current geographic distribution of diseases as a baseline, the potential for migration of disease was analysed as a function of projected landscape and hydrological change, and depicted with a time-series of thematic maps. The resulting scenarios were overlaid with data concerning societal infrastructure from WP4, and fed back to WP4 for collaborative assessment and depiction of the risks associated with changing societal exposure to CSIs. All internal data, as well as the final data products, were to be disseminated via CLINF GIS (WP6). WP3 was organised into three sub-WPs: data synthesis (WP3.1), risk assessment (WP3.2), and depictive map-making (WP3.3):

WP3.1: Synthesizing climate-change scenarios of diseases, disease habitats, and societal infrastructures.

Objectives: 1. Combine data regarding CSIs (WP1) and landscape-hydrology change (WP2) for synthesized assessment of how geographic CSI distribution is regulated by weather and landscape characteristics. 2. Transfer synthesized projections to WP4 for assessment of societal risk.

WP3.2: Uncertainty and risk.

Objectives: 1. Statistically assess how errors and uncertainties in the inputs from WP1 and WP2 combine and influence the probabilistic predictions of WP3.1. 2. Combine the probabilistic predictions of WP3.1 with the societal costs identified in WP4, into an adequate expression of societal risk (with risk defined as the product of probability and cost).

WP3.3: Geographic projections of climate sensitive infectious disease (CSIs’).

Objectives: 1. Based on predictions of migrating diseases from WP3.1, and of societal risks from WP3.2, WP3.3 seeks to map predictions of the geographic shift of CSIs’, including the associated societal risks, under climate change.

CLINF WP4: Climate Sensitive Infections: Societal Impacts and Adaptation Needs

The aim of WP4 was to understand how the spread of climate sensitive infections (CSIs’) will affect societal and individual well-being, ontological security, and adaptive capacity, in the North. Ontological security is defined as: The sense of security of individuals and communities about the potential to preserve and develop identity and tools for understanding and controlling their social and material environment. A three-pronged approach will be applied to the analyses of the linkages between the spreading of CSI and the consequences for health and well-being. The three lines of inquiry focused on: (1) the significance for ontological security in local communities in terms of destabilizing health; (2) impacts on animal husbandry with respect to CSI health effects on both animals and humans, and on economic and cultural conditions; and (3) adaptation strategies and adaptive capacity across Northern societal scales. The associated sub-WPs were:

WP4.1: Selection of cases.
Objective: Select cases on animal husbandry activities (sheep farming, reindeer herding) for in-depth study.
WP4.2: Assessment of societal infrastructure which may spread CSI.
Objective: Understand the linkages between societal infrastructure, such as transport and services, and CSI.
WP4.3: Description of human-nature interactions in animal husbandry households.
Objectives: To understand the socio-economic and cultural significance of human-nature interactions at case study sites, and how these are affected by CSI exposure.
WP4.4: Identification of local adaptation strategies and needs.
Objectives: To understand the previous and current adaptation strategies to multiple stressors, and the need for future adaptation in the CSI context.
WP 4.5: Perceptions of risks and security for humans and animals from the spread of CSIs'.
Objectives: Understand the consequences of CSIs', regarding how individual and community security is perceived and understood at the case study sites.
WP 4.6: CSI costs for animal husbandry.
Objective: Provide a solid estimate of the current costs of health effects from zoonotic disease, and future costs of projected change to disease vectors and CSI for both humans and animals.
WP4.7: Costs for adaptation and contingency plans related to CSI.
Objective: Analyse regional and national disease control, adaptation contingency policy, and national planning, for CSI and related costs.
WP4.8: Adaptive capacity in animal husbandry.
Objectives: To establish the adaptive capacity of animal husbandry related to CSI, and other salient changes.

CLINF WP5: Traditional Knowledge, Gender, and Local Agency

Climate change has different impacts on the well-being of different groups of people in Northern local communities. Indigenous people, the elderly, women and children, are particularly vulnerable in the Arctic. In WP5, these factors are used to investigate: (1) How gender power-relations affect and are involved in overarching contexts of climate and environment changes, which impact human health and well-being; (2) What agency dispositions are available to men and women within northern communities (access to information; opportunities, and resources for agency); (3) Which adaptation and resilience strategies are available across genders; (4) How health risks and environmental/human security are perceived by women and men and, in turn, how their awareness affects their situation and agency. A particular emphasis has been to determine the extent to which traditional knowledge (TK) has a risk management potential, and can supplement the roles of local authorities. Here

TK is defined as knowledge and beliefs regarding relations between living beings and their environment. TK is culture and experience-based, transferred across generations, and includes empirical facts, social institutions and management, as well as inherited world views. It is often focused on practical application and provides a basis for cultural and community continuity. The sub-WPs of WP5 were:

WP5.1: The spread of CSI and everyday life, with a gender perspective.
Objectives: Providing an overview of available data in the study region.
WP5.2: Everyday practices and traditional knowledge, particularly their resilience potential with a gender perspective.
Objectives: Detect TK's potential for extending the potential of science.
WP5.3: Local environmental and health policies with a gender perspective.
Objectives: Clarify the role environmental change, in the regulation and control of activities that may pose local health risks to animals and humans.
WP5.4: *Risk management in a gender perspective.*
Objectives: The production, understanding, and communication of scientific and traditional knowledge regarding the links between CSI and inhabitants' everyday practices, with respect to health and well-being.

CLINF WP6: The CLINF Geographic Information System (CLINF GIS)
The highly integrated nature of CLINF makes the timely flow of data products across WPs essential. In order to facilitate this, WP6 developed a digital infrastructure called CLINF GIS as a central information-node for CLINF, providing a repository for the storage and sharing of intermediate CLINF data, as well as for the dissemination of final data products intended for the CLINF end-user segment. This web-based infrastructure is designed to support an environmentally friendly project culture by providing a virtual forum for collaborative work, thus reducing the need for travel and physical meeting. In addition, CLINF GIS is equipped with administrative functionalities in support of project coordination. The objectives of WP6 were:

Objectives: 1. Design and implement a web-based infrastructure, the CLINF GIS, for storing and disseminating intermediate and final (DOI-tagged) data products; 2. Equip the CLINF GIS with functionalities for chatting, video conferencing, document sharing, etc., thus minimizing the need for travel and physical meeting; 3. Equip the CLINF GIS with report and control functionalities for web-based project coordination and management; 4. Equip the CLINF GIS for instantaneous public dissemination of DOI-tagged data products and maps.

CLINF WP7: Project Management
CLINF coordination and management has utilised the integrative structure of four parallel and three cross-cutting WPs for practical project management and control. The leaders of the four inter-dependent technical WPs oversaw the work within their WP, and ensured the timely exchange of high-quality data products and other outputs to the entire project during its five-year projected timeline. The leaders of the cross-cutting WPs are involved in, and will interact with, all the technical WPs. This benefits not only project integration and a synergistic project culture, but also

assists the ability to manage and control the project. All WP leaders are expected to actively promote synergies across WPs, and synergistic collaboration will be an item at the agenda of all project meetings. Management methods were chosen to minimize the environmental impact of CLINF, and pay attention to issues of gender and ethics. The explicit objectives of WP7 were:

Objectives: 1. Implement and lead a management and control structure for the coordination of the CLINF consortium. 2. Identify and connect with external advisors and stakeholders in order to broaden the scope and outreach of CLINF. 3. Develop and establish a consortium agreement across the participating CLINF organisations. 4. Minimize environmental impact, as well as gender and ethical injustices, across CLINF.

4.5 Project Synergies

In addition to the integrated weave of the major CLINF scientific activities depicted above, other less central project activities have proved to be just as significant. These have included the convening of practical workshops arranged in bilateral collaboration with stakeholder organisations at the local, national and international levels. One example of this type of undertaking was a 2018 workshop on "Supplementary Feeding of Reindeer", arranged in collaboration with Sápmi reindeer herders in order to bilaterally address a central issue that captures typical OneHealth effects in a nutshell. With the ever-increasing atmospheric energies introduced with the warming of the North, an increasing frequency of maritime weather-fronts make their way across the Scandinavian mountain range, from the North Atlantic into the colder continental climate of the North-Scandinavian interior. This typically interrupts cold winter with relatively mild rainy weathers that introduce moisture to the surface of a snowpack that may measure several meters thick. Such mid-winter warm fronts tend to disappear as fast as they occur, leaving icy strata to descend into the accumulating snowpack. The deposition of such icy strata blocks winter reindeer-pastures, and may result in a need for supportive foddering. This, in turn, may require for the reindeer to be expensively corralled into dense packs, wherein the transmission of infectious diseases is facilitated by a combination of animal exhaustion and close-contact encounter. Thus, effects of warming combine into synergetic erosion of customary reindeer herding, and as a consequence, the constraining of traditional Sápmi practices and values (Hovelsrud et al. 2011; Riseth et al. 2011).

The provision of interdisciplinary educational programmes is another integral part of any ambitious integrated project design. In the educational context, the integrated knowledge of the multiple traditional science disciplines that are kept within the integrated project, should be utilised and taught as being essential for the assessment of holistically complex concepts like OneHealth.

Another typical integrative activity, that has proved to be important, is the specification and development of CLINF GIS. Launching such an international communicative infrastructure is a powerful action that, in the case of CLINF, holds the potential of connecting west with the east, across nations with rather strict intranational designs of diseases reporting systems. The infrastructure provided with CLINF GIS, with which standardised international diseases data are OPENly disseminated, provides a vision of the possibilities constrained by the current (2019) lack of international harmonisation.

The CLINF database is yet another example of an important integrative activity. The CLINF data repository combines basically ALL diseases data officially reported "from Nuuk to Yakutsk", at least in the case of diseases reported via human health administration, with an abundance of weather and landscape data with relevance for the eventual CSI migration towards the North. In 2021, negotiations will be initiated with northern US and Canada, regarding the possibilities to expand this database into a rather unprecedented CSI database with true circumpolar coverage.

The dissemination of a potentially important database like the CLINF data repository, basically financed via public taxation across the Nordic countries, cannot be discussed without also mentioning OPEN principles and the initiative of OPEN Government Data (The Eight Principles of Open Government Data). In accordance with the OPEN initiative, "OPEN data and content can be freely used, modified, and shared by anyone, for any purpose". The CLINF NCoE has been a keen advocate of OPEN principles, and applies them whenever possible. This includes the OPEN publication of the CLINF database (www.clinf.org).

4.6 Discoveries and Lessons Learned

The CLINF project has engaged around 20 interdisciplinary-minded scientific workers from several countries over a period of 5 years. The scientific discoveries made in the context of such a large integrated project are numerous and multifaceted. As some of the more significant results from the inventory of diseases data have been already addressed in Chap. 3 of this volume, and with some of the CLINF results regarding predictive modelling and societal assessment will be covered in Chaps. 5 and 6, it is left to this chapter to highlight some of the central results associated with data inference.

As depicted in Figs. 4.1 and 4.2, above, important diseases like borrelia, tick-borne encephalitis, tularaemia, and others, seem to have translated geographically throughout the past 30-year climate reference period. This means that the associated populations of diseases not only have average geographic distributions that has been moving arbitrarily, but that the centre of gravity of these populations demonstrate a statistically significant linear geographic translation-trend through the observed period of time. It may hence be anticipated that the weather and landscape characteristics that regulate the geographic distributions of these diseases have changed systematically through the observed period of time. Such linear geographic trends may be parameterised in the bivariate orthogonal space of the centroid longitudes and latitudes of diseases report district, and statistically tested at high precision

(Aiken and West 1991). The observed linear distribution trends hence invite to further statistical inference regarding the exact nature of the associated regulatory mechanisms. Since the CLINF study-region encompasses many different regional climate zones, the rate and direction of geographic translation depends very much on the choice of region. CLINF, therefore, subdivided its study region, from Nuuk to Yakutsk, into subregions such as the separate nations of the Scandinavian peninsula (Norway and Sweden), Finland and western Russia combined, Siberia, etc. As an example of such regional subdivision, only the reporting districts from the Norwegian coast to the Russian Ural Mountains are included in the assessment depicted in Figs. 4.1 and 4.2.

Based on a study of regional diseases geography, it may be suggested that diseases carried by vectors such as ticks, midges, mosquitos, and rodents, seem to generally follow the landscape transitions introduced by the warming of the North. This corroborates the basic hypothesis of CLINF, and anything else would, in fact, be rather unexpected. The novel discoveries of CLINF, in this area of investigation, are linked to the fact that depictions such as *Fig. 2* may be used for quantifying the rates with which diseases have translated geographically through different regions. If these rates apply also to future scenarios – they certainly apply to the infinitesimally immediate future – this is exactly what is required in order to predict future CSI scenarios.

Future CSI scenarios cannot be predicted per se, but need to be assessed via large-scale land-surface and hydrography models that are capable of predicting the future status of the landscape- and weather variables that *regulate* CSI geographies (like discussed in Chap. 5 of this volume). This is the basic reason why CLINF have supplemented its diseases database with as much relevant landscape, hydrography, and weather (etc.) data as possible; by regressing these supplementary data on the observed variation of diseases incidences, regulatory CSI models were identified. When the thus identified regulatory driver variables were forecasted onto the future 50-year horizon, the corresponding future CSI scenarios may be predicted simply by inserting the forecasted driver variables back into the original CSI models.

The fundamental fact that diseases are reported at the spatial scale of diseases reporting districts only, typically at county size in the western world, is setting an important limit for the type of causal reasoning that may be applied to the CLINF modelling effort. When combined with the annual resolution at which incidences are cumulated, the resulting spatiotemporal scale becomes district-by-district and year-by-year. This scale contrasts with the smaller biological/ecological scales whereupon the ecology of vector organisms such as ticks, mosquitos, and rodents usually are assessed. Therefore, common biological/ecological causality does not necessarily apply to the scale of the overall CLINF research initiative (although CLINF also performs case studies at higher spatiotemporal resolutions, like in the case of tularaemia in Sweden). As an alternative, a formal statistical search (Aiken and West 1991) for the best subset of regulatory landscape/weather regressors was performed, although guided by biological/ecological causality experts.

As a result of the above procedure, using a broad arsenal of regression techniques (Aiken and West 1991), the observed variation (district-by-district and year-by-year) of many CLINF diseases could be explained at very high precision, although with varying degrees of explanation. In certain regions, the variation of some diseases was explained by 65%, while in other regions and with other diseases, the maximum degree of explanation reached 10%. It is suggested that these differences reflect the complexity of the respective CSI vector processes, and that CSIs may be clustered into functional groups that reflect the complexity of vector processes. As an example, the variation of "purely" tick-borne diseases, such as borrelia and TBE, seem to be relatively easy to explain as compared with the more complex vector processes of tularaemia (Akimana and Kwaik 2011).

One obvious interpretation of these results would be that what CLINF is actually inferring are latent vector processes that have been observed via diseases incidences, rather than the explicit variation of diseases themselves. The certainty with which future CSI scenarios may be predicted is strongly dependent of the different regression degrees-of-explanation discussed above. These certainties/uncertainties are transferred to the models with which future CSI scenarios are predicted, and causes the resulting prediction error to vary from one disease to another, although following the clustering of shared vector processes discussed above, and from one region to another. With such prediction errors generally perceived as being normal distributed (Aiken and West 1991), the statistical expectancy of the associated regression model may still be used as the most probable future CSI scenario.

4.7 Concluding Reflections

In addition to the scientific discoveries and lessons learned that were derived as a result of the CLINF integrated science design outlined throughout this chapter, many other insights are gained through the coordination of a relatively large integrated NCoE (Nordic Centre of Excellence). These will not be discussed much here, except for a few concluding reflections regarding the philosophy of interdisciplinary science. Two, in particular, are worthy of additional attention:

4.7.1 The Current Status of Interdisciplinary Science Integration

It is the view of the authors that true interdisciplinary[3] thinking must be kept within the minds of individuals. Our view is that interdisciplinarity requires for individual scientists to carry several traditional science disciplines within themselves, and be capable of employing integrative formal science methodology across disciplines.

[3] Interdisciplinarity: Working across traditional science disciplines.

This contrasts with the scenario where a number of intradisciplinary[4] scientists gather "around a table" to discuss across their respective disciplines. In the latter scenario, the interdisciplinary integration of ideas and perspectives is meant to take place in the cloud above the table where their words meet. Yet true interdisciplinary syntax, necessary to broaden the formalities of intradisciplinary science methodologies into an interdisciplinary context, cannot be present in such a cloud. In fact, the words that meet above the table are rarely compatible. This changes profoundly if and when the scientists that meet around the table, representing their respective fields of expertise, carry the synthesis within. This enables for a true interdisciplinary syntax to be formulated, and for science to expand into the greater realms that probably are necessary for grasping the large-scale problems of our time. Having, perhaps naively hoped for a rapid change into interdisciplinary science syntaxes for decades, one lesson learnt is that we still are not at that stage yet.

4.7.2 Causalism Versus Empirical Science, and the Complexity of Nature

As discussed above, CLINF data are collated at larger scales than those usually required for causal reasoning regarding the ecology of diseases vector organisms. Instead, it was discussed, a less causal biometric[5] approach was taken as an alternative. This scenario entails a possible conflict where, in vast scientific disciplines like biology and ecology, the rather rationalistic idea prevails that it is possible to see through observations of nature, and find the truth. On the other hand, rather classic empiricism applies to the biometric approach, where observations are statistically inferred without necessarily involving much causal reasoning, and where truth lies asymptotically ahead at the horizon of an infinitely large sample.[6] In addition to these different approaches to science, a causally based approach most often requires for the empirical sampling to be designed by terms of the spatiotemporal scales that apply to the target subject (such as the diseases vector organisms). This may lead to a conflict when the sampling design itself is provided á priori, as is the case in CLINF where diseases are reported via report districts only, and where the associated incidences are annually cumulated. Much like the lack of a shared interdisciplinary science syntax discussed above, the meeting between causalists and biometricians often lacks a shared integrative syntax. Obviously, the easy way out would be to have both sides educated into common methodological grounds, but we still are not there either.

[4] Intradisciplinarity: Working within a single traditional science discipline.

[5] Biometry: The statistical inference of biological observations and phenomena.

[6] Basic asymptotic theory of statistics: https://en.wikipedia.org/wiki/Asymptotic_theory_(statistics)

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Chapter 5
Modeling Climate Sensitive Infectious Diseases in the Arctic

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Abstract Forecasting the likely future prevalence of climate sensitive infectous diseases (CSIs) in the Arctic requires prediction of how environmental conditions, both aquatic and on the land, will change under a changing climate, together with knowledge of how these changes relate to the environmental conditionals for viability of CSI host organisms. This requires the use of land surface and hydro-climatic models that have been tested against past data and can be driven by climate projections provided by Global Circulation Models for a range of climate scenarios (Representative Concentration Pathways). Uncertainties in the climate projections combine with uncertainties in the environmental models, and this combined uncertainty propagates through into subsequent CSI occurrence modelling. This chapter will describe the available environmental models, together with the data needed to drive and test them, and how we can address the uncertainty within these models, in the context of Arctic CSI prediction.

Keywords Hydro-climatic models · Land surface models · Satellite observations · Uncertainty · Climate change

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5.1 Introduction

Understanding and predicting the evolution of CSIs in the Arctic under climate change relies on using current data with biophysical or statistical models to identify the factors that control CSIs and then predicting how these factors will change in the future. The collection of data on CSI incidence and its relation to environmental variables are described in Chap. 4 of this volume. Table 5.1, below, shows which variables are considered the most important for a range of potential CSIs. This provides the context within which we can evaluate the relevance of datasets and models for predicting CSI behaviour.

The environmental variables are almost all time-varying and fall into four broad classes:

1. Climate: air temperature, precipitation, solar radiation, humidity;
2. Land surface: land cover, fraction of absorbed photosynthetically active radiation (fAPAR), leaf area index, length of growing season, soil properties, soil temperature;

Table 5.1 Environmental variables affecting several potential Climate Sensitive Infections (CSIs)

	Borreliosis	Brucellosis	Tickborne encephalitis	Tularemia
	Ticks	Domestic animals, air	Ticks	Ticks, deer flies
Land cover	x	x	x	x
fAPAR	(x)	x	(x)	x
Leaf area index (LAI)	x	x	x	x
Length of growing season	x	x	x	x
Soil temperature		x		x
Soil moisture	x	x	x	x
Evapotranspiration		x		x
Runoff				x
Snow covered area	x	x	x	x
Snow water equivalent		x		x
Timing of snowmelt	x	x	x	x
Soil freeze/thaw				x
Air temperature	x	x	x	x
Precipitation	x	x	x	x
Humidity	x	x	x	x
Solar radiation				x
Soil properties		x		

Quantities derived from these primary variables, such as temperature extremes and values during previous years, may also influence the behaviour of CSIs. fAPAR is fraction of absorbed photosynthetically active radiation whose possible influence is indicated by parentheses. The second row shows the relevant disease vectors

3. Hydrological: soil moisture, evapotranspiration, runoff;
4. Cryospheric: snow covered area, snow water equivalent, timing of snowmelt, soil freeze/thaw.

These variables interact in complex ways that need to be represented in any attempt to model current and future behaviour.

One of the key approaches to unravelling these interactions and feedbacks is through biophysical models that attempt to represent the physical processes involved. This requires land surface and hydrological models that typically are driven by climate variables. There are many points of contact between these two types of model, since credible models of vegetation processes must represent hydrological variables, such as soil moisture, while hydrological models need, for example, information on vegetation cover and its dynamics. However, many land surface models do not contain elements such as water routing that are fundamental in models devoted to quantifying the water cycle.

For developing and testing models that describe current or past behaviour we can use a wide range of datasets provided by meteorological or Global Circulation Models (GCMs), but these are increasingly being supplemented by satellite data that provide pan-Arctic datasets on vegetation and cryospheric variables. However, for prediction the models must be able to be run independently of measurements, which means that all relevant time-dependent processes, such as snow cover, land cover change, LAI etc., must be controlled by internal parameters. Hence a crucial use of current data is in parameterising the models.

Naturally, as we look into the future, we become less and less sure of what we predict. Hence a essential aspect of modelling is to try to quantify what controls its uncertainty, how this grows with time and how this affects our predictions about CSIs. This has many facets. Perhaps most fundamental is how humanity will respond to climate change as regards its use of fossil fuels and land management. The Intergovernmental Panel on Climate Change (IPCC) encapsulates these different possible responses in "Representative Concentration Pathways" (RCPs) that drive the climate models. Differences in the RCPs are then exacerbated by differences in the models themselves. There are also significant differences in how the land surface and hydrological models represent the ensuing processes. In the following Sections we describe how these model-data-uncertainty elements are entangled in understanding the future of CSIs in the Arctic.

5.2 Environmental Datasets

During the past decades, Arctic and subarctic areas have seen increases of mean air temperatures well above the globally documented average (IPCC 2019). Warming of the Arctic has been manifested by changes in the Earth's cryosphere. Earth observation datasets, spanning nearly four decades, show reductions in monthly average sea ice extent, in particular for the ice minimum in the summer and autumn months

(Stroeve et al. 2012). This reduction in sea ice has been shown to contribute strongly to increased volatility in winter precipitation patterns; following estimates of continuing sea ice decline, this been projected to increase precipitation by more than 50% in the Arctic (Bintanja and Andry 2014). These seasonally varying changes are further likely to contribute to increased variability in soil moisture and snow cover conditions. This is corroborated by reductions in the extent, duration and mass of seasonal snow cover across the northern hemisphere land areas (Brown et al. 2017). These changes in snow cover dynamics have potentially significant impacts on the global climate system, snow-dependent ecosystems, and the water cycle (Sturm et al. 2017). In spring and summer months, the increase of snow-free terrain presents a positive feedback mechanism to warming, as does the increase in open sea, which both exhibit increased absorption of solar radiation compared to sea ice or snow cover (Derksen and Brown 2012). On the other hand, in particular mountain watersheds storing freshwater provide a vital resource, which may be under threat in a warming climate. Currently, seasonal snow provides the main source (> 50%) of freshwater runoff for 1/6th of the world's population (Barnett et al. 2005). Under present RCP scenarios, the increase in greenhouse gas emissions will continue to affect Arctic temperatures, potentially further aggravating changes in the Earth's cryosphere.

Observed and predicted changes in precipitation, soil moisture, snow cover and other components of the water cycle are likely to impact also animal and bacterial populations in Arctic and sub-Arctic areas. Perceived changes include the introduction of invasive mammal species to Northern areas (Hellmann et al. 2008), as especially snow cover is a main factor in the survival of many mammal species. Since these species act as carriers of different zoonotic and other diseases, these changes will potentially impact the spread of new CSIs across the Arctic. For example, populations of white-tailed (Odocoileus virginianus) are strongly dependent on snow cover and have in recent years expanded in Scandinavia and Finland; there are indications this species may play an important role in spreading Salmonella, Yersinia and STEC (Sauvala et al. 2019). Simultaneously, receding snow cover and changes in winter precipitation will likely affect the survival of different native species, such as reindeer. The increase of events such rain-on-snow precipitation and Arctic greening have been shown to introduce potential hazards to reindeer survival (Fauchald et al. 2017; Langlois et al. 2017), also rendering weakened populations vulnerable to infections. Consequently, the monitoring of environmental parameters, in particular related to the cryosphere, provide valuable indicators when estimating stress factors imposed on Arctic ecosystems by ongoing climate change.

The CLINF GIS database gathers together a suite of key environmental datasets which serve several purposes. Firstly, the data can be used to track past trends in Earth processes over the Arctic, which, together with information on disease prevalence, can be used to derive climate-related proxy indicators for disease spread and identify potential CSIs. Secondly, the data are needed to drive and test climate and hydrological models which predict future scenarios on relevant environmental conditions. The data entail a combination of observed and modeled (reanalysis) data, which rely both on satellite sensors and ground-based observation networks. Basic climatological information on, e.g., air temperature, precipitation, radiation, wind, pressure, and humidity are derived from the ERA-Interim database; these are atmospheric reanalysis datasets released by the European Centre for Medium-range Weather Forecasts (ECMWF). The assembled data cover a period from 1979 to 2016. The data are required as driving data for land surface models, but can also be independently applied to derive indicators based on, e.g., variations in air temperature or precipitation over areas of interest.

Further, accurate land surface information is critical for hydrological modeling and for tracking climate-induced and anthropogenic changes in land use. The European Space Agency (ESA) Land Cover Climate Change Initiative (CCI) Climate Research Data Package (CRDP), included in the database for years 1992–2015, contains an annual time series of consistent global land cover maps at a spatial resolution of 300 m. Further land surface related parameters include fAPAR and the leaf area index (LAI), derived from satellite observations for the years 2002–2017. These high-resolution (500 m) data serve to inform on changing vegetation conditions for tracking, for example, Arctic greening.

Earth observation is a powerful tool for monitoring Arctic areas, where sparse population and low level of infrastructure limit conventional surface (weather station) observations and also the accuracy of reanalysis products. While collected ERA-Interim data cover such parameters as snow depth, sea ice extent, soil moisture and soil freezing, these are complemented by satellite-observed datasets. Data on sea ice extent and Snow Water Equivalent (SWE), i.e., the total amount of freshwater stored in snow given by the product of snow depth and density, are derived from an ensemble of satellite datasets extending back to 1979. The ESA CCI Soil Moisture products provide harmonized estimates of soil moisture variability for 1979–2016; similarly, to sea ice extent and SWE, the data are compiled from observations by several satellite systems. These data are available typically at moderate to coarse resolution (tens of km). Several indicators of climatic changes can be derived from the dataset. As an example, Fig. 5.1 depicts the date of snow clearance (the date when the seasonal snowpack has completely melted) in spring over the Northern Hemisphere. Depicted is also the trend of the average date of snow clearance for land areas above 40°N. Although there is large variability from year to year, on average snow clearance occurred 2 days earlier per decade over the study period.

Table 5.2 Environmental datasets collected for the CLINF GIS database. The table is not exhaustive as further datasets continue to be added based on availability and relevance to the spread of CSIs.

5.3 Modelling Land Surface Processes for CSI Prediction

The disproportionately increased warming in the Arctic due to climate change will cause (and is causing) drastic changes in the terrestrial energy, carbon and water balances of the Arctic, with large effects on such biophysical variables as growing

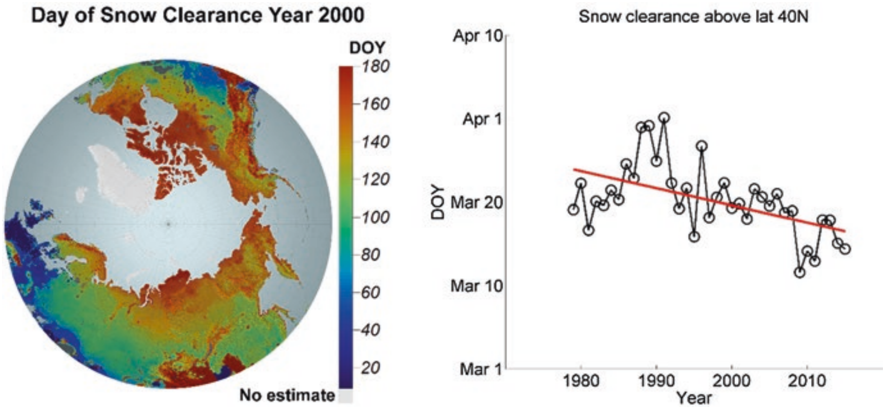

Fig. 5.1 Left: Day of snow clearance as day-of-year from January 1st in the year 2000, using method by Takala et al. (2009). (From Pulliainen et al. 2017). Right: the trend of mean snow clearance date above latitude 40°N

season, land cover (including species changes), snow cover, soil moisture, soil freeze-thaw and permafrost thaw. Many of these variables and associated processes are related to the behaviour of CSIs (see Table 5.1). There are also major consequences for insect, animal and human populations in the Arctic.

These processes are highly inter-dependent, with complex interactions and feedbacks that cannot be considered in isolation when trying to assess the effects of climate change on the land surface. For example, land cover plays a major role in the energy balance and in the transfers of water, heat and trace gases between the surface and the atmosphere. However, vegetation activity has exhibited major changes over recent decades, as evidenced by the greening of the tundra but browning of high latitude forest systems (Miles and Esau 2016). Because it has much lower albedo than snow, vegetation contributes to Arctic warming, with increased effects as low vegetation is replaced by shrubs that emerge from the snow cover. Such vegetation changes modify the niches available for CSI vectors such as ticks. Vegetation is also important in the heat input to the soil from the atmosphere both by shading and, as in the case of Arctic mosses, providing an insulating layer between the atmosphere and the soil, hence affecting diseases like brucellosis and tularemia (Table 5.1). Furthermore, the vegetation-soil system plays a major role in the hydrological cycle through evapotranspiration to the atmosphere (Sect. 5.4). For CSI prediction it is therefore essential to quantify the spatial and temporal variation in vegetation, and how this is linked to other biophysical variables. Similar considerations apply to all the variables affecting CSIs.

Simultaneous consideration of the multiple interacting high latitude processes and feedbacks relevant to CSIs requires the use of land surface models (LSMs) that can treat all these processes within a consistent framework. The development of LSMs has been driven largely by the need to understand interchanges of trace gases, water and energy between the land and the atmosphere under a changing climate

Table 5.2 Summary of main environmental datasets in CLINF GIS database

Data class	Dataset name	Temporal range	Data source
Climate	Air temperature	1979–2016	ERA interim (ECMWF)
	Precipitation	1979–2016	ERA interim (ECMWF)
	Radiation	1979–2016	ERA interim (ECMWF)
	Wind	1979–2016	ERA interim (ECMWF)
	Air pressure	1979–2016	ERA interim (ECMWF)
	Humidity	1979–2016	ERA interim (ECMWF)
Land surface	Land cover	1992–2015	Land cover CCI climate research data package
	fAPAR	2002–2017	MODIS (aqua+Terra)
	Leaf area index (LAI)	2002–2017	MODIS (aqua+Terra)
	Length of growing season	2002–2017	Derived from fAPAR and LAI
	Soil properties	NA	ISRIC World Soil Information (SoilGrids)
	Soil temperature	1979–2016	ERA interim (ECMWF)
	Topography	NA	Global 30 arc-second elevation (GTOPO30)
Hydrological	Soil moisture	1979–2010 1980–2017	ERA-interim/Land reanalysis[a] GLEAM-3.2a model[b]
	Evapotranspiration	1979–2010 1980–2017	ERA-interim/Land reanalysis[a] GLEAM-3.2a model[b]
	Runoff	1901–2012	GSIM[c]
Cryospheric	Snow covered area	1995–2010	ESA GlobSnow SE v1.5
	Snow water equivalent	1979–2016	ESA GlobSnow SWE v3.0
	Sea ice extent	1979–2016	NOAA Sea ice index, version 3
	Soil freeze/thaw	2009–2016	SMOS level 3 soil F/T

[a]European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis (ERA)-Interim/Land reanalysis datasets
[b]Global Land Evaporation Amsterdam Model (GLEAM-3.2a)
[c]Global Streamflow Indices and Metadata (GSIM) archive

and, as such, they form a core component of the Earth System Models (ESMs) used to inform IPCC projections of future climate. However, the enormous international effort in climate modelling has led to numerous LSMs, which differ in the processes they try to represent (e.g. fire, the nitrogen cycle, permafrost, etc.) and in how these processes are parameterised. A key consideration in CLINF is whether any of these models are suitable for use in CSI prediction.

A generic diagram of the structure of the type of LSM used in CLINF is shown in Fig. 5.2 below. Its emphasis is on vegetation, soil and water processes, rather than energy balance, although vegetation and soil temperature and temperature gradients are accounted for. The versions of the LSMs used (JULES [Comyn-Platt et al. 2018], CLM5 [Lawrence et al. 2019], LPJ-GUESS [Hickler et al. 2012] and two forms of the ORCHIDEE model [Druel et al. 2017; Guimberteau et al. 2018]) were

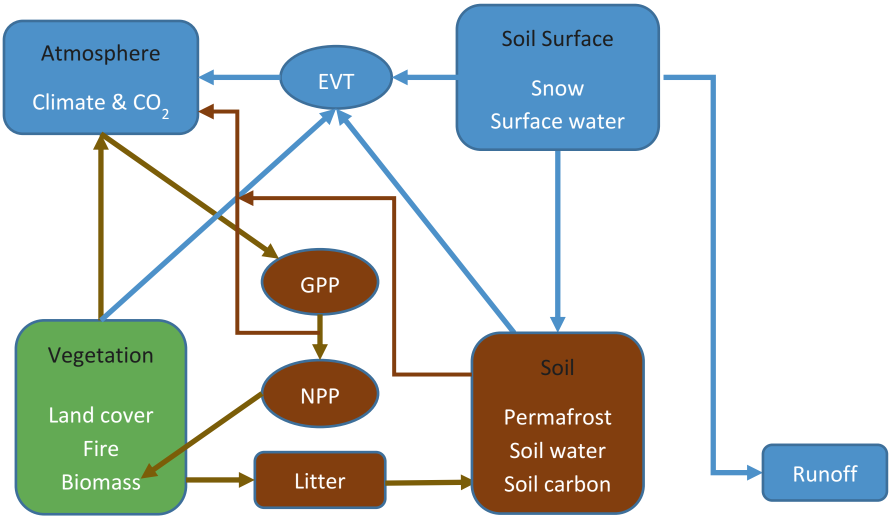

Fig. 5.2 Generic structure of the vegetation-soil-atmosphere component of a Land Surface Model. Flows of water and carbon are shown by blue and brown arrows respectively. EVT is evapotranspiration, GPP is Gross Primary Production (photosynthesis) and NPP is Net Primary Production

chosen because they include specific components relevant to high latitudes, including Arctic vegetation types and permafrost, unlike many LSMs designed for global application. In a full Earth System Model, each of them would be coupled with an atmosphere-ocean model, but in CLINF we run the models separately and drive them with climate variables provided by one of the Global Circulation Models. They are all designed to be predictive, which means that all processes within them are parameterised, including land cover change, vegetation activity, fire, snowmelt, etc., which can be observed at large scales from satellites (see Sect. 5.2); such observations can then be used to constrain model parameters.

Of the environmental variables identified as affecting potential CSIs (Table 5.1), the atmospheric variables and soil properties (the last five entries in the table), together with atmospheric carbon dioxide concentration, are drivers of the LSMs; all other variables are calculated (the models may be initialised with current land cover but land cover change is then under the control of the model). However, different models use different process representations and parameters, so make different predictions, not just the future but also about past behaviour. To assess their value for CSI prediction we therefore need to evaluate the variability in the models across the range of variables in Table 5.1.

Methods to quantify such spatio-temporal variability (Leibovici 2010; Leibovici et al. 2019) allow the inter-model variability to be decomposed into its common spatial, temporal and model-specific components. An example is shown in Fig. 5.3 for Net Primary Production, which is the amount of biomass produced by photosynthesis, so is strongly related to the length of the growing season, fAPAR and LAI. The analysis shows that 90% of the variation between the models is captured by the product of a single spatial pattern (Fig. 5.3a) and a single temporal pattern (Fig. 5.3b), together with a model-specific multiplier varying by less than 14% between the LSMs (Leibovici et al. 2019). Hence using different LSMs introduces little uncertainty into subsequent CSI predictions based on the variables associated with NPP, i.e. fAPAR, LAI and growing season.

The same type of analysis applied to the *differences* between the LSMs provides specific information on how the LSMs disagree. Figure 5.4 shows the spatio-temporal pattern that most closely captures these differences (Leibovici et al. 2019). Within this pattern, all the LSMs give similar values except that due to Druel et al. (2017), which over the whole time-period gives smaller values of NPP than the other LSMs in the red regions (Fig. 5.4a) and greater in the green regions.

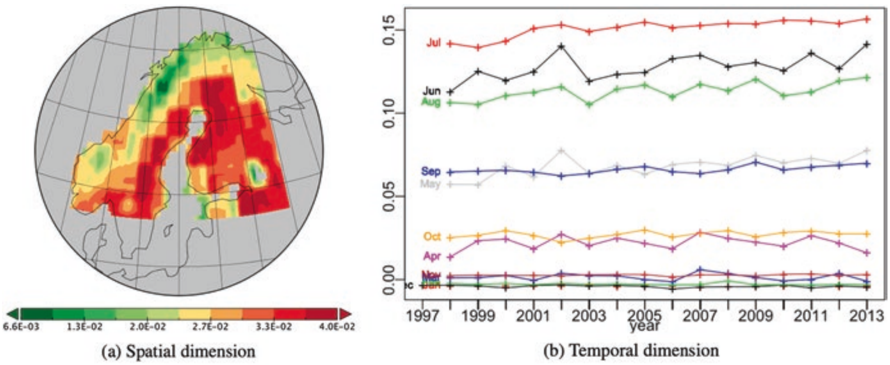

Fig. 5.3 (**a** & **b**) The spatial and temporal patterns capturing 90% of the variability in Net Primary Production from the Land Surface Models over the CLINF region for the period from 1998 to 2013

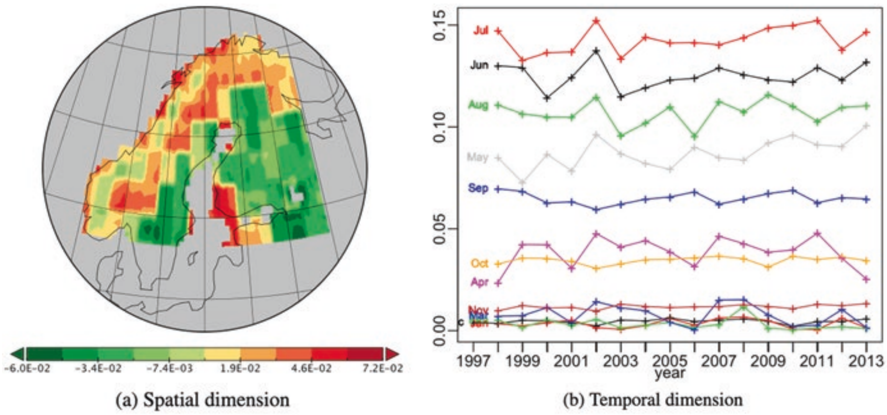

Fig. 5.4 (**a** & **b**) Spatial and temporal patterns capturing the main differences in Net Primary Production for the Land Surface Models used in CLINF over the CLINF region for the period from 1998 to 2013

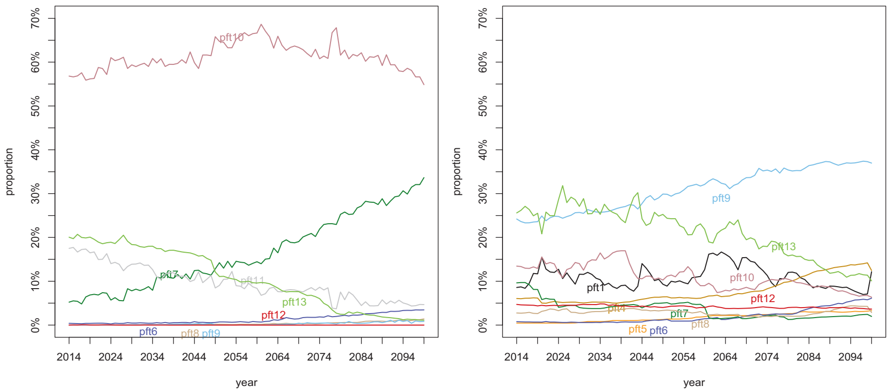

Fig. 5.5 Changes in the proportions of dominant plant functional types (pfts) across the CLINF region as predicted over the twenty-first century by LPJ-GUESS (left) and ORCHIDEE (right). The pft numbering is as follows: 1: bare ground; 4: temperate needleleaf evergreen; 5: temperate broadleaf evergreen; 6: temperate broadleaf summergreen; 7: boreal needleleaf evergreen; 8: boreal broadleaf summergreen; 9: boreal needleleaf summergreen; 10: C3 grass; 11: C4 grass; 12: nonvascular moss & lichen; 13: boreal broadleaf shrubs; 14: C3 arctic grass. The right-hand fig. is from Leibovici and Claramunt (2019)

However, for other variables the models do not show the same level of consistency. One of the most important is land cover. This is driven by model-specific parameters that control the suitability of a given plant functional type to exist in a grid-cell under the given climate and soil conditions, and hence its ability to colonize new ground as this becomes available due to plant mortality or improved growth conditions. The extent of model differences is illustrated in Fig. 5.5, below, which shows the predicted changes in the dominant proportion of vegetation type in the CLINF region over the twenty-first century for the LPJ-GUESS and ORCHIDEE models (both with climate forcing provided by IPSL-CM5A-LR under RCP 8.5). The most obvious difference is that LPJ-GUESS predicts far more cover by C3 grass than ORCHIDEE and a significantly increasing area of boreal needleleaf evergreen forest. The only clear point of agreement is that both LSMs predict a decline in shrub cover over the century, but this contradicts current observations of the spread of shrub cover in the Arctic (Myers-Smith et al. 2011). The differences between the LSMs and their inconsistency with data indicate that the parameters controlling land cover dynamics in both models need significant reappraisal. Similar remarks apply to the other LSMs considered. This type of analysis therefore provides significant motivation for the community to improve their models, with the study of CSIs giving an important underpinning requirement for such improvement.

5.4 Hydrological Surface and Subsurface Changes Influencing Communities

The climate in the Arctic is changing at almost three times the rate and magnitude experienced in the rest of the world and this is affecting Arctic peoples, animals and the environment (Hoberg and Brooks 2015). The Arctic region also comprises a range of different ecological and physical environments that interact with, and feedback on, the global climate system. These changes can threaten northern societies but also open new opportunities: for example, warming may open new local sources of moisture, such as open water previously under ice (Bintanja and Selten 2014), while the melting of glaciers (Dyurgerov et al. 2010) and permafrost thaw can strongly influence both water (Karlsson et al. 2012) and carbon (Schuur et al. 2015) cycling conditions throughout the Arctic. Furthermore, ecosystem regimes may shift (Karlsson et al. 2011; Wrona et al. 2016), and infrastructure damages may occur, with critical consequences for regional water security and health (Daley et al. 2014).

Wetlands constitute a large proportion of the Arctic landmass and play an important role in sustainable regional development, as they are linked to ecosystem services and the livelihoods of local people, and their opportunities to adapt to climate change (Seifollahi-Aghmiuni et al. 2019). There is so far weak evidence for the correlation of observed changes in Arctic vegetation density with hydroclimatic changes over the Arctic region (Groß et al. 2018*)*, but hydroclimatic changes are known to considerably affect the resilience of Arctic wetland ecosystems and are causing shifts in current regimes (Karlsson et al. 2011). Nevertheless, the combined effects of natural and human pressures and management efforts on Arctic wetland ecosystems, their biodiversity and functioning, and the benefits they provide to human wellbeing and health, are still poorly understood (Seifollahi-Aghmiuni et al. 2019).

Permafrost in the northern circumpolar region has been disappearing in recent decades (Romanovsky et al. 2010), with important surface implications. Thawing of permafrost can release large amounts of carbon to the atmosphere (Schuur et al. 2015) and lead to re-emergence of long-frozen pathogens, posing increased risks to the health and wellbeing of animals and humans (Revich et al. 2012). There is thus an urgent need to quantify and predict permafrost changes under ongoing and future warming conditions. Systematic model simulations of different surface warming trends combined with various local soil-permafrost conditions have indicated that thaw-driven regime shifts in wetland/lake ecosystems, and associated releases of previously frozen carbon and pathogens, may be expected to occur in and be more severe for peatlands than for other soils (Selroos et al. 2019).

Use of GCM and ESM projections for water-related change assessment and planning typically relies on regional downscaling, either through physically-based regional climate models (Sun et al. 2016) or by various statistical means (Mizukami et al. 2016), sometimes further processed through hydrological models. However, all downscaled results ultimately depend on the ability of the driving GCM/ESM to adequately represent the hydroclimate of land areas at relevant scales (Bring et al. 2015). Direct GCM/ESM use to simulate and project hydroclimatic changes has been found to represent observed temperature better than observed water conditions, in terms of precipitation, evapotranspiration and runoff (Asokan et al. 2016). The spatial scale of process resolution may be a reason for such differences between modelled and observed values, although some studies have found small or no effects of scale on GCM performance for hydroclimate on land (Asokan et al. 2016; Bring et al. 2015).

In view of the key role of hydroclimatic conditions for different types of changes in the Nordic-Arctic region, Bring et al. (2019) tested the performance of GCMs/ESMs specifically for the hydroclimate of this region, extending from Western Greenland to Eastern Siberia, and including Sweden, Finland, Norway, Iceland, Greenland and Russia. There were four main reasons for this geographic delineation. First, it includes a gradient of Arctic environments, including ice caps and glaciers, tundra and boreal forests. Second, it covers a range of Arctic communities, including Inuit, Sami and several indigenous peoples in Russia, but also several of the largest Arctic urban areas, such as Reykjavik, Tromsø and Murmansk. Third, it enables use of the longest time series of data from direct hydroclimatological observations (Bring and Destouni 2014) and the most detailed global and downscaled climate model simulations (Fig. 5.6). Fourth, the selected region includes most of the areas identified as hotspots of projected future hydroclimatic change (Bring et al. 2017). These hotspots coincide with a relatively high concentration of population compared to other parts of the pan-Arctic region, indicating that the highest density of change impacts on humans in the Arctic may be concentrated here.

Over this region, Bring et al. (2019) investigated available data from 64 Nordic-Arctic hydrological basins, and compared climate model results to observations across different scales and variables. They found an unexpectedly similar level of model-observation agreement for runoff and temperature, with model outputs for both having relatively small error and bias for different basins and on whole-region scale, compared to the other water cycle variables of precipitation and evapotranspiration. The results did not show clear or consistent differences in model performance for different basin sizes across the different hydroclimatic variables. However, the better performance of the temperature-runoff variable pair compared with the poorer performance of the precipitation-evapotranspiration variable pair only emerged fully at the whole-region scale. Moreover, a tendency was found for better model performance with increasing basin size for runoff and to some degree also for precipitation.

Performance ranking of the multiple GCMs/ESMs tested against hydroclimatic observations by Bring et al. (2019) showed no single climate model performed best across all studied variables. The overall poor climate model performance as regards precipitation and evapotranspiration has important implications for modelling of hydroclimatic responses. Specifically, it points at options for direct use of relatively

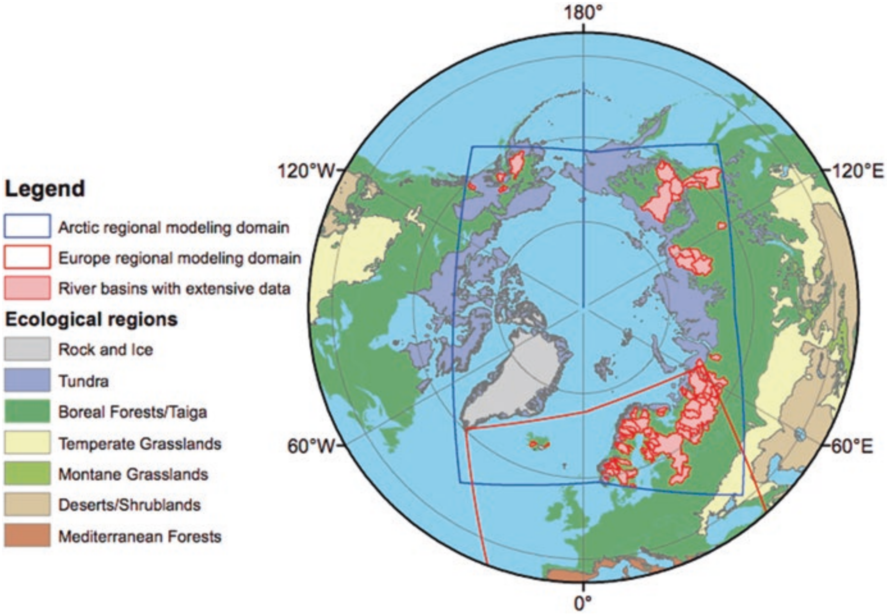

Fig. 5.6 Hydrological basins (red) within the pan-Northern region for which extensive and complete hydroclimatic data series are openly available

good GCM/ESM results for regional runoff projections, instead of driving downscaled hydrological modelling of runoff by much poorer GCM/ESM results for precipitation and evapotranspiration.

5.4.1 Infectious Disease Sensitivity to Hydroclimatic Changes

Hydroclimatic changes, which may be particularly large at high latitudes, can also affect regional outbreaks of infectious diseases, jeopardising human and animal health. To assess the risk to health of such changes, it is necessary to identify the sensitivities of various diseases to variability and change in hydroclimatic conditions. Ma et al. (2019) developed a method for analysing this sensitivity for tularemia and its possible endemic disease level (N* in Fig. 5.7, top panels) under different prevailing hydroclimatic conditions.

Ma et al. (2019) considered the case of tularemia based on a previously tested and established statistical model for this disease, developed by Rydén et al. (2012). Figure 5.7 illustrates schematically how the number of disease outbreaks converges to the expected endemic level N* associated with the considered combination of hydroclimatic conditions, and how that level may go beyond some societally acceptable threshold value under changed hydroclimatic conditions in future years.

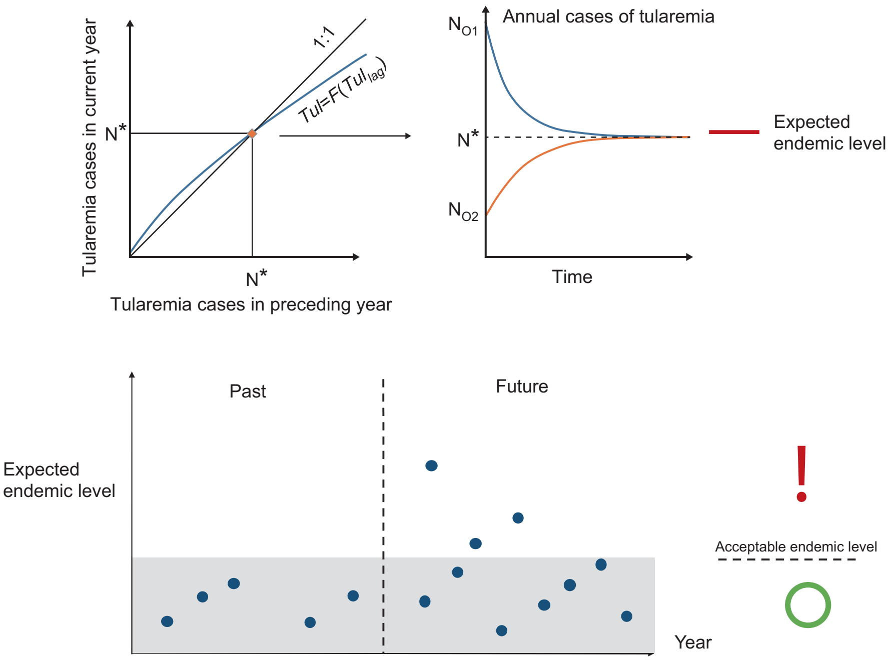

Fig. 5.7 (Top) Schematic diagrams of how the number of tularemia outbreaks, under any given combination of disease-relevant long-term average hydroclimatic conditions, converges to an expected endemic level N*: (top left) from each year to the next (blue line; the black line indicates the same number of cases in both years); (top right) over time, starting from any initial number of cases, N_{01} or N_{02}, the number still converges to the same N* level (dashed line) for the same hydroclimatic conditions. (Bottom) Schematic diagram of past and future values of expected endemic level, depending on prevailing/projected hydroclimatic conditions, which can/should be compared with some societally accepted endemic level (dashed line), beyond which projected disease changes are unacceptable and mitigation measures are required

Tularemia is one of the most well-researched endemic diseases in high-latitude regions (Waits et al., 2018) with outbreak numbers quantitatively related to hydroclimatic conditions by the statistical disease model of Rydén et al. (2012). In their study of the implications of this model for possible future hydroclimatic changes, Ma et al. (2019) found high disease sensitivity to different combinations of hydroclimatic variable values, and the possibility of shifts in major disease increases even for relatively small changes from current average conditions, with variable values still remaining within the range of past regional observations.

Figure 5.7 also illustrates the possibility of identifying threshold hydroclimatic conditions beyond which the endemic level of the disease goes above some societally accepted level, for instance defined by the World Health Organization. Further research is required on how projected hydroclimatic changes may affect outbreaks of various infectious diseases, with particular focus on potential threshold combinations of driving variable values, and on the spatio-temporal generality and transferability of quantitative disease models that can be used for such projections.

5.5 Conclusions and Prospects

Fundamental to understanding and predicting the viability and spread of CSIs is identification of the environmental envelopes within which they can flourish, though this will almost certainly need to be supplemented by knowledge about the host and affected species and their risk of exposure to the disease (including for humans). Coherent, integrated environmental information is increasingly becoming available both from enhanced observational capabilities, especially from satellites, and advances in bio-geophysical models. Hence the framework needed to assess CSI risk and how this will develop is essentially in place. However, the value of this framework for CSI prediction is limited by two factors, spatial scale and uncertainty.

As regards CSI analysis, spatial scale is not a major limitation for many of the variables derived from satellite data (Table 5.2), since in many cases the observations have spatial resolution around a few hundred m. However, a basic factor in the spatial resolution of the LSMs and hydrological models is the grid-size of the climate models used to drive them, which for GCMs is typically around 0.5° (around 50 km in latitude by 25 km in longitude at 60°N). The models may attain an effective finer resolution by exploiting higher resolution land cover, for example, but this may still be insufficient to characterise the variety of environmental conditions within a landscape that affect CSI viability. Nonetheless, the analysis of tularemia described in Sect. 5.4 makes clear that while detailed mapping of disease hotspots are unlikely to be provided by models, the effect of changing conditions can be investigated by these models and this yields significant policy-relevant conclusions.

Uncertainty is intrinsic to any measurement or model estimate. For measurements, uncertainty describes the statistical distribution of estimated values of a given quantity, so is conceptually simple, though may be hard to quantify in practice. For example, estimating LAI from satellite measurements relies on a model for how solar radiation interacts with the vegetation canopy. Flaws in this model combine with effects such as sensor noise to give LAI estimates that may be biased as well as having significant dispersion. Nonetheless, this type of uncertainty is well understood and can be characterised if there are sufficient reference data to calibrate the estimates.

Uncertainty in LSM or hydrological model calculations is much harder to characterise because it contains many cumulative factors that cannot be adequately described simply by statistical methods, especially when it comes to prediction. First and foremost is how humanity will respond to climate change. Although the four Representative Concentration Pathways (RCPs) defined by the IPCC set out possible atmospheric greenhouse gas concentration trajectories, no probability is attached to them. Secondly, for a given RCP different GCMs make different predictions about how climate will behave, with particular disagreement as regards precipitation. The ensuing uncertainty feeds through into the climate drivers of LSMs and hydrological models. However, as we have shown above, the models themselves differ, even with the same drivers, either because of differences in process representation or in model parameterization. This adds another layer of uncertainty, all of which propagates into CSI models based on the values of land surface and hydrological variables. The implication is that, at our current level of understanding and capability, long-term prediction of CSI behavior is probably of little value for policy decisions. Much more useful will be the development of predictions looking no more than a decade or two into the future, since these will be strongly constrained by current observations of the state of the Arctic. Furthermore, the large set of observations we already have provide a major resource to winnow out the models that do not perform very well and to motivate model improvement.

As noted in Chap. 4 of this volume, addressing the complex effects of climate change on diseases in the Arctic and the ensuing societal impacts requires a highly multi-disciplinary team with expertise in health, geospatial statistics, data analysis, environmental observations from space, ecology, environmental modelling, and numerous aspects of social science. In addition, to have real impact CLINF needs to understand how to translate its findings into forms that can be assimilated by the many political, economic and social groups that intersect in the Arctic. One of the key contributions of CLINF is assembly of the necessary range of capabilities and, over time, learning how to make them interact with a common goal and within a common framework. This has inevitably been a slow process because of the lack of common methodologies, or even a common language, shared by different research communities. Equally inevitably, it has involved researchers moving out of their comfort zone and tackling questions that they have not been faced with before. However, doing so is both scientifically stimulating and leads to better understanding of the strengths and limitations of their own approaches to Arctic questions. Such insight is a prerequisite for improvement, with implications well beyond the CLINF project itself.

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Chapter 6
Reindeer Herding and Coastal Pastures: Adaptation to Multiple Stressors and Cumulative Effects

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Abstract Many reindeer herders in northern Norway use coastal pastures for grazing. Such use comes with challenges for herding flexibility, coastal grazing and traditional adaptation practices. We are addressing three of those challenges here, predominantly focusing on Nordland County. First, we look at how climate change affects the pastures through increased woody vegetation (shrub and forest), along the coast, increasing the tick distribution and abundance. Second, herders are increasingly experiencing pasture encroachments through physical infrastructure and human activity, making coastal grazing challenging. Last, climate change and the spread of climate sensitive infections (CSIs) to new geographical areas create potential risks for the herders, and for citizens in general. Many CSIs are zoonotic infections that may be transmitted between humans and animals. Arthropod vectors (i.e. mosquitos, midges, ticks) as well as animal hosts are sensitive to climate change. The distribution range of ticks have moved northwards because of warmer and wetter weather conditions. This increasing risk of tick-borne diseases and the introduction of such diseases to new areas is the focus of our inquiry within our

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project CLINF under the Nordic Center of Excellence Arctic Programme. In this chapter we explore these threats to reindeer herding through the coproduction of knowledge approach. We consider the effects of multiple and interacting changes in climate, pasture access, encroachments and the spreading of CSIs. We approach the multiple stressors in a holistic manner and identify the interactive and cumulative effects on reindeer herding.

Keywords Reindeer herding · Multiple stressors · Climate adaptation · Holistic approach · Co-production of knowledge · Supplementary feeding

6.1 Reindeer Herding in Northern Norway in a Nutshell

6.1.1 Historical Background

Reindeer (*Rangifer tarandus*) are an important resource for Arctic Indigenous peoples and have been exploited for food and other subsistence since the last glaciation (Kofinas et al. 2013). In Fennoscandia, large herds of wild reindeer migrated from coast to inland and was of high importance for all residents (Bjørnstad et al. 2012). Today there is agreement that the Sámi reindeer herding developed from a Sámi hunting and fishing culture (Aronsson 1991; Bjørklund 2013). Archaeological evidence shows that a kind of semi-nomadism or reindeer herding started as early as about 500AD. An early example of domesticated reindeer at the coast of Troms, Northern Norway, was reported at the end of the 800s (Bately and Englert 2007; Bjørklund 2013). The first report of domesticated reindeer was delivered by the North-Norwegian chieftain Ottar (Ohthere) when he visited King Alfred the Great in England in 890 (Bately and Englert 2007).

There are few discussions of reindeer domestication in the following centuries, but as a result of intensive hunting of reindeer and fur trade during the fifteenth and early sixteenth century, wild reindeer were decimated. Hence the Sámi people had to change their ecological strategies towards reindeer herding and domestication (Vorren 1998). As a result, an intensive reindeer husbandry economy with small herds for meat and milk appeared (Falkenberg 1985; Vorren 1998). This continued until the early twentieth century when extensive reindeer husbandry with larger herds emerged (Ruong 1954). The development of reindeer husbandry has been regionally diverse as the result of both geography and the effects of nation state policies in Fennoscandia (Riseth et al. 2016). Seasonal pasture use is based on both long and short animal migrations (Kalstad 1982). Continental winter pastures provide opportunities for large herds while coastal winter pasture limit herd size (Tveraa et al. 2007).

During the twentieth century reindeer husbandry has undergone several transformations. Firstly, there was a shift from subsistence use and milking towards meat and market production. Secondly, a general modernization occurred including ordinary schooling for children and family sedentarization, i.e. that families changed their dwellings from traditional *goahti*[1] and *lávvo*[2] to ordinary wooden houses like peasants. Generally, this was completed during the first half of the century. Thirdly, a change from animal and human muscle power towards increased motorization with snowmobiles and cars commenced in the 1960s. In suitable landscape the ATV is used for person transport, helicopters are increasingly used for gathering the herds and trucks for animal transportation. Finally, from the 1970s the cooperation with governmental authorities increased along multiple dimensions. In short, this implied significant changes from an independent lifestyle towards a livelihood occupation, increased integration into the broader society, and increased dependency on the state (Riseth 2006; Berg 2000; Ulvevadet 2012) (Fig. 6.1).

6.1.2 A Brief Summary of the Current Status of Reindeer Husbandry

In general, reindeer herding in Northern Norway is highly susceptible to external pressures created by infrastructure development, predation, the expansion of shrubs and forests, modernization and climate change. Reindeer husbandry industries are also influenced by government regulations, international agreements and pasture conditions that are under continuous change. Contemporary reindeer herders are increasing feeling the impacts from climate change, in addition to the effects of natural variability, pasture encroachments and fragmentation, and institutional barriers (Kløcker Larsen et al. 2017; Risvoll 2015; Löf 2013). Combined these factors significantly contribute to loss of grazing land for their animals.

Large carnivores, such as lynx, wolverine and golden eagle are increasingly causing severe losses of reindeer in Norway. The pressure from such predators is particularly high in Troms and Nordland Counties (Danell 2010). Norwegian national predator policy is based on a two-fold objective: (1) that of preserving biodiversity and (2) maintaining traditional local livelihoods. Risvoll and Kaarhus (in press) show that carnivore regulation in Norway is founded on a decentralized management basis. However, many reindeer herders and other local actors involved in aspects around herding experience barriers in having their knowledge, views and experiences acknowledged and considered valid at the national level.

Climate sensitive infections (CSIs) are here defined and modified from Omazic et al. (2019) as infections causing disease where the vectors (e.g. mosquitos, midges or ticks) or the hosts (e.g. rodents, deer, reindeer, birds, hares) are sensitive to changes in climate (van Oort et al. in review). CSIs represent a new and potentially pertinent challenge to reindeer husbandry. In this chapter we are including CSIs in the bundle of the multiple stressors described below, even though we do not yet have

[1] Turf huts.

[2] Herder tents rather similar a Native American teepee.

Fig. 6.1 Map of Northern Norway

solid evidence that such infections are currently being experienced. In our inquiries, we surmise that reindeer are exposed and sensitive to some of the diseases following in the wake of CSIs, and we explore whether the current adaptation strategies are sufficient to meet such challenges (Fig. 6.2).

Fig. 6.2 Reindeer migration in Nordland in autumn

6.2 Studying Adaptation: Multiple Methods and Approaches

Reindeer herders adapt to multiple stressors (e.g. climate change impacts, management, encroachments, predators). Following the approach outlined in Hovelsrud and Smit (2010) we have identified a range of exposure-sensitivities and the herders' adaptation strategies. We draw on empirical data from case studies (Yin 2014) in reindeer herding districts of Nordland County in Norway. The data have been collected using mixed methods, including semi-structured interviews, informal conversations and observations. The empirical work is a continuation of a practice-oriented and iterative research process between some of the scientists and herders that has been ongoing for the past 10 years. That the work is long-term has allowed researchers an opportunity to participate in, observe and document herders' perceptions and experiences of change over several seasons and years (see for example Risvoll 2015; Risvoll and Hovelsrud 2016; Riseth et al. 2011, 2016; Riseth and Tømmervik 2017).

An interview guide has been used in all the interviews. The guide included questions about the use of pastures throughout the year, changes in migratory routes of the herd and observed changes in climate and the environment. We asked whether there are linkages between climate change and diseases in the reindeer, how they handle the risk of infections during slaughter, and whether they are finding ticks on the animals. Some questions are related to how herders and other study participants detect diseases, the role of traditional knowledge and the level of veterinary knowledge about reindeer health. Other questions pertained to the need for supplementary feeding. These included queries about the type of feed, where and when the animals were fed, and the benefits and challenges of keeping and feeding the animals in fenced areas. Another set of questions pertained to herding adaptation with respect to the presence of predators other natural and societal stressors. Finally, we addressed the herders' perspectives on the linkages between locked pastures, warmer temperatures, migration to coastal pastures and CSIs.

In addition to individual interviews, we have kept ourselves informed of the policy and management developments in reindeer herding that have a bearing on the herders' flexibility to adapt and to continue with their traditional practices and activities. Flexibility is at the heart of adaptation for reindeer herding as it for other primary industries which utilize natural renewable resources (e.g. Riseth et al. 2018; Risvoll and Hovelsrud 2016; Brännlund and Axelsson 2011). We will return to the issue of flexibility later in this essay.

6.2.1 Co-producing Knowledge: Researchers and Reindeer Herders

In many ways, our empirical data gathering methods (see Smit et al. 2010) resemble what is now increasingly called the coproduction of knowledge (e.g. Bremer and Meisch 2017). Interest in the concept, which was first introduced by Elinor Ostrom and colleagues in the 1970s, has gained speed in the past decade. This is particularly the case in its use within the climate change literature. The concept of coproduction has many applications and definitions. Here we refer to coproduction as deliberate processes for producing actionable knowledge about the combined effects of climatic and societal change. Such processes therefore include collaboration between different kinds of knowledge systems. Below we briefly outline what applying coproduction of knowledge entails.

Bremer and Meisch (2017) provide quite a comprehensive overview over how the concept has been applied and in what context. They identify two main divisions in coproduction of knowledge research. The first refers to coproduction as deliberate collaboration towards a common goal. The focus is on developing guidelines for how knowledge should be coproduced and to what end. In climate change research the communication of climate change knowledge ideally flows iteratively between scientists and stakeholders. In this case, the main concern is with the coproduction of 'demonstrably useful' knowledge for policy making (Maria Carmen Lemos and her colleagues quoted in Bremer and Meisch 2017: 2).

The second area of coproduction of knowledge pertains to the description and analysis of how coproduction happens across power relations, social orders and different forms of knowledges and contexts. This area of coproduction is called *descriptive* because it is interpreted through "the shifting relationships between science and society, and nature-including around climate change-rather than intervening to actively change these relationships" (ibid). The authors who promote this perspective (e.g. Sheila Jasanoff, Bruno Latour, Bryan Wynne) are on a quest to understand how science, technology, and society interact to make and remake each other (Bremer and Meisch 2017: 2). This perspective focuses on understanding how the products of science and technology flow across societal and knowledge boundaries.

Situating themselves within the context of the climate change challenge Bremer and Meisch consider the applications of both perspectives in the literature and suggest a conceptual prism of eight lenses for understanding the co-production challenge (2017: 13). They distinguished between two *descriptive* lenses: the constitutive and interactional, and six *prescriptive* or normative ones: extended science, iterative interaction, social learning, empowerment, public services, and institutional (ibid).

Our experiences in working with Indigenous and local communities echo Bremer and Meisch's (2017) suggestion that the coproduction of knowledge is a complex meeting place where different practices overlap, converge and diverge, and where the different understandings of reality come to the fore. This is even more pertinent when we include Sámi traditional knowledge in the process of coproduction.

In our inquiries we are concerned with how to best combine Sámi and scientific knowledges to understand both the challenges and solutions to CSIs and other multiple stressors. Here we are also inspired by the observations of Dannevig et al. (2019) and Kerkhoff and Pilbeam (2017). We bring different knowledges together to develop an understanding of the spreading of CSIs (problem, challenges, opportunities, solutions). By combining scientific and traditional knowledge we honor the importance and relevance of reindeer herders' knowledge. We thereby challenge the privileged role of science in decision-making processes (Kerkhoff and Pilbeam 2017) (Fig. 6.3).

By highlighting the role and value of different forms of knowledges in understanding the CSIs problem we open the possibility for including these insights into policy making. We listen carefully to reindeer herders and have iterative discussions to clarify and broaden our knowledge bases. This enables us to coproduce new knowledge about the multiple stressors that concern herders and how the CSIs may interact with other current stressors. The iterative process and exchange, including ground truthing the findings, are critical for successful coproduction (e.g. West and Hovelsrud 2010). Without utilizing knowledge coproduction and iterative exchange we would not be aware of the depth and complexity of the multiple and intertwined stressors and adaptive responses of, in this case reindeer herders.

6.3 Adapting to Multiple and Interacting Changes

Multiple and interacting types of change provide significant challenges for society, in general, and finding solutions to these alterations can be a major challenge (Rockström et al. 2009; Young et al. 2010). Such challenges originate from large scale climatic and environmental changes to socio-economic, institutional and

Fig. 6.3 Reindeer pasturing under migration in Nordland

political shifts that may occur across societal and geographic scales. It is well known and documented that reindeer herders adapt to such multiple and interlinked changes (cf. AMAP 2017). Reindeer herders have historically drawn on a broad range of adaptation strategies. However, the rate, speed and cascading effects of contemporary change are causing major difficulties for them and their animals (Risvoll 2015). Flexibility is an important adaptation feature for reindeer herders. This is a flexibility that is increasingly diminished by the effects of multiple stressors and types of interactions (Riseth and Johansen 2019). This is of great concern to the herders (Risvoll and Hovelsrud 2016). Currently, climate sensitive infections clearly emerge as an additional stressor to those already facing reindeer herding today.

Climate change adaptation pertains to adjustments in natural and human systems in response to actual or expected climate stimuli or their effects. The adaptation strategies are meant to moderate harm and make use of opportunities (Smit et al. 2001). The concept of adaptation is increasingly referred to as a process that takes place along multiple dimensions, and in the context of multiple stressors (e.g. Leichenko and O'Brien 2008; Hovelsrud and Smit 2010; AMAP 2017: 219–252). The processes of adaptation include barriers, limits, opportunities. The processes as seen as creating options that emerge across institutions (e.g. municipalities, states), sectors (e.g. tourism, agriculture, transport), and actors (e.g. businesses, policy makers, government officials, individuals) (AMAP 2017: 219–252). Adaptation is a context-dependent process, largely taking place locally. It is shaped by exposure-sensitivities to hazards or risks and cumulative change, the local capacity to adapt and the structure of the community (e.g. Hovelsrud and Smit 2010; Smit and Wandel 2006).

Exposure-sensitivity is an important concept in adaptation and is understood as the way and the degree to which a community is both exposed and becomes sensitive to stresses due to changing conditions and situational characteristics (Smit et al. 2010: 5). The adaptive capacity of communities is shaped by several factors and processes. These range from access to resources and knowledge, economic and livelihood flexibility, enabling institutions, governance, infrastructure and connectivity (Hovelsrud and Smit 2010; Keskitalo and Kulyasova 2009). Therefore, a one-size fits all national climate adaptation policy is insufficient (e.g. Westskog et al. 2017). This means that there is a real potential for conflict to emerge between the different interests or actors about the goals and outcome of adaptation.

In this chapter we are focusing on three interlinked changes affecting reindeer husbandry: (1) Climate change and its effects on pastures; (2) Growing pasture encroachments; and (3) The impact of climate change on the spread of CSIs to new geographical areas. In all these cases, we are considering the herders' responses to these changes through the conceptual lens of climate change adaptation, which is suitable for analyzing the effects of current and future multiple stressors, including CSIs.

6.3.1 Climate Change and its Effects on Reindeer Pastures

Projected climate change within the Nordic region, including Nordland County, Norway, the focus of our inquiry, indicates that there will be increasingly warmer and wetter weather in the region and a higher frequency of extreme weather events, including droughts, floods and cold and heat spells (Hanssen-Bauer et al. 2015). Snow is projected to be reduced significantly or disappear entirely along the Nordland coast. At the same time, the amount of snow may increase in the mountains (Hanssen-Bauer et al. 2015). Snow may combine with more precipitation falling as rain and increase the number of freeze-thawing events. This is likely to create more incidents of "locked pastures" (Vikhamar-Schuler et al. 2016). Locked pastures are characterized by ice crusts that form by freeze-thaw cycles. This creates hard layers of snow and ice that makes it difficult for reindeer to dig through.

Thus, the pastures may be inaccessible through long periods in the winter. Such changes will create more challenging grazing conditions for reindeer (Riseth and Tømmervik 2017; Risvoll and Hovelsrud 2016). This, in turn, may force the herders to direct their reindeer to lower altitudes in Sweden and/or to the coastal lowlands in Nordland County (Fig. 6.4).

Fig. 6.4 Spring migration in Nordland
All Photo credits Camilla Risvoll

Other environmental conditions will also be altered due to climate change. An increased number of shrub and forest vegetation may force the reindeer to move to higher altitudes (or latitudes) as the climate becomes less suitable in the southern regions. Woody vegetation such as shrub and forest has increased on the Norwegian coast by more than 30% between 1975 and 2010 (Tombre et al. 2005, 2010; Tømmervik et al. 2010a). The vegetation changes may also affect the quality and palatability of feed. Crowberries or dwarf birch, not favored by reindeer, displace other more palatable feeds such as grasses, herbs and fresh leaves of willow and birch (Tømmervik et al. 2010b; Bråthen et al. 2007). In most parts of Nordland County the reindeer population density is currently so low (below three heads pr. square km) that this facilitates willow and birch expansion (Tømmervik et al. 2010b; den Herder et al. 2004).

We know that climate change is not the only, or even the main driver of change for reindeer herders in Nordland County or elsewhere in the Arctic. Nevertheless, they report pronounced climate change impacts such as freezing-thawing events and variations in snow conditions. Such events are closely linked to topography and geography, and detailed knowledge of the local context is therefore critical. Human activities and infrastructure can create hindrances for the natural migration of reindeer. They can also interfere with traditional husbandry practices, compounding their negative effects.

6.3.2 The Growth in Pasture Encroachments and Fragmentation

The land available for reindeer grazing due to climate change has become more limited and fragmented. In addition, the spread of encroachments has increasingly become a major challenge for the herders (Tyler et al. 2007; Eira 2012; Risvoll and Hovelsrud 2016). In Nordland County, encroachments include infrastructural developments such as roads and railways; human activities such as urbanization; extractive industries; the creation of hydroelectric power and windmills along with other land uses such as recreational activities and the establishment of protected areas (Risvoll and Hovelsrud 2016).

Additionally, large carnivores are putting great pressure on reindeer herding in Nordland and reducing the herders' flexibility to utilize the landscape (Risvoll and Kaarhus in press). Predators are not a major topic in this chapter, but it should be noted that they play a significant role in shaping the grazing area available for herders.

Encroachments fragment the landscape and negatively affect the access to grazing land for the herders. In many cases force the herders to migrate their herds towards the coast in an east-west direction. In so doing they may encounter other obstacles such as infrastructure barriers or developments. Many of the obstacles are often related to the physical geography and topography of the land, which requires the herders to draw upon significant skills and knowledge about animal behavior in relation to the landscape.

Their herder's adaptation options are significantly reduced by the combination of fragmentation, predation and unfavorable weather events. Traditional adaptation strategies are significantly compromised by the interactions and effects of the multiple stressors. The herders are always on the alert for new ways to keep their animals safe.

6.3.3 The Impact of Climate Change on the Spread of CSIs to New Geographical Areas

Rising temperatures are causing species to spread into new geographic areas. They may compete with existing species for feed and space. Such migrations are not limited to vegetation and animals, but also include infectious diseases with the help of their arthropod vector or reservoir animals. Warmer and wetter conditions may enable vector-borne infections to move increasingly further north and may find new host species. In this way, these infections may establish in new northern regions. On the other hand, the occurrence of hot, dry and cold spells may limit their migration – or push them even further north.

Vegetation change may facilitate the spread of some CSIs to reindeer and northern populations of sheep through ticks. This is mainly the common tick (*Ixodes ricinus*), which has been detected in the vegetation near the Arctic Circle (Hvidsten et al. 2015). The ticks survive best in dense vegetations like shrubs and forests (MacLeod 1932; Steigedal et al. 2013). Steigedal et al. (2013) found that tick abundance was higher in areas without sheep. This suggests that high density of sheep may reduce the shrub encroachment and keep the vegetation and tick population down (Jauregui et al. 2009). The same may hold true for reindeer; if the animal density is high enough, they can keep the vegetation down, and thereby may reduce the tick prevalence.

The introduction of new infectious diseases, as well as vector- and reservoir species, also means new forms of species co-existing in new places. The introduction of new CSIs, especially zoonotic infections, may pose a new risk to both animal and human health. If a new infection is introduced to an area where the animal population is immunologically naïve i.e. has no protection by antibodies, the infection may cause serious outcome for both individuals and whole populations. Jore et al. (2011) and Nilssen (2010) conclude that *I. ricinus* has now reached coastal areas as far north in Norway as Harstad 69°N and has been found sporadically further north in Finnmark County. It is not yet certain whether these ticks represent resident populations or transient populations introduced by migratory birds or large mammals such as red deer *(Cervus elaphus*) (Hvidsten et al. 2015).

The future expansion of such tick-borne infections along the coast (Hoye et al. 2011) may result from increased breeding of Greylag goose *(Anser answer)* and the large increase in Arctic goose populations of the Svalbard-breeding Pink-footed

Goose *(Anser brachyrhynchus)* and the Barnacle Goose *(Branta leucopsis).* These geese have their spring staging sites along the coast of Norway (Tombre et al. 2010, Sandström et al. 2013). Other diseases that spread by migratory geese through parasites like *Toxoplasma gondii* (Sandström et al. 2013) have been observed and diagnosed along the Norwegian coast and as far north as in the Svalbard Archipelago (Hoye et al. 2011).

In our inquiry we focused our attention on the *I. ricinus* tick which are of an exceptional medical importance as vectors for zoonotic infections. According to recent prediction models, the range of *I. ricinus* may encompass all of Finland, Norway and Sweden as far as 70°N (Jaenson and Lindgren 2011; Jore et al. 2011). The most well-known tick-borne disease in humans in Europe is Lyme borreliosis, caused by the bacteria *Borrelia burgdorferi* sensu lato. Tick-borne encephalitis (TBE) is the most severe human tick-borne viral disease in Europe (Randolph and Sumilo 2007). Its potential northern expansion is one reason why it is critical to monitor the potential growth of tick distribution areas in the North.

Anaplasma phagocytophilum (granulocytic ehrlichiosis, pasture fever) and *Babesia divergens* (piroplasmosis, red water, summer disease) are tick-borne zoonotic agents carried by *I. ricinus* of increasing concern when ticks are moving North. Updated figures on their prevalence and geographical distribution are missing. *A. phagocytophilum* is causing granulocytic anaplasmosis (Stuen 2007). Pets, horses and humans may develop high fever, fatigue and loss of appetite, but the bacteria can also cause high mortality in lambs (mainly due to secondary infections as pneumonia), abortion in sheep and distinct reduction in milk production in dairy cows. Estimated figures show that approximately 300,000 lambs are exposed to *A. phagocytophilum* annually in Norway (Stuen 2016).

Bovine babesiosis, is characterized by high fever, hematuria and a high mortality if not treated (Zintl et al. 2003). Animals may become chronic infectious carriers for several years. In Sweden, antibodies to *Babesia* spp. have been associated with seropositivity to Lyme borreliosis in humans (Svensson et al. 2019). In cattle, *B. divergens* normally occurs in the southern and central Sweden, and is now also occasionally reported in Finland and Norway.

Further, *B. canis* spread by *Dermacentor Reticulatus,* causes severe disease in dogs, even if still not endemic in Sweden it might soon reach us along with its tick vector. Sensitive, reliable and quick diagnostic methods for the clinical diagnoses of these tick-borne pathogens are needed, to provide appropriate care of infected animals and accurate figures on their occurrence. We argue that these two diseases and their vector/hosts are good examples of CSIs.

In the context of climate change, as noted above, tick and its host animals are sensitive to climate variables such as increased temperatures, precipitation, and changing freeze-thaw cycles and snow cover. These are conditions that are being observed and documented in the Northern regions. *A. phagocytophilum* in sheep and *B. divergens* in cattle are well-known diseases in several regions of Norway and Sweden and are now causing significant problems in certain geographic areas (Stuen 2016; Karlsson and Andersson 2016).

The outcome of ticks and the associated diseases on semi-domesticated reindeer is not known. Reindeer have been observed with ticks in Nordland County and they probably contracted these ticks in Brønnøy and Velfjord (Torstein Appfjell pers. com. 2017), However, thus far, no tick-borne infections e.g. Anaplasmosis and Babesiosis have been diagnosed in reindeer in this area. However, reindeer has been shown to be susceptible to babesiosis (Wiegmann et al. 2015).

6.4 The Role of Traditional Knowledge and Local Context in Adapting to Multiple and Interacting Stressors

Herding and pastoralism, in general, imply the moving of animals in search of good pastures as a response to seasonal and spatial variations in conditions (Niamir-Fuller 2000; Johnsen et al. 2017). Utilizing a variety of pastures is increasingly becoming an important adaptation strategy for reindeer herders to respond to increased encroachments, predators and climate change (Risvoll 2015). The choices and responses carried out by herders are often based on knowledge that is locally situated and context dependent (Kløcker Larsen et al. 2017). Obtaining a better understanding of the complexity and dynamics of pastoralism requires a focus on the local context and on how pastoralists and other key actors observe and perceive change. On many levels, however, regulatory practices and regimes keep treating scientific and administrative expertise as superior to locally contextualized knowledges (Howitt et al. 2012).

Local knowledge of environmental conditions is an important asset for individuals or systems to adapt to and shape change. Adaptation strategies depend on contextual factors to a large degree (Kofinas et al. 2013). This suggests a need for local knowledge, experience and adaptive capacity. All societies have a knowledge base which forms a foundation for the activities of everyday life. To refer to knowledge as traditional implies that its foundation has historical depth, that it is passed on from generation to generation, and that individuals have access to such knowledge in their daily lives.

However, as times and local conditions change, the knowledge also develops, adjust and changes in order to be relevant for new situations. Traditional knowledge is therefore dynamic. It is often characterized as permeating all daily activities and pertains to and gives meaning in different communities to all life forms. Sámi traditional knowledge (*árbediehtu* in the Northern Sámi dialect, *árbbediehto* in Lulesámi and *aerpiemaahtoe* in South Sámi) and refers to an independent knowledge system deeply rooted in all Sámi culture and the Sámi view of life.

We need to remind ourselves that traditional knowledge (TK) is directly related to the community's nature and resource base, its traditional practices and its management system. It is also indirectly related to social institutions through rules, customs and moral codes. Traditional knowledge includes world views, belief systems, religion, and ethics. Collectively, they form a basis for interpreting one's surroundings. Sámi TK is also locally situated, often with people who maintain a traditional

Sámi way of life. Historically, reindeer herding has developed and changed in relation to external pressures, as well through politics and natural occurrences (Riseth et al. 2016). However, technological and societal-based change have proceeded at an increased pace, especially during the last half century. This challenges TK as the primary source of knowledge within reindeer herding.

Since the mid-eighteenth century major outbreaks of infectious diseases in northern Sweden have caused massive losses of reindeer. Several local Sámi herding communities have collapsed as a result. One outcome was that many herders quit herding and settled by northern Norwegian fjords combining fishing and farming (*fiskarbonden*). Another result was a change in reindeer herding based on a common recognition that the risk for infectious diseases required an upper limit to the intensity of herding. Where the landscape allowed, extensive summer herding developed in places like Finnmark. In more demanding landscapes, other types of summer strategies were developed in Nordland and Troms. These adaptation strategies included moving away from wet and dirty areas towards the mountains, glaciers and snow patches, when possible, to reduce disease risks (Pirak 1937; Ruong 1937).

Moving the herds up in the mountains remain important adaptive strategies for reducing insect infestations (Qvigstad 1941; Vorren 1998; Tømmervik et al. 2010b). This is also a strategy for reducing the potential threat of ticks and other pest insects (Nilssen et al. 2000) like the reindeer nose botfly *(Cephenemyia trompe)*. The data from our study show that the historically-based practices of not keeping the animals too close together, or in the same spot, are still important strategies when herders make adaptation decisions to counter challenging situations (Riseth and Tømmervik 2019). Traditional knowledge is at the core of the current adaptation strategies and will most likely continue to be so when herders are faced with new and previously unknown challenges. The increasing prevalence and risk of ticks in coastal areas is one such new phenomena. This is a risk the herders may have to address in the very near future.

6.5 A Holistic Approach to Understanding the Effects of Interacting Multiple Stressors on Reindeer Herding

Reindeer herding is situated within a context of multiple local, nationally and even globally driven stressors. The rate of change in northern Norway is increasing, both in terms of climate change and altered socio-economic conditions. Multiple stressors pose serious challenges to reindeer herding. For the purpose of our analysis, we have distinguished between stressors that are human induced and those which stem from the environment and climate change. These are not entirely new forces at work here. Environmental and societal conditions have always varied to some degree over time and territory. Reindeer herding households have always adapted to a broad range of seasonal weather variability, socio-economic conditions and changing national policies and shown a high degree of resilience to multiple challenges over their history.

However, the rate and magnitude of change are increasing the pressure on herders in an unprecedented way. Increasingly, the flexibility in their response to such changes is narrowing. Additionally, the different stressors that they confront can now be seen to interact in new and different ways. This requires them to adopt new adaptation strategies that, in turn, may create unexpected feedback loops. The increased practice of supplementary feeding of reindeer illustrates this well.

Supplementary feeding is an adaptive response to the several pressures highlighted above and it helps to solve certain critical problems in current reindeer husbandry. But it also creates new challenges, such as increased potential for disease. The diseases related to animals being close together in fenced areas are not necessarily CSIs. But the increased density of reindeer may cause a stress reaction, which weakens the immune response of the animals. In addition, the transmission of infectious diseases in general thrive in dense populations. Taken together these effects increase the potential sensitivity in reindeer to CSIs. Supplementary feeding as a practice therefore illustrates the value of adopting a holistic approach to understanding change and adaptation in reindeer herding (Horstkotte et al. forthcoming).

The coproduction of knowledge provides us with an opportunity to gain a better understanding of how the herders view the different challenges ahead them and how their responses will affect reindeer herding in the future. Close cooperation between herders and researchers is required. Their common inquiries are essential. Only through a holistic approach are we able to understand the effect that current challenges and changes will have on herding in the Nordic region.

To understand how a new potential challenge, such as CSIs, is affecting reindeer herding today we have highlighted three areas of change which interact and have significant cumulative effects on herding. Climate change effects on pastures is not, in and of itself, an unsurmountable challenge. Neither is pasture encroachments and fragmentation. It is when their combined effects are analyzed that we better can understand how they can present new forces that will create potential challenges (or even opportunities) in the North. It is for this reason that we bring attention to how a third and new type of change, the introduction of CSIs, will have profound impacts on the region.

The CSIs will interact with other changing environmental conditions caused by climate change such as regrowth, northward movement of host, reservoir and vector species. As we have seen, the adaptive capacity of reindeer herders is much affected by milder and more unpredictable winters that can result in more frequent icing and thawing events. They are also affected by increased fragmentation and encroachments of pastures. Combined, these changes reduce access to pastures and the flexibility of the herders.

While land-use changes and climate change are seriously affecting the herders, these are to a large extent overlooked by the government (Riseth et al. 2018). In addition, the well-developed adaptation strategies to respond such changes are under pressure because of encroachments, pasture fragmentation, predators, and the threat of animal disease. The threat of tick-borne diseases in reindeer is a new phenomenon for herders. Such threats are increasing in rate and magnitude as we write. CSIs comes on top of other concerns in reindeer herding, and the exposure to such infections emerge as a result of adaptation to other conditions. For example, current adaptation strategies to locked pastures is to move the herd to the coast. However, this increases the likelihood of encountering tick-borne diseases, because the ticks are more prevalent in coastal areas. This is an example of double vulnerability in reindeer herding and illustrates that CSIs exacerbates the current challenges from multiple stressors. The increasing encroachments from human activities often disrupts herders' options to move the herd. The adaptive response is to feed the animals, which in turn increases the risk of disease. Combined with CSIs such as tick-borne diseases, Sámi reindeer herders are therefore under pressure from several fronts.

The methodological and analytical conundrum of such cascading, interacting and cumulative effects of change in animal husbandry is immense. It requires an unprecedented openness between the different scientific disciplines and practitioners. Our approach has been two-fold: carrying out a co-production of knowledge process between researchers and animal husbandry practitioners, and drawing on a range of scientific disciplines in order to understand the nature and magnitude of exposure-sensitivities and change.

The most critical message from the study of how CSIs affect reindeer herding is that the multiple stressors and changes must be considered from a holistic perspective. Currently, CSIs are not necessarily a threat on their own. However, when they are seen together with other environmental and societal challenges and changes facing the North, it is clear that herding may become severely affected by their arrival. The adaptation options are gradually diminishing and beyond the herders current and traditional responses. Only by focusing on the challenges and consequences identified by both herders and scientists, are we prepared and able to understand how the different drivers of change create new risks and stresses for herding.

The CLINF project has provided a unique interdisciplinary basis for understanding the different pieces of the puzzles inherent in emerging CSIs. However, CSIs have not yet manifested as a clear problem for the herders in our case study region. This makes it difficult to study their effects. We are up against a similar problem as we were in early days of studying how climate change impacts society (e.g. Hovelsrud and Smit 2010). In CLINF we have defined a scientific problem, namely CSIs, which has not yet become a societal concern. We also argue that CSIs will require adaptation strategies and an acknowledgement of the risks by herders and national management down the line. Exposure to CSIs may even increase as a result of current adaptation strategies to other stressors. This illustrates the tremendous pressure reindeer herding is currently facing. We have yet again learned that an interdisciplinary team of scientists is required for addressing "wicked problems" (Rittel and Webber 1973). Additionally, the social science portion of the project has created space for involving stakeholders in the identification of the challenges and is therefore transdisciplinary.

Transdisciplinarity and a coproduction of knowledge approach generates other types of data, including qualitative, that is not common in the physical sciences (e.g. climatology, biology, hydrology), and vice versa. To bring the different data sets together in broad analyses relevant to reindeer herders or other practitioners requires a high level of respect for each-other's work and scientific fields. This is very hard to achieve in practice, and not necessarily because of any ill-will between participants. In conducting our inquiries, we adhere to the requirements of our own scientific disciplines with respect to approach, research questions and methodology. These, in turn, shape our findings. When we readily accept each other's spheres of inquiry and publish freely together we have reached an important milestone in generating knowledge that is relevant and useful for society. In CLINF we are on the road towards this goal. We have learned valuable lessons for future collaborative studies.

Without a holistic understanding of the local context, originating from the coproduction of knowledge concerning how changes interact and cumulate, we will not be prepared to analyze how CSIs will affect reindeer herding. The local context is always situated in a broader national and international policy scape. The newfound understanding of CSIs therefore comes with significant management, policy and research implications for future studies.

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Part III

Chapter 7
The ARCPATH Project: Assessing Risky Environments and Rapid Change: Research on Climate, Adaptation and Coastal Communities in the North Atlantic Arctic

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Abstract The NordForsk Centre of Excellence-funded project *Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies* has as its acronym "ARCPATH" which reflects its focus on the Arctic region and the NordForsk focus on "pathways to sustainability". ARCPATH is a ground-breaking project designed specifically to synthesize results derived from a variety of traditionally very different and separate academic disciplines. In this spirit, the project seeks to address the complex and interlinked issues of climate and socio-economic change occurring in the Arctic by focusing on near-term changes, with the overarching goal of fostering responsible and sustainable development. This requires the reconciliation of environmental, social, and economic demands. These aspects are central to the project's three main goals: *(1) To predict regional changes in Arctic climate over the coming decades using innovative methods to capture both anthropogenic and natural factors in global and high-resolution regional models; (2) To increase understanding and reduce uncertainties regarding how changes in climate interact with multiple societal factors, including the development of local and regional adaptation mea-*

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sures; (3) To combine improved regional climate predictions with enhanced understanding of environmental, societal, and economic interactions in order to supply new knowledge on potential "pathways to action".

Keywords Adaptation · ARCPATH · Climate change · Coastal communities · Sustainability

7.1 Introduction

The NordForsk Centre of Excellence-funded project *Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies* has as its acronym "ARCPATH" which reflects its focus on the Arctic region and the NordForsk focus on "pathways to sustainability". The project's home and leadership are shared by the Nansen Environmental and Remote Sensing Centre (NERSC) in Bergen, Norway (Dr Yongqi Gao as lead) and the Stefansson Arctic Institute in Akureyri, Iceland (Dr Astrid Ogilvie as co-lead). The project websites are: http://www.ncoe-arcpath.org/ and http://www.svs.is/en/projects/arcpath. ARCPATH is a ground-breaking project designed specifically to synthesize results derived from a variety of traditionally very different and separate academic disciplines. In this spirit, the project seeks to address the complex and interlinked issues of climate and socio-economic change occurring in the Arctic by focusing on near-term changes, with the overarching goal of fostering responsible and sustainable development. This requires the reconciliation of environmental, social, and economic demands. These aspects are central to the project's three main goals: *(1) To predict regional changes in Arctic climate over the coming decades using innovative methods to capture both anthropogenic and natural factors in global and high-resolution regional models; (2) To increase understanding and reduce uncertainties regarding how changes in climate interact with multiple societal factors, including the development of local and regional adaptation measures; (3) To combine improved regional climate predictions with enhanced understanding of environmental, societal, and economic interactions in order to supply new knowledge on potential "pathways to action"*.

ARCPATH methods involve extensive cross-disciplinary collaboration including contributions from: climatology (global modelling; dynamic downscaling; historical climatology); environmental science; economics; oceanography and cryosphere research; marine and fisheries biology; fisheries management; anthropology; governance systems; human eco-dynamics; and traditional ecological and local knowledge. Drawing on these separate but interlinking disciplines is enabling ARCPATH to form a truly synergistic Centre of Excellence. The project is collecting, assembling, and analysing a wide variety of different data sets and information with a focus on local communities in Iceland, Greenland and northern Norway. ARCPATH methods include the use of: (1) Earth System Models – the Norwegian Climate Prediction Model (NorCPM) and the European ESM (EC-Earth) Model with assimilation of data from oceans and sea ice in order to perform global climate predictions; (2) Regional Arctic Climate Models to perform Arctic climate predictions; (3) Quantitative economic modelling, supported by qualitative interviews. The quantitative modelling follows the Economics of Ecosystems and Biodiversity (http://www.teebweb.org/) ecosystem services economic modelling framework. ARCPATH uses proven ethnographic research methods to solicit community insights concerning local changes, and to document how people are adapting/adjusting to these changes and impacts. The main social science research methods involve: participant observation, semi-structured and specialist interviews, official documents and surveys (see e.g., Fowler and Mangione 1990; Cochrane et al. 2008; Malinauskaite et al. 2019a). See also the chapter by Chambers and colleagues in this volume on community engagement. Evaluation of historical data follows established methods of analysis (Ogilvie 2010).

7.2 ARCPATH's Work Packages

The ARCPATH project is structured in such a way that there are seven discrete but interlinked work packages. The main goal of Work Package 1, *Arctic Linkages: Climate, Environmental Change, and Human Eco-Dynamics,* is to form an historical context for the project as a whole in that it is exploring and establishing linkages among changes in climate, social-ecological systems, and marine systems. The main objective of Work Package 2, *Improved Global Climate Prediction by Initialization of Arctic Sea Ice and Sea-Surface Temperatures,* is to improve our capability for decadal climate predictions by starting the predictions from realistic ocean and sea-ice conditions. The climate modelling and prediction aspects are described in more detail in the chapter in this volume by Shuting Yang and other ARCPATH colleagues. The main goal of Work Package 3, *Arctic Climate Predictions and Regional Downscaling,* is to improve climate predictions for the Arctic/Nordic Seas to the year 2030 by using high-resolution global-coupled simulations and regional downscalings. The main focus of Work Package 4, *Climate, Social-Ecological Systems, Cetaceans and Tourism* is to analyse to what extent climate change, tourism, and industrial development puts cetaceans (and human societies dependent on their use) under increasing and unsustainable pressure. Thus there is an integrative focus on marine changes in the Arctic, with particular regard to linkages among environmental changes and changes in cetacean populations, and the growth of whale-watching tourism. The emphasis in Work Package 5 is on *Marine Governance, Security and Rapid Social and Environmental Change* has considerable overlap with Work Package 4. Recent work has concentrated on field research on fisheries governance issues, including investigating social and economic impacts of Individual Transferable Quota (ITQ) systems in coastal communities. ARCPATH places much emphasis on interdisciplinary synthesis and Work Package 6, *Synthesis*, focuses entirely on efforts at synthesis among the individual work packages of the project. As this is the topic of Chap. 18 of this volume, its undertakings will not discussed here except to note that this work package is designed to: (1) Harvest the principal scientific findings of ARCPATH and to generate new cross-cutting insights and concepts; (2) Explore the policy and action relevance of these findings; (3) Mobilize the generated knowledge in order share it with the academic community, policy-makers, practitioners, NGOs, the media and the general public; and (4) Identify gaps in knowledge and directions for future research. Furthermore, although researchers are now recognizing the importance of synthesis of research findings in order to facilitate knowledge mobilization and project legacy, many of these projects attempt to conduct synthesis at the very end of the research. ARCPATH is unique in that it is developing methods of building synthesis into the research process at all phases of research from design to application and legacy. Finally, Work Package 7 encompasses *Project Management and Dissemination*. The project is managed by the project leaders, Yongqi Gao and Astrid Ogilvie, with assistance from Project Manager, Kjetil Lygre. In addition to this, ARCPATH has an executive committee drawn from the work package leaders and an advisory board drawn from colleagues who are leaders in their fields and who have extensive experience in the fields of ARCPATH research. The following section describes the context for ARCPATH research efforts.

7.3 Arctic and Subarctic Change

Evidence of striking changes in global and Arctic climate over recent decades has increased dramatically and a large body of literature has ensued. The *Arctic Human Development Report* (AHDR, Einarsson et al. 2004) and the *Arctic Climate Impacts Assessment* (ACIA 2005) are examples of major studies that have focused on the rapid warming of the Arctic and its potential impacts on both Arctic and global communities. Their findings, even more compelling now than a decade ago, continue to be corroborated by other inquiries (Forbes 2011; IPCC 2014; IPCC SR 15 2018; AHDR 2014; Stroeve et al. 2014; Kahn 2016; Overland et al. 2018a, b; Arctic Report Card 2019; Box et al. 2019; Bravo 2019).

Rapid changes in the Arctic and globally may also include regime shifts that interact with one another to cause cascading effects (Rocha et al. 2018). The IPCC Fifth Assessment report (2014) concluded: “Effective decision-making to limit climate change and its effects can be informed by a wide range of analytical approaches for evaluating expected risks and benefits, recognizing the importance of governance, ethical dimensions, equity, value judgments, economic assessments and diverse perceptions and responses to risk and uncertainty” (*Summary for Policymakers*, 3.1.)

Focusing on specific locations for in-depth studies, ARCPATH considers these broad environmental and societal concerns in the context of developments also in the wider Arctic and Subarctic. Today, much research is being conducted in Alaska and on the north coast of British Columbia regarding the impacts of rapid environmental and socio-economic changes, marine mammal health and human-whale interactions and conflicts (Moore 2014; Neilson et al. 2012; Fraker 2013). In Alaska, whales and whaling communities are impacted significantly by climate change and biodiversity loss (Kishigami 2010). In particular, whaling communities are seeking new livelihood strategies and opportunities for economic development while trying to maintain their cultural connection to whales and whaling (Druckenmiller et al. 2012). ARCPATH draws on this research and identifies implications for the wider Arctic and Subarctic world.

7.4 Global and Local Climate Change in the Arctic

Figure 7.1, below, shows the annual-mean temperature variations over the North Atlantic Arctic compared with global-mean variations. Although far from synchronous there are noticeable similarities between the two. Particularly striking is the early-twentieth-century global warming from 1920–1940. This warming has been attributed to a combination of anthropogenic (aerosols and greenhouse gas) factors as well as natural fluctuations within the climate system associated with the Pacific and Atlantic Oceans (Tokinaga et al. 2017). In particular the warming of the tropical Pacific and cooling of the northwestern Pacific during this period forced atmospheric circulation changes that warmed the Arctic (Svendsen et al. 2018).

The natural forcing related to Atlantic Multidecadal variability, also commonly known as the Atlantic Multidecadal Oscillation (AMO), is reflected strongly in the North Atlantic temperature series shown in the Figure (see also Delworth and Greatbach 2000; Zhang et al. 2007; Semenov and Latif 2012; Wigley and Santer 2013; Delworth et al. 2016). The subsequent cooling in the Arctic to the mid 1970s,

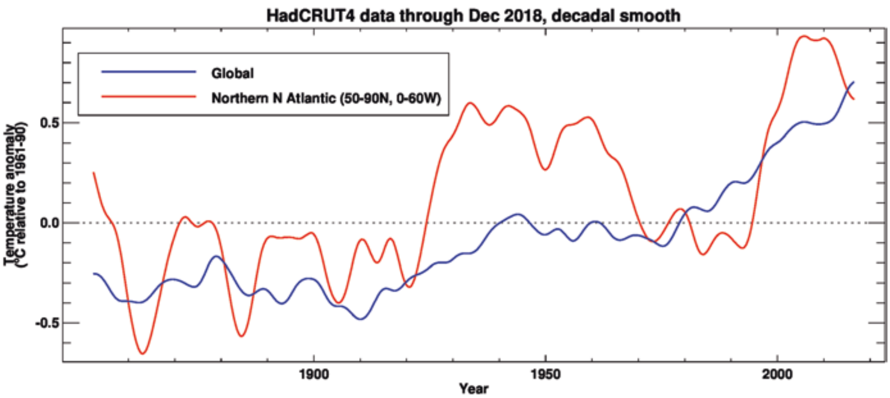

Fig. 7.1 Annual-mean temperature variations over the Atlantic Arctic compared with global-mean variations from 1850–2018. The data have been filtered with a low-pass filter to highlight changes on decadal and longer time-scales. The data are from the gridded HadCRUT3v land-plus-marine dataset (Brohan et al. 2006). (Updated February 2019 courtesy of Professor Tim Osborn, Director, Climatic Research Unit, Norwich, UK)

manifested as a levelling-off of the global trend, is largely the result of aerosol cooling associated with increased emissions of SO_2, a trend that ceased in the 1980s. Although the North Atlantic region is clearly more variable than the global record in terms of temperature, both show another strong warming trend over 1995–2005. While internally generated variability and decadal fluctuations (such as those related to ocean–atmosphere interactions) are important, longer multi-decadal time-scale changes are primarily attributable to anthropogenic forcing. There are indications of a downturn in the northern North Atlantic temperatures since about 2005. This may modulate the secular anthropogenic warming trend in the Atlantic sector of the Arctic and Subarctic in coming decades.

The climatic regimes of Iceland, Greenland and northern Norway are quite different from one another, but the climate systems that affect them are closely linked by virtue of geographic proximity. As a result of the warming effect of the Irminger Current (see Fig. 7.2) Iceland enjoys a relatively mild climate. Greenland has a true arctic climate with its surrounding waters dominated by the cold East Greenland Current. In the past, the region has experienced relatively severe ice conditions, with ports commonly closed for long periods due to winter ice and icebergs (Ogilvie 2010; Miles et al. 2014). In the early part of the twenty-first century sea ice has only

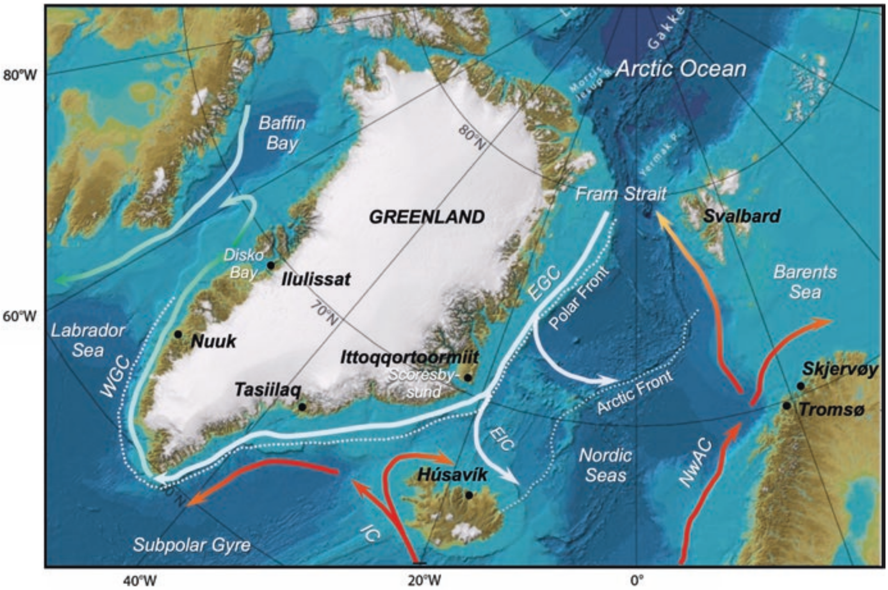

Fig. 7.2 Geographical settings and locations of ARCPATH primary focus areas. Major temperate (warm colours) and cold (cold colours) ocean currents are shown: East Greenland Current (EGC); West Greenland Current (WGC); East Icelandic Current (EIC); Irminger Current (IC); and Norwegian Atlantic Current (NwAC). The Polar front indicates the modern mean limit of polar waters and sea ice of Arctic Ocean origin. Bathymetry from the International Bathymetry Chart of the Arctic Ocean (IBCAO). (Figure courtesy of Dr Martin Miles, NORCE Norwegian Research Centre and University of Colorado-Boulder)

been a rare visitor to the coasts of Iceland. In recent years, the climate of Greenland has been marked by record warm temperatures, reduced sea ice, significant ice loss by melting, and glacier-area loss (Box et al. 2019; Andersen et al. 2019). Iceland is greening, having experienced very warm years recently, and it is possible that the country's glaciers that have always been such a dominant feature of the landscape will have disappeared within the next 200 years (Trausti Jónsson, pers. comm.). Both Iceland and Greenland are experiencing longer growing seasons for crops and vegetation in general, coupled with increased uncertainty concerning the movements and locations of fish stocks. For northern Norway, the pronounced retreat of sea ice (e.g., Onarheim et al. 2014) and increasing influence of Atlantic Water has characterized climate shifts in the region in the Barents Sea (Lind et al. 2018) and around Svalbard (Polyakov et al. 2017) to the extent that the term "Atlantification" of the Arctic was recently coined. These oceanic changes are likely to have had a substantial and direct contribution to the recent climate warming across the region (Isaksen et al. 2016; Arctic Report Card 2019).

7.5 ARCPATH Study Locations

The countries of Iceland, Greenland and Norway are linked both geographically and historically. The settlement of Iceland, primarily from Norway and the northern British Isles, began in the late-ninth century. Approximately 100 years later, small colonies of Norse people from Iceland established two settlements in southern Greenland. They also travelled annually to the Disko Bay area to hunt for prized walrus ivory. By the time Norwegian and Danish missionaries arrived in western Greenland in the early eighteenth century, the Greenland Norse had long disappeared, leaving a mystery that fascinates people to this day (Seaver 1996; Barlow et al. 1997; Ogilvie et al. 2009; Ogilvie 2016; Frei et al. 2015; Barrett et al. 2020).

Greenlanders have traditionally subsisted on marine mammals (Born et al. 2017; Nuttall 2019). This form of subsistence has also been important in Iceland, but on a far smaller scale, although the practice is clearly as old as the first settlement (Kristjánsson 1980; Perdikaris and McGovern 2008; Frei et al. 2015). Although foreign fleets have pursued large-scale whaling in Greenlandic waters in past centuries, native Greenlanders have hunted whales only for domestic use. This practice continues today, including in ARCPATH study areas.

Whaling has been significant in Norway where minke whales are still hunted under an "objection" to the International Whaling Commissions's global ban on commercial whaling, which came into effect in 1986. Commercial whaling has been conducted intermittently in Iceland for more than a century. Initially, large Norwegian whaling stations were operated from the mid-1880s until World War I, first on the Vestfirðir peninsula (northwest Iceland) and later on the east coast. By about 1912, stocks had become depleted to the extent that whaling was no longer profitable, and, in 1916, the Icelandic Parliament passed an act prohibiting all whaling. In the following decades, whale stocks gradually recovered. Whaling was resumed on a relatively small scale in 1948 and has continued with intervals. In 2009, Icelandic authorities allowed controversial commercial whaling for a period of 5 years, with an annual quota of up to 150 fin whales and 100 minke whales. In early 2019 the Icelandic authorities decided to step up commercial whaling by allotting increased quotas for 5 years, 2019–2023, allowing the taking of 209 fin whales and 217 minke whales. However, adapting to changed conditions, Icelanders now also focus on promoting whale-watching as part of a rapidly growing tourist industry (Einarsson 2009; Huijbens and Einarsson 2018).

For the specific locations of all project components see Fig. 7.2. ARCPATH's Iceland component is primarily focused on the municipality of Norðurthing, comprising the towns of Húsavík (population 2307) and the settlements of Kópasker (population 122) and Raufarhöfn (population 186). Particular emphasis is given to Húsavík as this is where whale watching has become a major industry over the past 25 years (Einarsson 2009; Huijbens and Einarsson 2018). The surrounding area of Skjálfandi Bay is visited by several whale species including minke whales and blue whales (Rasmussen 2014). The adjacent island of Grímsey (population 86) was once an important fishing centre, but is now suffering from depopulation. In Húsavík there has been significant emphasis on alternative economic enterprises with considerable success. With a major focus on whale watching it has come to be called the "Whale watching capital of Europe". This can be interpreted as a sign of constructive adaptability and cultural flexibility on the part of its residents (Einarsson 2009, 2011a, b; Huijbens and Einarsson 2018).

A rival for this title is the region around the island of Andøya in northern Norway situated 138 km south of Tromsø by ferry. There sperm whales (*Physeter macrocephalus)* have been observed for several years. The main village on the island is Andenes (population 2694). ARCPATH has focused on this as well as the island of Skjervøya that is situated 87 km north of Tromsø by ferry. The island's main town is Skjervøy (population 2881). Both of these locations have been chosen for special study because of their similarity to Húsavík in terms of being small towns focusing on whale watching and also experiencing a growth in marine traffic with possible impacts on the marine mammals. The whales most frequently seen around Skjervøya are humpback and killer whales. This is because the herring shoals that they feed on are currently to be found there. When the herring leave and move elsewhere, as they frequently do, the whales will follow them and also leave. If this should occur in the future, it would mean an end to the current large ongoing whale-watching operations. As well as being a tourist destination, Skjervøya is dependent on the fishing industry. These study areas are of particular interest due to changes in fishing practices and a boom in marine and other forms of tourism, which may become the new economic backbone for the coastal communities involved as long as the whales and their food sources remain. These ARCPATH locations share a common denominator regarding general human ecology. They are small resource-dependent communities, in particular, with regard to access to fish stocks. They are potentially vulnerable in terms of the health of the environment they exploit, so issues of pollution and overexploitation are key.

The Greenland component has focused primarily on coastal communities in eastern Greenland. They include Ittoqqortoormiit (formerly named Scoresby) with a population of 470 as well as Tasillaq (formerly known as *Ammassalik* or *Angmagssalik)* with a current population of 2062. Ittoqqortoormiit is a small community, established in 1924 when the Danish government decided to relocate some 70 Inuit from the more southerly community of Ammassalik along with 10 Inuit from the west coast of Greenland to this location. This was part of a plan to emphasize Danish sovereignty in East Greenland.

As of 2019 ARCPATH has also focused its research efforts on the Disko Bay (in Greenlandic *Qeqertarsuup tunua*) area of western Greenland, in particular, on the towns of Ilulissat (population 4905), the island of Qeqertarsuaq (population 845) and the community of Aasiaat (population 3112). These communities all share the common twentieth-century Greenlandic experience of a rapid transformation from scattered settlements based on hunting to an urbanizing post-industrial economy (Nuttall 2019). Shared characteristics include both economic and cultural reliance on marine resources for subsistence, along with the receipt of transfer payments from the Greenlandic government. Seal and other marine-mammal hunting remain an important part of mixed-economy subsistence activities, along with a growing tourism industry which includes whale watching. In Ilulissat, there are also prospects for increased infrastructure and economic development in connection with oil and gas exploration off the west coast. In all these communities, ARCPATH is studying the effects of marine-resource governance and marine-mammal hunting practices on community viability and resilience.

ARCPATH fieldwork has been undertaken in each of the study areas in all years of the project. Although project study sites have much in common, they are also different in several ways in terms of language, history, culture. They also can vary from one another in social-ecological as well as socio-economic factors. For this reason, research approaches are slightly different for the different regions. Thus, for example, there is more emphasis on Indigenous knowledge and traditional hunting practices in the Greenland sites. Also, whale watching tourism is less developed there than for Iceland and Norway.

7.6 Areas for Investigation

As noted above, the ARCPATH project is divided into seven specific focus areas that take the form of work packages. The following paragraphs discuss each of these with special attention given to current highlights and results. The main goal of Work Package 1, *Arctic Linkages: Climate, Environmental Change, and Human Eco-Dynamics,* has been to form an historical context for the project as a whole, in that it is exploring and establishing linkages between changes in climate, social-ecological systems, and marine systems. Work has continued on analyzing past climate variations, together with adaptations to climate impacts on economic activities such as fishing and multiple use of cetaceans. At the start of the project a main focus was on analysis of the past sea-ice record for Iceland, in particular in terms of correlations with the North Atlantic Oscillation (NAO) index and Atlantic and Pacific Ocean multi-decadal variability. As this is an example of project synthesis, the results of this work are also discussed in Chap. 19 of this volume.

The linkages between the historical and systematic instrumental data are a continuing focus of the project in Work Package 1. Emphasis has been given to temperature variations for Iceland (which correlate well with the sea-ice index) plus analyses of storminess, ecosystem services of cetaceans and fisheries in the past, and perceived adaptations to climate impacts. In particular, there has been a focus on these specific tasks: To examine correlations between fisheries and temperature changes in the North Atlantic back to ca AD 1700; and to evaluate the incidence of extreme weather events, such as increased storminess, and human adaptation responses in our study areas in the past (Ogilvie 2020). It is clear that a correlation exists between ocean temperatures and marine stocks. Although other factors were involved, it is highly likely therefore that climate was of importance for the fisheries in several respects. If the weather was particularly stormy, for example, then many lives were lost at sea, and more fishermen were drowned during cold and stormy periods such as between 1698 and 1704. Until comparatively recent times, when many different fish species began to be caught in Iceland waters due to warmer ocean temperatures, the main species caught was cod. It is a fish that is highly dependent on water temperatures for survival with 4–7 °C being optimal. During the period from 1680 to 1760, for example, when many severe years occurred, fisheries were generally poor. It is possible therefore, that the waters around Iceland became less favourable for cod reproduction and survival. There is an interesting parallel here with research from Work Package 4 which shows that blue whales and white-beaked dolphins appear to be changing their migration routes due to changing water temperatures.

The main objective of Work Package 2, *Improved Global Climate Prediction by Initialization of Arctic Sea Ice and Sea-Surface Temperatures,* has been to improve the capability for decadal climate predictions by starting the predictions from realistic ocean and sea-ice conditions. Prediction uncertainties are being partly reduced by using two different climate models EC-Earth3 and NorCPM. The ocean and sea ice have been initialized with a so-called anomaly initialization. This means that observed deviations from the mean climate are added to the mean climate of the model. This method is used because the climate that is simulated by a model differs somewhat from the observed climate, and starting a prediction from the pure raw observations leads to unwanted drifts in the model, which degrades the prediction. To clarify, initialisation refers to the method used to adjust the model to be close to the observed conditions in terms of ocean temperature and salinity, and sea-ice cover. In this way, the model is able to make a prediction of how the ocean, sea ice, and climatic conditions will evolve over the next months and years.

Regarding the sea-ice component of EC-Earth, ARCPATH uses a 5-category ice thickness module, which means that five different ice thicknesses can be represented in each grid box of the model instead of having the same ice thickness within each grid box as formerly in the project. A more advanced (non-linear) method to link the observed to the modelled sea-ice conditions has been developed. To test the impact of the improved initialization, first test simulations with EC-Earth have been carried out. It has been found that the improved sea-ice initialization is important for the near-surface atmosphere in the first 2 years of prediction (Tian et al. 2020). The skill of decadal climate predictions based on already existing climate predictions from the CMIP5 data archive (six different models) and from the EC-Earth (v2.3) decadal experiments have been analysed (Koenigk et al. 2018). In general, only weak prediction skill is found in surface air temperature for predictions going further than 3 years into the future. The skill or accuracy of the system is estimated by performing prediction experiments for past conditions, and comparing the evolution of the predictions with what was observed. A common way to measure skill is correlation, but many others exist.

The second prediction system used in ARCPATH is the Norwegian Climate Prediction Model (NorCPM) similar to EC-Earth (see e.g., Counillon et al. 2016). This uses a multi-category sea-ice model and an advanced method to merge (assimilate) observational data into the model (Ensemble Kalman filter, EnKF). The assimilation of sea-ice concentration into the NorCPM has been implemented and tested (Kimmritz et al. 2018). It has been found that updating the multi-category sea-ice state is of great importance in reducing errors of sea-ice concentration and thickness, near-surface temperature and salinity. Further, the NorCPM is the first system demonstrating the benefit of strongly-coupled data assimilation of ocean and sea ice in a fully-coupled system. This is a method that enables data in one model component (the ocean) to correct another component of the model (sea ice). It has been found that, while assimilating only sea-surface temperatures (SSTs) already provides good skill for sea-ice extent in winter, assimilation of sea-ice concentration prolongs the skill into the summer by reducing the error of sea-ice thickness in the first year (as shown in Kimmritz et al. 2018). The added value of assimilating new observational estimates of sea-ice thickness from satellites into NorCPM has also been tested (Xie et al. 2018). It remains to be seen to what extent this improvement will lead to improved prediction skill. In tandem with Work Package 3, Work Package 2 offers a first case for performing high-resolution predictions with regional models.

The main goal of Work Package 3, *Arctic Climate Predictions and Regional Downscaling,* has been to improve climate predictions for the Arctic/Nordic Seas to the year 2030 by using high-resolution global-coupled simulations and regional downscalings. High resolution in climate models means that climate processes can be better resolved and variables can be provided at smaller spatial scales. This is especially important in regions where temperature or precipitation varies over small distances as in mountainous regions or along coastlines. The geographical locations that ARCPATH focuses on, the coastal communities of Iceland, Greenland and Norway, are exactly such regions, requiring a high spatial resolution. These regions are being affected by the complex interactions of socio-economic, biological and climatic changes. This work package aims to provide more reliable information concerning changes in the climatic variables that are relevant for livelihoods in coastal communities. In order to deliver relevant climate information on the local scale to Work Packages 4 and 5 (see below) two strategies are being followed. The first is to perform high resolution global climate predictions (25 km resolution) and the second is to perform regional model simulations (around 10 km resolution) where predictions with ARCPATH global models standard resolution (around 100 km resolution) from Work Package 2 are used as forcing data at the boundaries of the regional model.

The period 2002–2011 was chosen for a case study of regional downscaling of the global predictions for the Nordic regions. This period includes the large observed ocean temperature changes in 2003–2004 which are likely to be linked to the movement of whales from southwestern parts to northern parts of Iceland in this year. A first ensemble member of the 2002–2011 period has been performed with NorCPM and provided for downscaling in the regional climate model called HARMONIE, known as HCLIM. The downscaling with HCLIM of this first prediction period has begun.

The main focus of Work Package 4, *Climate, Social-Ecological Systems, Cetaceans and Tourism*, has been to analyse to what extent climate change, tourism, and industrial development puts cetaceans (and human societies dependent on their use) under increasing and unsustainable pressure. Thus there is an integrative focus on marine changes in the Arctic, with particular regard to linkages between environmental changes and changes in cetacean populations, and the growth of whale-watching tourism. Over the life of the project, social, economic and marine biological research and fieldwork has taken place in Iceland, Greenland, the seas around Svalbard and northern Norway. This includes anthropological fieldwork in Húsavík documenting present and historical multiple marine resource use, for example fishing and whale-watching activities, as well as collaboration with local authorities in terms of developing a Marine Protected Area to better manage the multiple and growing use of the seaspace of Skjálfandi Bay (Cook et al. 2020). Ethnographic fieldwork has focused on the seasonal use of marine mammals by vocational and recreational hunters in Ittoqqortoormiit in East Greenland. This involved mapping the annual hunting cycle, including the hunting of narwhal and polar bear. For northern Norway, the focus has been on the shifting relationships between migrating whales, fisheries, and tourism in Andøya and Skervøya and how research can contribute to new knowledge dialogues to develop responsible whale-watching practices (Malinauskaite et al. 2019b).

For Iceland, a key focus is on the blue whales that have have increasingly been moving north and currently come into Skjálfandi Bay every summer in June. ARCPATH has now produced a photo-identification catalogue of 148 different individuals (Madsen 2018; Madsen et al. 2019) and for the first time there are matches of the same blue whales sighted off Svalbard and from Húsavík. This possible shift might be due to warming Arctic waters and climate change. In line with ARCPATH findings it has been suggested earlier that blue whales are moving even further north for this reason (Iversen et al. 2009).

A key task in Work Package 4 has focused on social-ecological systems, ecosystem services and cetaceans in the Arctic, where the research objective is to analyse trade-offs between different ecosystem services derived from multiple uses of cetaceans. To address this task, five research questions have been posed: (1) What is available in terms of previous research on the topic?; (2) How do people benefit from and value the ecosystem services provided by marine mammals in the Arctic?; (3) What are the different social groups that co-produce and use the ES associated with marine mammals? How are the benefits distributed between social groups within communities?; (4) How have marine mammals in the Arctic been managed to date and what are the trajectories for their future management?; What are the actors and institutions involved?; (5) How can the valuation of whale ecosystem services be used to inform decision-making processes and the governance of marine protected areas? Recent work has addressed all five research questions with fieldwork being conducted in our research locations, in particular in Húsavík and Andøya. A recent project development is the inclusion of locations in western Greenland as study areas. Fieldwork has now been undertaken in Ilullisat, Aasiaat and Disko Island.

The emphasis of Work Package 5 has been on *Marine Governance, Security and Rapid Social and Environmental Change.* Work has been concentrated on field research on fisheries governance issues, including investigating social and economic impacts of Individual Transferable Quota (ITQ) systems in coastal communities. ARCPATH research is finding serious flaws in the design of this form of marine resource governance due to significant social, economic and ecological externalities that are not sufficiently dealt with in policy design, implementations and assessments. A major publication that team member Níels Einarsson has contributed to in the *Proceedings of the National Academy of Science* (Young et al. 2018) has shown that ITQs are panacea solutions to fisheries governance that need to be reviewed due a range of negative social equity concerns as well as their lack of flexibility and sophisticated ecosystem understanding. In fisheries management—as in environmental governance more generally—regulatory arrangements that are thought to be helpful in some contexts frequently become panaceas or, in other words, simple formulaic policy prescriptions believed to solve a given problem in a wide range of contexts, regardless of their actual consequences. When this happens, management is likely to fail, and negative side effects are common. Several of the key case studies and arguments in this publication derive from ARCPATH research.

This research suggests that fisheries policy is a key driver of change in fisheries-dependent coastal communities. Thus ARCPATH is focusing on the social, cultural, environmental and economic externalities related to the introduction of the ITQ system, concentrating on Icelandic fisheries (but also considering Norway) and how this management model continues to impact people's livelihoods and human development in fishing villages, especially in terms of opportunities of small-scale and local actors regarding fishing rights. One common outcome of ITQ systems is the consolidation of fishing rights or quotas in large companies and away from small communities. This can lead to decreased access for newcomers, reduced training opportunities for youth on the remaining vessels, and increased cost of quotas as a limited commodity. The lack of job opportunities in the fishing sector causes increased rates of outmigration by youth and women, which threatens the resilience of those communities.

At the same time, ARCPATH research suggest that there continues to be an interest from youth in partaking in fisheries livelihoods and local governments are looking for options for the renewal of the fisheries workforce. ARCPATH research is leading to experimentation with programmes that increase access to fisheries for youth and newcomers such as recruitment and educational programmes, summer youth fisheries, and newcomer quotas. In the future, ARCPATH plans to undertake further research focusing on intergenerational and gender aspects and the current or future youth and newcomer cohort in Icelandic fisheries. ARCPATH is also developing several practical recommendations to enhance local and national policies towards a more sustainable fisheries management that includes options for newcomers and women, and that protects workers rights, including immigrants. These would include important considerations for human well-being and job satisfaction, the right to work, gender equality, human rights, low environmental impacts, and equity in sustainable development.

Iceland, like many other fishing nations, has mostly focused on the ecological and the economic aspect of sustainable fisheries, overlooking other ecosystem services of ocean environments such as heritage, cultural value of food items, recreation, and education. ARCPATH research is leading towards a critical investigation of the definition of sustainable fisheries. Small-scale fisheries, in particular, can provide locally-sourced food with reduced food miles, fuel costs and greenhouse gas emissions. These fisheries offer not only flexible use of ecosystem services and diverse employment but also a sense of local fate control, belonging, cultural identity and pride in the community. These are all core aspects of Arctic human development. Such environmental and social aspects of energy efficiency and quality of life are seldom considered in definitions of sustainable fisheries, but may in fact be some of the more important factors to be taken into account in future climate change mitigation. As noted above, Work Package 6 on Synthesis is not discussed here as this is the topic of Chap. 19 in this volume.

Work Package 7 has focused on the challenges of Management and Dissemination. The management structure of ARCPATH was described earlier in this chapter and does not need to be discussed further here. However, more should be said regarding dissemination. In a project such as ARCPATH, dissemination is crucial. This is because ARCPATH is of great international relevance, both because of the global significance of the Arctic, and also because of its novel approach and focus that aims at providing policy relevant and robust knowledge that will directly benefit Arctic residents. Research results, thus, have clearly defined socio-economic relevance to the national interest of Nordic countries. They should be disseminated to policy makers and stakeholder groups.

Through its research efforts, ARCPATH will facilitate planning adaptation strategies and also encourage taking advantage of new opportunities to reduce environmental and economic risks. ARCPATH brings together a strong team, experienced in collaborative studies, and situated at institutions in the forefront of Arctic research. The combined multi-disciplinary expertise of team members, covering climate and social sciences, and extending from marine biology to environmental economics, is creating the synergistic environment needed to address the crucial issues facing northern societies.

Through the training of young scientists, ARCPATH is helping to secure the long-term capacity in this field within the Nordic region. A week-long summer school focusing specifically on ARCPATH research has already been held in Norway in July of 2018. Its focus was on *Climate Teleconnections and Predictions: Past, Present and Future* and enrolled some 30 graduate students. Lectures were provided by ARCPATH members and invited speakers. A further summer school is envisaged for 2020, in Iceland, focusing on Marine Protected Areas. As part of this course the students will travel to the Westman Islands and observe the Beluga sanctuary that is being created there (see Beluga sanctuary (2020) in references). In addition to this, courses on marine mammals have been led annually by ARCPATH team member Marianne Rasmussen from the University of Iceland's Research Centre in Húsavík.[1] ARCPATH research findings are also being disseminated through the teaching and outreach programmes of the team. In addition to these standard ways of dissemination, ARCPATH is collaborating with photographers and artists in a novel way of disseminating information regarding arctic change to the general public (Ogilvie 2017a). See e.g., the video by Andrea Sparrow of the Arctic Arts Project (Sparrow 2020) and the film and book *Out of Ice* by environmental artist Elizabeth Ogilvie (Ogilvie 2017a, b).

7.7 In Conclusion

As noted in the original ARCPATH grant application, the rapid and far-reaching changes in the Arctic will cause global effects but will first and foremost impact Arctic Nordic regions. It is thus essential that Nordic researchers combine their expertise in order to elucidate and understand these changes. ARCPATH has built a Nordic Centre of Excellence that builds on the long experience of established researchers, leading experts in their fields, as well as including many young scientists who bring fresh insights and who will help to achieve long-term Nordic added value. These goals and achievements are well established for ARCPATH.

The strong, multi-disciplinary, and collaborative group that constitutes ARCPATH is generating knowledge of high importance for development in the Arctic Region, actively creating a critical mass for success and expertise. ARCPATH team members facilitate close collaboration between disciplines such as physical sciences focusing on climate predictions, natural sciences focusing on ecology and behaviour of cetaceans and social sciences such as anthropology and economics focusing on the societal importance of cetaceans and the implications of climate change. The project therefore not only acknowledges that multiple disciplines are

[1] For information on this see http://rannsoknasetur.hi.is/summer_course

needed to identify responsible development paths for the Arctic region but is integrating them in the research.

Combining the expertise from each participating institution is facilitating important synergies in knowledge creation, and it is clear that the research conducted could not be done by each partner institution on its own. For example, by linking climatological data with the ecology and behaviour of marine mammals, ARCPATH is already drawing international talent to the Nordic region through international recruitment of senior scholars, post doctoral scholars and PhD students. The transdisciplinary approach of ARCPATH, which by definition relies on active collaboration with stakeholders, is expected to deliver significant added value for those who live in our study communities. Stakeholders have participated in the research through qualitative interviews and quantitative surveys research methods and are expected to be able to rely on the results for better-informed decision-making. Thus, for example, the project aims to deliver tangible knowledge for decision-makers contemplating the establishment of a Marine Protected Area in Skjálfandi bay in northern Iceland. An exciting and unexpected ARCPATH development is the collaboration with the initiative at the Autonomous University of Barcelona, the CER-ARCTIC Research Centre, on the two interconnected issues of Arctic social-ecological change that lend themselves well to cross-regional comparisons and knowledge transfer by the use of empirical cases. This Centre may be seen in part as a development issuing from ARCPATH. It is envisaged that, even after the end of the project, ARCPATH research goals and values will be continued through future projects.

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Chapter 8
The Climate Model: An ARCPATH Tool to Understand and Predict Climate Change

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Abstract Climate models are sophisticated computer programs that simulate the mathematical equations representing the known physics of the climate system, which includes the atmosphere, ocean, land surface and ice. Climate models are used for a variety of purposes from studying the dynamics, interactions and feedbacks in the climate system, quantifying the climate variability in the past and present, to predicting and projecting future climate change. The overall objective of ARCPATH is to combine improved regional climate predictions with enhanced understanding of environmental, societal, and economic interactions in order to supply new knowledge on potential "pathways to action". In ARCPATH climate modelling is one of the most important methods applied to understand how climate in the Arctic affects, and is affected by, the rest of the global climate system. Here we introduce the basic concept of climate modelling with examples from the two models used in the ARCPARTH project: the Norwegian Earth System Model (NorESM) and the European Earth System Model (EC-Earth).

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ARCPATH applies decadal climate prediction and regional high-resolution models to provide more accurate information on climate change in the Arctic and Nordic Seas over the next few years. Decadal climate prediction is a new research area that uses advanced statistical methods and ocean and sea ice measurements to better synchronize climate models to observed climate for obtaining reliable climate forecasts. We present the ARCPATH research in these new fields aimed to better meet society demands for local and regional adaptation measures such as fishery, shipping and whale-watching tourism.

Keywords Climate modeling · Global climate models · Regional climate models · Climate projections · Arctic climate change

8.1 Introduction

Climate is generally defined as a statistical description of weather in terms of its mean and variability over a certain time-span and a certain area. The Earth's climate system is an interactive system consisting of the atmosphere, the ocean, the cryosphere, the land surface and the biosphere that is directed or influenced by various external forcing mechanisms (Fig. 8.1). The most important external force is solar

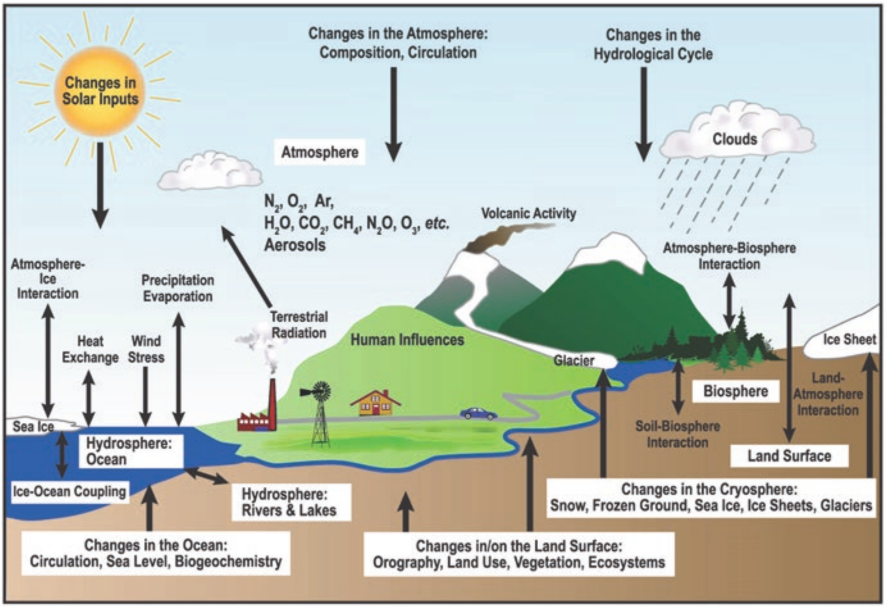

Fig. 8.1 Schematic view of the components of the climate system, their processes and interactions. (Source: IPCC AR4, 2007, FAQ 1.2, Figure 1)

radiation that powers the climate system and drives the seasonal variations. Other external influences include natural phenomena, such as volcanic eruptions, and human-induced changes in atmospheric composition that can alter the radiation balance of the Earth by changing the fraction of solar radiation that is reflected to the space, and by altering the thermal radiation emitted from Earth as longwave radiation back towards space. The climate system responds directly to the changes of these external factors, as well as indirectly, through a variety of internal feedback mechanisms (IPCC 2001, 2007, 2013).

Although less familiar to those outside the climate research community, the internal dynamics of the climate system can also cause the climate to fluctuate. These internal dynamics are discernable in the large-scale atmospheric and oceanic circulation patterns, as well as in the smaller scale weather patterns and ocean eddies. These circulations help to bring the imbalance caused by large solar heating in the tropical regions and large thermal cooling in high-latitude regions into equilibrium. This mechanism is similar to the cooling of coffee by turbulent mixing that occurs when cold cream is added. The mixing in the coffee cup causes temperature to vary throughout the cup until a uniform temperature is reached. In a similar fashion, the somewhat chaotic atmospheric and oceanic circulations lead to variations in climate. Those changes in the more inert ocean give rise to slower climate fluctuations. These fluctuations combined with the external driven changes produce the observed variations in climate.

A climate prediction attempts to produce an estimate of the most likely evolution of the climate in the future at lead times of months to a decade ahead. It, thus, needs to encompass both internal variability and changes due to the increases of greenhouse gases (GHGs) and other external factors. In the same way as weather forecasts depend on the initial state of the atmosphere (the weather of tomorrow is very dependent on the weather of today), climate predictions depend on an accurate description of the initial state of the climate system. In the case of climate prediction, the physical state of the ocean is most important. It allows climate to be partly predicted from a few weeks to several years into the future. In contrast to climate predictions, a climate projection captures the response of the climate system to different future scenarios in changes in GHGs and other external factors. Climate projections provide information on long-term climate change, i.e., from several decades and longer into the future.

The behavior of the climate system, its components and their interactions, can be studied and simulated using tools known as climate models, which are built based upon well-documented physical processes. There exists a spectrum of climate models. The simplest model is the energy balance models that represent the Earth system in one box and deduce globally averaged surface air temperature by solving the global energy balance. The contemporary complex three-dimensional global climate models include the explicit solution of energy, momentum and mass conservation equations at millions of points on the Earth in the atmosphere, land, ocean and cryosphere. Recently, models of atmospheric chemistry, marine and terrestrial ecosystems have been added to the full complexity climate models transforming them into Earth System Models. Over the recent decades, climate models have been developed and used extensively to explore climate processes and natural climate variability, to study why the climate has changed as observed, and to project quantitatively how the climate will change in the future in responses to human-induced forces. Techniques have also been developed to optimally combine observations into climate models to closely resemble the actual internal fluctuations of the climate system, so as to provide more accurate predictions for the near future. Regional climate models have been developed for more detailed studies of regional phenomena on a higher resolution than what is practically unattainable with global models.

The overall objective of the ARCPATH project is to combine improved regional climate predictions with enhanced understanding of environmental, societal, and economic interactions in order to supply new knowledge on potential "pathways to action". Climate models are important tools applied in ARCPATH to understand how climate in the Arctic affects, and is affected by the rest of the global climate system. In particular, climate models are used to provide climate change predictions in the Arctic over the next decade in ARCPATH. In this chapter we introduce the models used in the project and how they are applied in ARCPATH.

8.2 Global Climate Models and Their Long-Term Projections

Global climate models, also known as general circulation models (GCMs), are mathematical frameworks that are built on fundamental laws of physics governing the major climate system components, i.e., the atmosphere, land surface, ocean and sea ice. Such models account for how energy, mass and momentum are exchanged and interact among different components of the climate system. A GCM divides the globe into three dimensional grids of cells for each climate component, with a certain horizontal and vertical resolution (see for example, https://www.climate.gov/file/atmosphericmodelschematicpng). Each of the components has equations describing the resolving physical processes on the global grid for a set of climate variables such as temperature and wind. Processes taking place on spatial and temporal scales smaller than the model's resolution, such as individual clouds or convection in atmosphere models, are represented in a parametric way in terms of the resolved processes. To "run" a GCM is to repeatedly solve the equations in each grid cell at each time step on powerful supercomputers with the specified climate forces (e.g., parameters that represent the amount of GHGs in the atmosphere).

The complexity of GCMs has grown over time, as they incorporate more and more components and processes of the Earth's climate system. The early climate models in the 1970s and early 1980s consisted of only atmospheric general circulation models with the clouds represented in a simple manner, prescribing the amount, distribution and radiative properties to compute atmosphere radiation. More recent generations of GCMs consist of fully coupled models of the atmosphere, ocean, land and cryosphere. They usually incorporate a much more comprehensive and detailed representation of clouds, based on consistent physical principles, so as to simulate cloud feedbacks that strongly affect the sensitivity of climate to changes in GHGs (e.g., Cess et al. 1989; Senior and Mitchell 1993). The most recent GCMs may even include representations of aerosol processes and the carbon cycle.

The horizontal and vertical resolution for the atmosphere and ocean in the GCMs has also increased considerably over time from roughly 500 km horizontal resolution and 9 vertical levels in the 1970s to roughly 100 km horizontal resolution or higher and 95 vertical levels at present, as computers available for running the models become larger and faster. Nowadays GCMs are able to simulate many important aspects of Earth's climate: large scale patterns of temperature and precipitation, general characteristics of jet streams, storm tracks and extratropical cycles, and observed changes in global mean temperature and ocean heat content as a result of human greenhouse gas and aerosol emissions (Flato et al. 2013).

In ARCPATH, two global climate model systems are used for investigation of the global and Arctic climate changes: the Norwegian Earth System Model (NorESM) and the European Earth System Model (EC-Earth). The central components of both NorESM and EC-Earth consist of models for the atmosphere, ocean, land surface and sea ice. Figure 8.2 depicts the composition of the most recent version of the EC-Earth model, EC-Earth3 (Döscher et al. 2020). The Atmospheric model (IFS) simulates the atmospheric circulation with physical processes such as clouds, convections, and radiations, and plays a large role in transport of heat and water around the globe. The IFS includes a land surface module, H-TESSEL, which simulates surface characteristics such as snow cover, soil water and rivers. The ocean

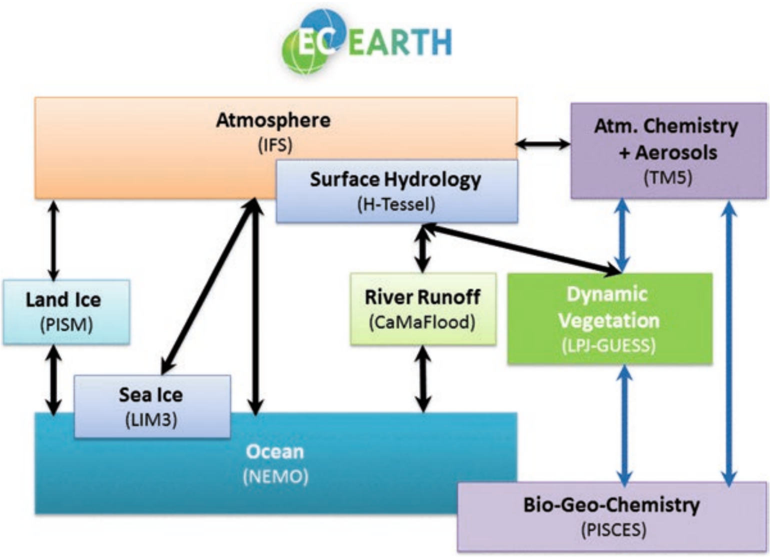

Fig. 8.2 Box diagram of the global climate model EC-Earth. The colored boxes indicate the components of the climate system with the name of the component model given in parentheses, respectively

component (NEMO) in EC-Earth3 simulates ocean current movement and mixing. NEMO embodies a sea ice model that simulates the growth, melt and movement of sea ice. The ESM configuration of the EC-Earth3 not only models the physics of the climate system, but also explicitly imitates the transport of carbon and other tracers through the Earth climate system. It includes a tracer model (TM5) for interactive simulation of the atmospheric chemistry and transport of aerosol particles and reactive gases, a dynamical vegetation model (LPJ-Guess) and an ocean biogeochemistry model (PISCES). An ice sheet model (PISM) is also coupled into the EC-Earth3 to simulate the evolution of ice sheets in a changing climate and their feedback to the climate system.

The EC-Earth3 can be run at different resolutions. Its standard configuration has the atmospheric resolution of about 80 km × 80 km horizontally and 91 vertical layers from the surface to 1 Pa (about 90 km) at the top of the atmosphere, and the ocean horizontal resolution of about 1° including a refinement at the equator of up to 1/3° and 75 vertical levels. At such resolutions, the model configured for the atmosphere-ocean-sea ice coupling system (i.e., EC-Earth3) can simulate the climate evolution of about 10–20 years in 1 day on a contemporary supercomputer. The full ESM configuration (i.e., EC-Earth3-ESM) may achieve about 2–5 simulation years in a day.

A detailed description of the EC-Earth model and references to its component models may be found in Döscher et al. (2020). The other global climate model utilized in the ARCAPTH project is the Norwegian Earth System Model, NorESM. The structure of the NorESM is similar to the EC-Earth, but it comprises different component models. One may refer to Bentsen et al. (2013) for a comprehensive description.

To understand how the Earth climate has changed in the past and at present, and how it will change in the future, the Coupled Model Intercomparison Project (CMIP) led by the World Climate Research Programme (WCRP) has coordinated a broad range of climate models worldwide to perform a large number of simulations for the known historical forcings (anthropogenic and natural) and various future emission scenarios. These coordinated simulations have provided a quantitative basis for assessing many aspects of future climate changes for the past IPCC climate change assessment reports (IPCC 2001, 2007, 2013). The currently ongoing CMIP phase 6 (CMIP6) simulations, together with the information from the past CMIPs and the observations, will form the basis for the upcoming sixth IPCC assessment reports (IPCC AR6) which is scheduled to be published in autumn 2020. Both NorESM and EC-Earth have been used to participate the past phases of CMIP (i.e., CMIP3 and CMIP5), and also the current CMIP6. The modelling groups in ACPARTH, including DMI, NERSC, SMHI and UiB, are the key developers of either EC-Earth or NorESM, and have made great efforts to contribute to CMIP6.

Figure 8.3, below, shows the ensemble of global mean surface air temperature changes relative to the preindustrial period 1850–1879, and the total Arctic sea ice in March and September as simulated by the EC-Earth3 model following the CMIP6 historical (from 1850 to 2014) and four future Shared Socioeconomic Pathways (SSPs), that is, the SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5 (from 2015 to

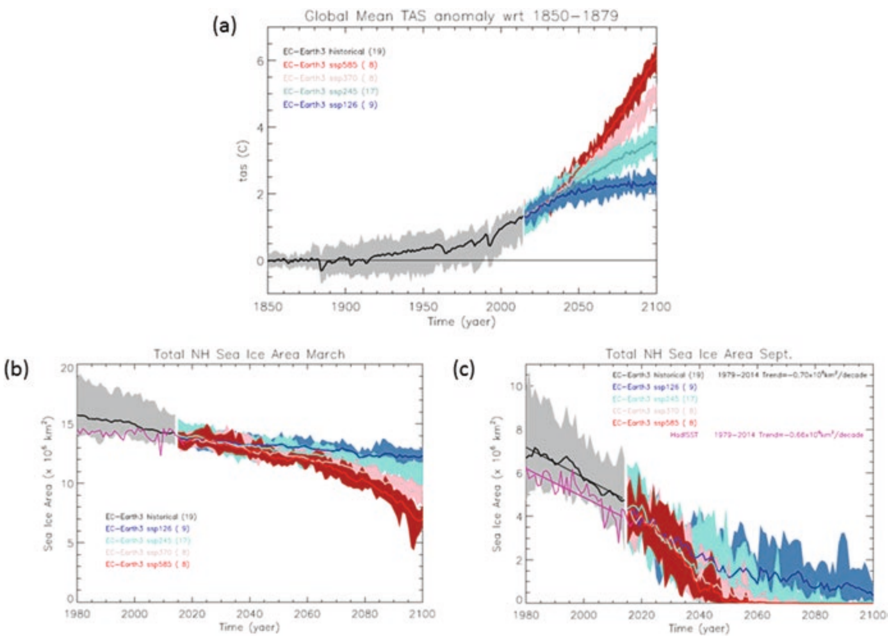

Fig. 8.3 Annual averaged global mean surface air temperature anomaly (in °C) with respect to the period 1850–1879 (**a**), total Northern Hemisphere sea ice area (in million km^2) in March (**b**) and September (**c**) as Simulated in the CMIP6 historical (black) and future scenarios SSP5-8.5 (red), SSP3-7.0 (pink), SSP2-4.5 (cyan) and SSP1-2.6 (blue) using the global climate model EC-Earth3, respectively. The lines are the respective ensemble means, while the shadings represent the spread of all members in the ensemble. The ensemble size of each simulation is indicated in parentheses. The sea ice in (**b**) and (**c**) are only plotted from 1980 after modern satellite observations, where the HadISST observational data set is also plotted in purple. The straight line in the (**c**) indicates the linear trends calculated for the historical ensemble (black) and the HadISST data (purple) for the period of 1979–2014

2100). The SSPs are a new set of emission and land use scenarios produced with integrated assessment models based on new future pathways of societal development, and related to the Representative Concentration Pathways (RCPs) used in CMIP5 (O'Neill et al. 2016). The SSP1-2.6 envisions relatively optimistic trends for human development, with substantial investments in education and health, rapid economic growth and well-functioning institutions, but meanwhile it assumes an increasing shift of economy toward sustainable practices, leading to a forcing pathway for climate stabilizing at 2.6 W m^{-2}. The SSP5-8.5 conceives optimistic development trends similar to SSP1-2.6, but with an energy intensive, fossil-based economy which results in an increasing climate forcing pathway reaching 8.5 W m^{-2} in 2100. The SSP1-2.6 and SSP5-8.5 scenarios represent the high and low end of the range of future forcing pathways, respectively. The SSP3-7.0 represents a medium to high end of the future forcing pathway of 7.0 W m^{-2}. It envisions societies that are highly vulnerable to climate change due to more pessimistic development trends with little investment in education or health, fast growing population, and increasing regional rivalry, leading to societies that are highly vulnerable to climate change. SSP2-4.5 envisions a central pathway in which trends continue their historical patterns without substantial deviations, leading to a moderate climate forcing level of 4.5 W m^{-2}.

Due to the chaotic nature of the climate system, tiny differences in things such as temperatures, winds, and humidity in one place can lead to very different paths for the system as a whole, resulting in large uncertainties in individual simulation. A method commonly used to represent these uncertainties is to perform an ensemble of simulations using the same model configurations and the forcings (e.g., GHG concentrations, aerosol loadings, and changes in the solar forcing) but started with different starting conditions. The color shading in Fig. 8.3 represents the evolutions of all members in the ensemble of the simulations, reflecting the range of natural variability of the modelled climate system, while the ensemble mean represents the evolution of the group as a whole conveys the responses to the historical and scenario forcings. The EC-Earth3 model projects increases in global mean surface air temperature continuing throughout the twenty-first century driven by increases in anthropogenic greenhouse gas concentrations. The projected average warming in the near future (until about 2040) is insensitive to the choice of the scenarios. However, the warming is very likely to exceed the natural variability that is seen in the twentieth century. The amount of warming in projections for the end of the century depends on the particular emission scenario (SSPs) selected. By the end of the twenty-first century (2081–2100), the EC-Earth3 projects that global averaged surface air warming relative to 1981–2000 will range from about 1.6 °C for the low scenario (SSP1-2.6) to about 4.8 °C for the high scenario (SSP5-8.5). The projected warming is about 2.8 °C for the moderate scenario (SSP2-4.5), and 4.0 °C for the subsidiary high scenario (SSP3-7.0). Geographically, warming is the greatest over land, with a maximum over the high northern latitudes, and least over the Southern Ocean (Fig. 8.4). An outstanding feature in the distribution of the warming shown in Fig. 8.4 is that the warming in the Arctic region is about 2–3 times the global warming, which is often referred to as Arctic amplification (Masson-Delmotte et al. 2013).

The EC-Earth model captures well the declining trend in the Arctic sea ice observed in recent decades, even though the model seems to overestimate the amount of Arctic sea ice in the present day. Figure 8.3 also reveals that, as global warming continues, the Arctic sea ice loss will accelerate with a possibly complete loss of summer sea ice in the second half of the twenty-first century. Arctic sea ice in summer may disappear as early as around year 2040 in the high (SSP5-8.5) and subsidiary high (SSP3-7.0) emission scenarios. The disappearing of summer sea ice may occur around year 2050 in the moderate emission scenario (SSP2-4.5). Even in the low emission scenarios (SSP1-2.6), the total area covered by sea ice in summer will be in a “ice free” condition of less than 1 million km^2 toward the end of the twenty-first century. The loss of Arctic sea ice has been suggested to contribute to occurrence of extreme weather and climate in Europe as well as other mid-latitude continents (eg., Francis and Vavrus (2012); Yang and Christensen (2012)).

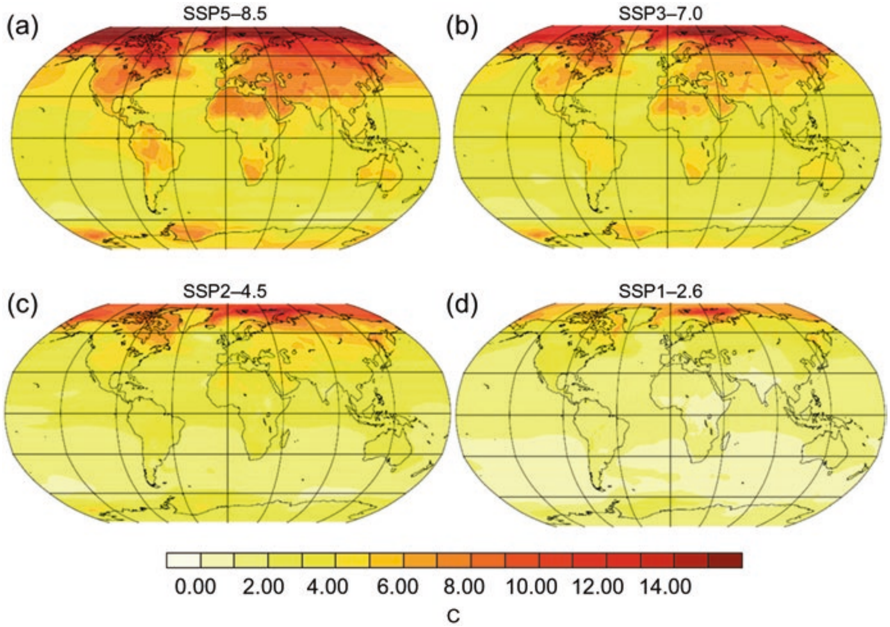

Fig. 8.4 Projected surface temperature changes for the late twenty-first century (averaged over 2081–2100) relative to the period 1981–2000 for the SSP5-8.5 (**a**), SSP3-7.0 (**b**), SSP2-4.5 (**c**) and SSP1-2.6 (**d**) scenarios, averaged over ensemble simulations by the global climate model EC-Earth3. Unit in °C

Furthermore, the timing of a seasonal ice-free Arctic is seen to have great implications to global and regional economic activities including shipping and fishery, and tourism.

8.3 Decadal Climate Prediction

In addition to providing information on long-term climate change, climate models can be used to make decadal predictions and thereby deliver accurate information on how climate will change over the next few years. Information on these timescales is also of great interest to society, and the private and public sector, as it can be used to increase efforts at resilience and aid sustainable development. Climate prediction is generating a new frontier in climate services. ARCPATH applies two state-of-the-art decadal prediction systems based on the NorESM and EC-Earth to provide a more refined picture of how Arctic climate will evolve over the next 10 years. These systems also contribute decadal predictions to the CMIP6 (Boer et al. 2016). Here we introduce the concept of decadal prediction, with examples drawn from NorESM.

To appreciate the nature and significance of decadal climate prediction for the Arctic it is important to consider the historical evolution of Arctic surface temperatures (Fig. 8.5), which are closely related to sea ice conditions (Semenov and Latif 2012). A statistical technique (a low-pass filter) is applied to the surface temperature time-series to focus on fluctuations with time scales longer than 10 years. The Arctic has warmed dramatically over the historical period and conditions in the Arctic are now around 2 °C warmer than they were at the turn of the last century. This is a warming rate around twice the global average. The warming of the Arctic has been far from continuous. During the last 100 years there were two periods of rapid warming, punctuated by periods of rapid cooling. During the early part of the last century the Arctic warmed by almost 1.5 °C, and thereafter cooled by almost 1 °C so that the conditions in the 1970s were only a little warmer than they had been in 1900. However, from the 1970s to present, the Arctic warmed again by almost 1.5 °C. The magnitude of these decadal changes is large compared to the overall warming of the whole time period and therefore important when considering the long-term warming of the Arctic.

It is well known that simulations with ESM that only account for the changes in greenhouse gas concentrations, aerosol loadings, and other external factors cannot reproduce the exact evolution of Arctic climate. This type of simulation was the focus of the previous section. In Fig. 8.5 (grey line and shading) we show the resulting Arctic surface temperature from such a simulation with the NorESM. The long-term warming from 1900 to present is well reproduced, as is the magnitude of warming since the 1970s. This indicates that both the long-term and the recent changes are driven mainly by the increasing concentration of greenhouse gases in the atmosphere and other external factors (IPCC 2013). However, on average only about 50% of the warming and cooling trends around the middle of the last century are captured.

Freely evolving dynamics within the climate system is a key reason that the NorESM simulations are not able to reproduce the observed evolution of Arctic climate, although inaccuracies in the model and external factors also contribute. As explained in the introduction to this chapter, climate variations are driven by both external factors and internal freely evolving dynamics. The ten NorESM simulations in Fig. 8.5 include exactly the same historical changes in external factors. While the chaotic behaviour of the climate system causes each simulation to have a different realisation of internal climate fluctuations (grey shading). Thus, the common behavior of the ten simulations (grey line) describes the common response of the Arctic temperature to external factors and the departures from the common response result from internal dynamics of the climate system. Furthermore, climate models show that internal dynamics can produce decadal changes in Arctic temperature of similar magnitude to observe. In particular, multi-decadal changes associated with fluctuations in the Atlantic and Pacific Oceans have been shown to alter heat transport into the Arctic. These changes can explain up to 50% of the observed variations (Delworth et al. 2016; Svendsen et al. 2018).

Our ability to predict climate on decadal timescales in the Arctic relies on accounting for both external factors and internal dynamics. This is the case, in general, for all climate prediction on these timescales (Keenlyside and Ba 2010). While accounting for external factors is traditional, accounting for internal dynamics is a

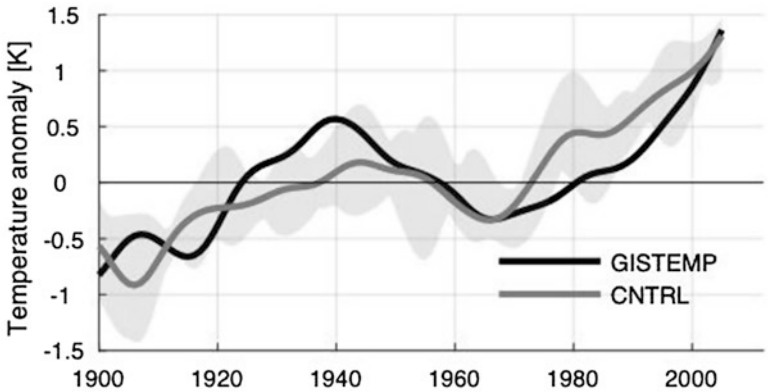

Fig. 8.5 Arctic surface temperature from GISTEMP observations and NorESM simulations from 1900 to present (CNTRL). The Arctic is defined as the region north of 70 N. There are 10 different model simulations that each represent a possible realisations of climate under the same prescribed external factors (e.g., greenhouse gas concentrations, aerosol loadings, and changes in the solar forcing). Each of these simulations are started from different possible pre-industrial climate conditions. The grey line shows the mean of these simulations represents the changes caused by the external forcing. The shading shows the spread of the 10 simulations and represents the uncertainties from internal climate dynamics. (The figure is kindly provided by Lea Svendsen, University of Bergen, and based on Figure 3a of Svendsen et al. 2020)

relatively new aspect of climate prediction. As for numerical weather prediction, there are four main factors that contribute to skillful climate prediction. These factors include: accurate observations, a realistic model, ability to synchronize the model with the observations, and a sufficiently powerful computer to run the model. We will discuss progress on the first three of these below. It is nonetheless important to realize, as with a weather forecast, climate predictions are limited in the end by chaotic behaviour within the climate system.

Accurate Observations from the ocean, atmosphere, cryosphere, and land-surface are required to monitor and predict climate (Penny et al. 2019). Observations of the ocean are particularly important, as the ocean is a key cause of decadal variations in climate. This is because the ocean has vastly greater heat capacity and slower circulation than the atmosphere. A good example of this is the transport of warm water from the Atlantic into the Arctic by the Gulf Stream, and the North Atlantic and Norwegian currents. Once the warm water reaches the Barents Sea it can delay the start of the freezing season and the climate of the region. Measurements of ocean heat transport across the Barents Opening can provide skillful predictions of sea ice conditions 1 year later (Onarheim et al. 2015). Observations made further south can provide skillful predictions 7–10 years in advance (Fig. 8.6; Årthun et al. 2017).

Observations of the ocean are today routinely made from in situ networks and satellite systems (GOOS, https://www.goosocean.org). In situ networks consist of volunteer observation ships and research vessels, moored arrays (e.g. Barents Sea Opening; see Lien et al. 2016 and references therein), and autonomous floats (e.g.,

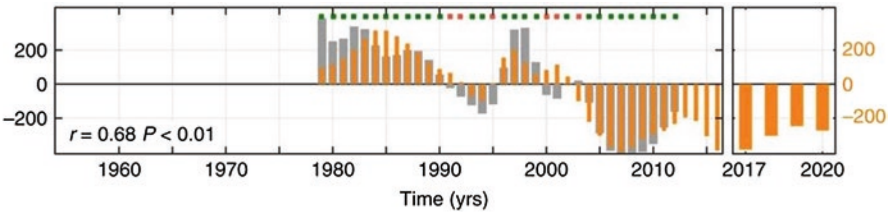

Fig. 8.6 Winter Arctic sea ice extent anomalies (in 10^3 km^2) from observations (grey) and predictions (orange) using ocean temperature in the Gulf Stream region 10 years earlier. The predictions are based on a simple statistical model that empirically captures the propagation of anomalous heat content. The Arctic sea ice anomalies have been statistically smoother to focus on decadal variability. The correlation skill is 0.68, significant at 99% level. (The figure is based on Figure 6d of Arthun et al. 2017)

Argo, Riser et al. 2016). Observations in the Arctic Ocean below sea ice are however extremely sparse, mostly relying on a few ice-tethered profilers (Toole et al. 2011) or scientific missions undertaken during the summer months. Observations of the atmosphere can be also used to obtain accurate estimates of the ocean state, because ocean variability is largely driven by the atmosphere. Fortunately, the atmosphere is very well observed because of its importance for weather forecasting.

Observations of sea ice are also of importance for high-latitude climate prediction. Measurements made from satellites have provided observations of sea ice extent since 1979, and sea ice thickness since around the 1990s (Smith et al. 2019). Accurate observations of the snow layer on top of the sea-ice are also crucial to prediction of the sea ice state, because of its influence on the thermal conductivity and reflectivity. Unfortunately, observations of snow depth over sea ice are usually lacking. Some novel measurements can now estimate the snow depth from dual-frequency radar freeboard (Lawrence et al. 2018).

Earth System Models, as described in the section above, have advanced greatly during the last decades and they can now realistically simulate many aspects of climate. They have also been used in skillful decadal predictions (Yeager et al. 2018). However, the models do have difficulties in capturing decadal climate variability. For example, most ESM models are able to simulate patterns of multi-decadal variability in the Atlantic with similarities to observations, but there is a great diversity in the timescales, spatial structure, and underlying mechanisms (Keenlyside et al. 2014). Thus, further model improvement will enhance climate prediction. In ARCPATH we are developing climate models with increased ocean model resolution in order to better capture the connectivity between the North Atlantic and Arctic and thereby improve high-latitude climate prediction (Langehaug et al. 2018).

Synchronizing the Numerical Model with the Observed Climate State is the necessary step for achieving skillful climate predictions using ESM. Data assimilation is a statistical method developed for exactly this purpose and has been key to achieving skillful weather forecasts. It is used to estimate the state of the system based on observations, a dynamical system and statistical information on their uncertainty. It is an essential method to estimate the most probable state of the climate system (e.g., the current amount of heat in the North Atlantic, the current strength of the Gulf Stream). As observations are sparse and may not always be available, one relies on the model to provide a representation of the entire dynamical state. As such, data assimilation can be seen as a way to guide the trajectory of a dynamical model and thereby make a prediction of the future.

The concept of data assimilation and numerical prediction may seem abstract, but it is quite analogous to the navigation App on your smartphone. Such an App estimates the most probable picture of the current traffic conditions based on available observations from traffic reports. The program then computes alternative possible routes and travel times. These are predictions. Their accuracy and the uncertainty depend on the quality of observations and the program (i.e., the model). The larger the distance to navigate and the greater the amount of traffic the more uncertain the prediction will be. This can be seen as similar to predicting how a temperature anomaly in the North Atlantic is transported by currents to the Arctic, and how using observations of the ocean conditions and the realism of the ocean model can improve the prediction.

A challenge with data assimilation is to minimize the error of the initial condition while still preserving the dynamical consistency of the model system. There has been great progress in recent years in the field of data assimilation in geosciences (Carrassi et al. 2018). Progress in data assimilation methods have been able to compensate for the sparseness of the observational data set from the Arctic. Advanced data assimilation methods such as the Ensemble Kalman Filter (EnKF, ibid) have proven very effective in jointly assimilating ocean and sea ice data. This approach is called strongly coupled data assimilation (Penny et al. 2017) and is advantageous because observations can be used from one part of the climate system (the ocean) to estimate the state of another (the sea ice) and dynamical consistency is enhanced. In ARCPATH we have focused on accurate initialisation of sea ice using such advanced data assimilation techniques in order to improve predictions of sea ice (see below). The emergence of new observational products such as sea ice thickness from SMOS and CRYOSAT-2 has the potential to further improve climate predictions at high latitudes.

Example of Seasonal-to-Decadal Prediction in ARCPATH

The Norwegian Climate Prediction Model (NorCPM, Counillon et al. 2016) uses the NorESM and the EnKF and is used to provide seasonal-to-decadal prediction. In Fig. 8.7 we present an example of a prediction relevant for ARCPATH, achieved with a version of NorCPM that uses only ocean observations (sea surface temperature and hydrographic profiles of temperature and salinity). The left panel shows a reconstruction and prediction of an index that measures the strength of the North Atlantic subpolar gyre. This is a component of the ocean circulation related to the Gulf Stream that is very relevant for the Nordic region's climate and where predictions have been found to be skillful (Yeager and Robson 2017). While a simulation that only includes historical forcings (i.e., the atmospheric drivers) shows no sign of decadal variability (black line and grey shading), a run with data assimilation (red

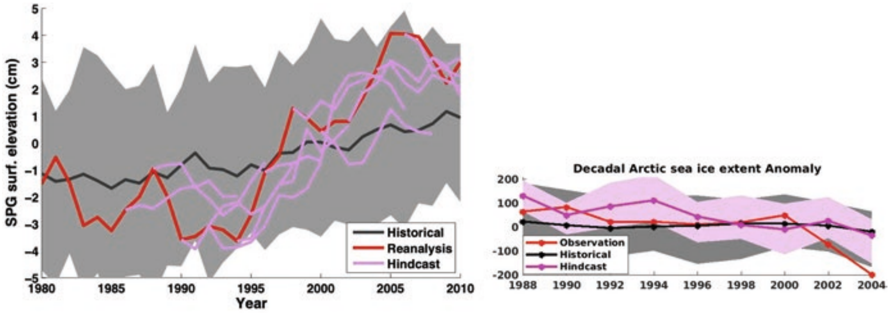

Fig. 8.7 Left show the Subpolar Gyre index in the historical run (black) with grey shading showing the uncertainty, in the run with assimilation (red) and in the climate predictions (pink). Right shows the decadal anomaly of Arctic sea ice extent (area of sea ice concentration larger than 15%, in 10^3 km^2) for winter (January–April) for the HadiSST2 observations (in red), the historical run (black), and the predictions (pink)

line) shows variability that matches very well independent observations (Counillon et al. 2016). Retrospective prediction experiments – simulations that do not use observation beyond the starting point apart from historical forcings – are able to sustain and predict most of the variability (pink lines).

The accurate prediction of the North Atlantic Ocean has been shown, as a downstream consequence, resulting in skillful predictions of decadal trends of Arctic winter sea ice extent (Yeager and Robson 2017). ARCPATH has shown encouraging results of skillful predictions of Arctic sea ice extent on seasonal to multi-annual timescales (Dai et al. 2020), but skill at decadal time scale appears limited (Fig. 8.7). Still there is hope for further improvement in the future through the assimilation of sea ice concentration (Kimmritz et al. 2019). Furthermore, Langehaug et al. (2018) have confronted the fidelity of the current version of NorESM in representing the propagation of anomaly that influences the variability of Arctic sea ice (Årthun et al. 2017). Work carried out in the ARCPATH project demonstrated that the propagation is greatly improved in the version of the system with increased resolution of the ocean model. One can therefore expect that prediction with a high resolution NorCPM system being developed will yield substantial improvement.

8.4 Downscaling and Simulation of Regional Scale Climate

Regional climate models follow the same physical equations as global climate models. The main difference is that they focus on a specific area of interest. Compared to global models, the resolution for this specific area of interest can be substantially higher. A typical resolution for regional climate models is around 10–25 km. In contrast to global climate models, regional models often focus on either the atmosphere or the ocean, although a few of the coupled ocean-sea ice-atmosphere models exist (see Giorgi (2019) and reference there).

The higher resolution in regional models enables better representation of orography, particularly in complex terrain as mountains and in regions with many islands or along coastlines, leading to better resolved climate processes. As a consequence, regional models can also provide more local information in those regions compared to global models. Studies have shown that regional models specifically improve the representation of weather and climate extremes such as precipitation extremes or mesoscale storms as polar lows or tropical cyclones.

However, climate does not stop at the boundaries of a regional model as winds and ocean currents transport energy and mass into and out of the regional model area. Thus, all regional models require input of meteorological variables such as winds, temperature, humidity and oceanic parameters such as sea surface temperature and sea ice concentration at their lateral and lower boundaries. This means that regional models always need to be fed by data from either observations (if available for the period of interest) or from GCMs. The latter are needed for all future scenario simulations using regional models. The regional model can then modify the information from the driving data set in the regional model domain by adding sub-GCM grid-scale details. However, the regional results are never entirely independent from the driving data, because the information from the lateral and lower boundary forcing permeates the interior domain and the internal model physics and dynamics. This means if the driving GCM has certain large-scale biases, the regional model will show similar large-scale biases, and if the GCM simulates a certain future large-scale climate change, the regional model will simulate a similar large-scale climate change. However, the regional models might provide more detailed local information due to their higher resolution and better representation of the orography.

The CORDEX-project (Coordinated Regional Climate Downscaling Experiment, http://www.cordex.org/) coordinates regional model simulations over 14 different regional domains of the globe. One of the domains is the Arctic. Both historical (starting from 1950) and future scenario simulations (until year 2100) have been calculated for this domain. ARCPATH-partners SMHI and DMI belong to the key-producer of Arctic-CORDEX climate simulations. The Arctic domain includes the target regions of ARCPATH. The regional simulations over this domain are thus a valuable data source for ARCPATH to explore both present and future climate changes and variability. The regional CORDEX simulations provide, for example, many local details of the coasts of Iceland, Norway and Greenland, which are relevant for societal actions in the coastal communities that are targeted within the ARCPATH project. It is important for these coastal communities to know if, e.g. extreme precipitation events will change in the future and how. Whether the number of days with high wind speeds will change is also desirable information for the coastal communities, as it has great implication for fishery and tourism (i.e., harbor days of boats) in the future.

As seen above, most global model simulations of the future climate indicate an accelerated climate change in the Arctic with a possibly total loss of sea ice in the second half of the twenty-first century. The simulated total loss of summer sea ice starting in the mid-twenty-first century in moderate to high emission scenarios (Fig. 8.3) would lead to a much longer period of ice-free conditions along the coastlines of Greenland. Sea ice in the Barents Sea would disappear year around. However, the uncertainties in the climate model simulations of the Arctic are high. The rates of Arctic warming and sea ice loss differ substantially among models and many models fail to reproduce the observed sea ice reduction.

The regional Arctic simulations performed in recent years have been demonstrated the long-term evolution of Arctic climate conditions when driven with reanalysis products. They were also to a certain degree able to reproduce sea ice reduction events as experienced in summers 2007 and 2012 (Döscher and Koenigk 2013).

Arctic Sea Ice Changes

The year to year variations of Arctic sea ice extent might increase in the future when sea ice becomes thinner and thus more vulnerable to atmospheric circulation anomalies. Regional downscalings of global climate model simulations with the regional coupled atmosphere-ocean-sea ice model RCAO show a number of 2007-like rapid sea ice reduction events throughout the first half of the twenty-first century (Koenigk et al. 2011). Anomalously warm temperatures in the winter before the summer event along with anomalous summer circulation situations that transport warm air into the Arctic have been identified as the main causes for these rapid reduction events (Döscher and Koenigk 2013). Warm winter conditions reduce sea ice formation. Thus sea ice thickness is thinner than normal in the beginning of the melting seasons and can more easily be melted during summer. The summer atmospheric circulation anomalies, which lead to sea ice reduction events, can vary. But a common feature of these circulation anomalies is that they favour an enhanced meridional flow and thus advection of warm air into the Arctic during the summer. Correctly simulating local sea ice conditions and potentially predicting high or low sea ice events in advance are highly important for coastal municipalities in Greenland, such as Ittoqqortoormiit. The living conditions of these coastal municipalities heavily rely on the accessibility confined by the occurrence of sea ice.

Temperature Changes in the Arctic

A strong projected sea ice loss can be related to a large atmospheric surface warming of up to 20 °C in winter and a strongly modified atmospheric vertical stratification with important impacts for cloud formation and precipitation in the Barents Sea area (Koenigk et al. 2015). The strongest warming in the Arctic occurs in autumn and winter and is linked to the decline in sea ice. This allows for large vertical surface heat fluxes from the relatively warm ocean (around freezing level) to the cold atmosphere above. While the warming in autumn is relatively uniformly distributed over the entire Arctic Ocean, the winter warming is most pronounced in the Barents Sea region since here winter sea ice is projected to disappear completely during the twenty-first century (Koenigk et al. 2015).

Precipitation Changes in the Arctic

The winter warming in the Arctic decreases with increasing height. Above 600 hPa, no amplification of the warming compared to lower latitudes can be found any longer. Thus, the warming is much stronger near the surface compared to further up in the Arctic atmosphere. Consequently, the vertical temperature gradient is increasing, which means that the atmosphere is becoming less stable during winter and the winter temperature inversion may totally disappear by the end of the twenty-first century in high emission scenarios. This has an important impact on the type of clouds that are formed in the Arctic. Clouds with larger vertical extension can be formed, which, in turn, can lead to more precipitation in Arctic regions where experience a sea ice retreat.

Climate models agree largely on an increase of precipitation in the entire Arctic in all seasons in the future (Fig. 8.8). Generally, the precipitation in the Arctic increases linearly with the Arctic temperature change (Koenigk et al. 2015). This increase reaches more than 50% by the end of the twenty-first century. In absolute values, the increase would be the largest in areas where sea ice disappears, since these are the areas with the largest temperature increase, hence also the greatest increase of vertical sensible and latent heat fluxes from the ocean to the atmosphere. It is clear that those regions which experience the largest sea ice losses, undergo at the same time huge changes in temperature and precipitation. An example of such an area is Svalbard, where annual mean temperature change may increase more than four times as much as in the global mean and where heavy precipitation events, even in the winter, may affect the safety of the town of Longyearbyen. As a consequence, the movement of many parts of Longyearbyen has been discussed.

While large scale changes in winter precipitation are foreseen by both global and regional model scenarios generally agree, in summer, the regional model simulations with RCA indicate generally much stronger precipitation increase compared to the global driving models. In all seasons, the regional model simulates a more

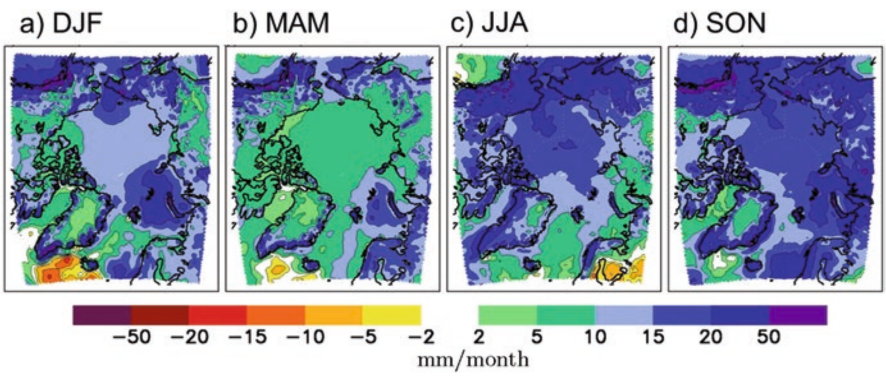

Fig. 8.8 Future scenario simulations with four global climate models following the high emission scenario RCP8.5 have been downscaled with the regional climate model RCA. Shown is the seasonal precipitation change between 2081–2100 and 1981–2000 in the regional RCA model, averaged over the four downscaling simulations

pronounced precipitation increase along coastal mountain ranges. This includes the east coast of Greenland, the Norwegian coast and all of Iceland.

Figure 8.9, below, shows the daily winter extreme precipitation in the period 1981–2010 that is simulated by four different regional climate models. A reanalysis data set (ERA-Interim) is also shown in Fig. 8.9 for a comparison. Both the pattern and amplitudes of the most extreme daily precipitation amounts are well simulated in all the four regional models. In summer, daily precipitation extremes are substantially larger in the Central Arctic and over the land areas in the Arctic and sub-Arctic, but they are somewhat smaller in the Nordic Sea area and over Iceland and Greenland coastal regions.

Cyclones and Polar Lows

The higher resolution nature of the regional climate models may also benefit the simulation of cyclones in the Arctic. Cyclones in the Arctic are often smaller in spatial extent (e.g. Polar Lows) than that in the mid-latitudes. Although their spatial scale is smaller than that of normal low-pressure systems, Polar Lows can have devastating impacts on shipping or on communities when they hit a coastal area. Further, due to their small size and rather short duration, weather forecasts often fail to adequately predict them. ARCPATH researchers contributed to two studies by Akperov et al. (2018, 2019) where regional models are used to investigate the representation of Arctic cyclones in the recent past and in a potential future climate

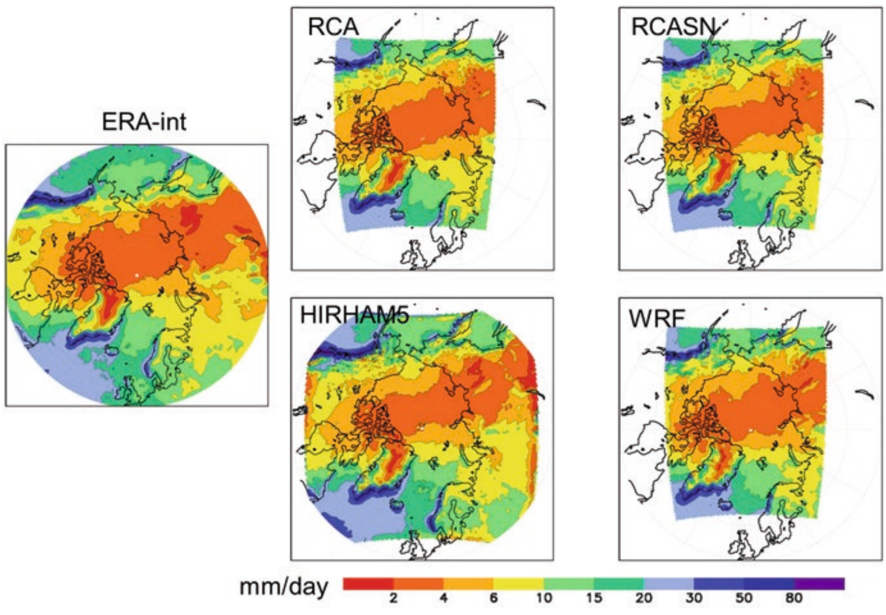

Fig. 8.9 Daily winter extreme precipitation in four different regional model simulations, 1981–2010 (RCA, RCASN, HIRHAM5, WRF) and in reanalysis data (ERA-Interim) as comparison. The 99-percentile of daily precipitation has been used here as index for extreme precipitation

scenario. They showed that regional models are well able to represent the main characteristics of cyclones in the Arctic region. The regional models are generally representing cyclone frequency in an effective manner. However, most models underestimate zonal wind speed in both winter and summer seasons, which likely leads to underestimation of cyclone mean depth. The observed trends in Arctic cyclones could be reproduced when a nudging of the observed large scale circulation has been performed. Free-running regional model simulations show however no clear trends in cyclones since 1950. This indicates that the observed trends in cyclones might be mainly due to natural climate variability.

Akperov et al. (2019) investigated trends in the Arctic cyclones in future simulations with regional climate models from the Arctic-CORDEX initiative under the RCP8.5 scenario, a high GHG emission scenario. Most of the regional model simulations show an increase of cyclone frequency in winter and a decrease in frequency during summer towards the end of the twenty-first century. However, cyclones tend to become weaker and smaller in the winter while they become deeper and larger in summer. Cyclone frequency increases over Baffin Bay, the Barents Sea, north of Greenland and throughout the Canadian Archipelago. It decreases over the Nordic Seas, the Kara and Beaufort Seas and over the sub-Arctic continental regions in winter. In summer, the models simulate an increase of cyclone frequency over the Central Arctic and Greenland Sea and a decrease over the Norwegian and Kara Seas by the end of the twenty-first century. The decrease is also found over the high-latitude continental areas, in particular, over east Siberia and Alaska.

Near-Term Climate Changes in the Arctic

To investigate short-term climate changes in the Nordic Seas region and to provide even more local information for coastal areas of Greenland, Iceland and Norway, ARCPATH has established a high resolution (around 10 km) regional atmosphere model HCLIM with a spatial focus on the Nordic Seas region. This model is used to downscale decadal prediction experiments from the global models that have already been described earlier in this chapter. Here, only first results are shown since additional simulations are currently being performed, and more analysis is needed in order to draw robust conclusions. Figure 8.10 shows a relatively good prediction skill of the annual near surface temperature variations at Ittoqqortoomiit in Greenland and Keflavik in Iceland during the prediction period for 2002–2011. The figure depicts the raw model output without applying bias correction, even though that has been a common praxis for climate predictions. Thus a cold bias can be seen in the simulated temperature in Ittoqqortoomiit. In contrast to the examples of Keflavik and Ittoqqortoomiit, the 10-year prediction for Tromsø in Norway does not demonstrate any skill (effectiveness). The predicted year to year variations do not agree with the observed variations for the 2002–2011 time period. This indicates that dynamical downscaling of regional models of climate predictions from GCMs can be important in order to provide more meaningful local details for near-term (1–10 years) climate change. However, more investigations are necessary to draw robust conclusions on the added value of performing regional downscaling of global climate model predictions.

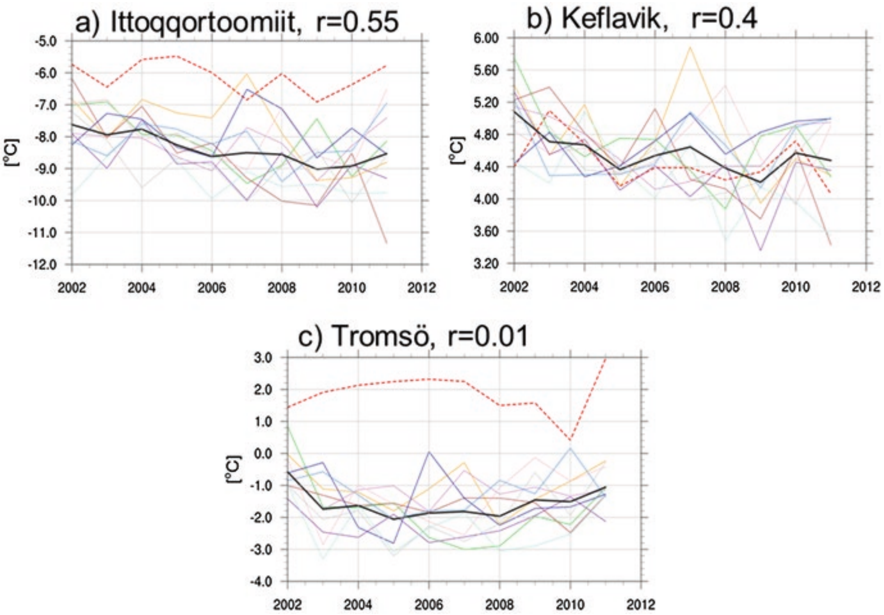

Fig. 8.10 Annual mean temperature in regional downscaling simulations with HCLIM of decadal hindcast predictions from the global NorCPM prediction system. The hindcast prediction has been started in January 2002. The red dotted line shows the observed two meter air temperature at three different locations in Greenland (**a**), Iceland (**b**) and Norway (**c**). The solid black line is the mean over the 10 prediction members (light colored lines)

The results from the regional model simulations over the Arctic and Nordic Seas show that regional models can represent key aspects of the Arctic climate system and provide more detailed information compared to global models. This is particularly the case for extreme events, such as precipitation or Polar Lows, and for the representation of the climate along mountainous coastal areas.

On the other hand, regional model simulations depend quite strongly on their lateral and lower boundaries. For future scenarios, regional models rely on data input from global models. The simulated large-scale climate change signals in the regional models are dominated by the global models. This means that regional downscalings of global climate scenarios are not an independent source of information for future climate change. The results from efforts of regional downscaling are strongly dependent on the driving GCM. The same regional model can simulate very different future climates if different driving GCMs are used. Thus, the outcomes from regional model scenarios should be taken with caution and should always be interpreted in conjunction with the results from the driving GCM. Further, one needs to keep in mind that increasing model resolution does not automatically improve all results. Many relevant sub-grid processes are neither resolved in GCMs nor in regional models, unless the model resolutions are further increased to beyond the limits of most current regional models (i.e, about 10 km). Therefore, regional models often show similar biases as the global models, particularly in the large scale distribution of relevant variables such as temperature or precipitation.

8.5 Summary

This chapter provides a short introduction to climate models (both global and regional) and the science of climate prediction and projection. In ARCPATH, two global climate models are used to provide global climate predictions. These global climate predictions will provide the boundary conditions for a high-resolution regional model, which will deliver valuable information to relevant stakeholders considering the challenges of adaptation to future climate change. A short summary of our discussion suggests that:

- A climate model is a computer program that solves the mathematical equations representing the known physics of the climate system;
- A climate model typically includes atmosphere, ocean, land and sea ice components and each component is a sub-computer-program;
- A climate model is a useful and powerful tool to understand climate variability and to quantify climate response to changes in external forcings;
- A climate model is the only dynamic-and-physics based tool to predict and project future climate change;
- A climate model can be used to provide climate predictions for the next seasons and years when combined with data assimilation techniques to synchronize the model with observations;
- High-resolution regional models are being used to provide more detailed information on climate change, but they do not generally reduce uncertainties. A novel aspect in ARCPATH is to apply downscaling of climate predictions.

8.6 Significance

At present, the Arctic is undergoing rapid climate and environmental changes. Local communities and operators in the Arctic region are directly affected. Further, the various interacting processes and feedback (e.g., atmosphere-sea ice-ocean interaction) taking place in the Arctic region can be seen to play significant roles in shaping both the global climate and the lives and livelihoods of many individuals across the globe. In response to such rapid change in the Arctic, future adaptation measures for sustainable development in the region need credible climate predictions from seasonal to decadal time scales. They also require more reliable climate projections with longer than multi-decadal time scales. Climate models are key tools for providing such information to decision-makers at diverse temporal and spatial scales.

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Chapter 9
Whale Ecosystem Services and Co-production Processes Underpinning Human Wellbeing in the Arctic: Case Studies from Greenland, Iceland and Norway

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Abstract The concept of ecosystem services (ES) has only just begun to be applied in the Arctic, and to an even lesser extent to marine mammals, such as whales. This chapter develops an ES cascade model and related ES co-production processes as they apply to whale resources in the Arctic. The result is a new conceptual model demonstrating the interconnectedness of social-ecological processes involving natural and human capital that enhance human wellbeing through the co-creation of whale ES. An ES cascade model is presented for whale ES, which connects the five linked stages of such ES production: the biophysical structure, functions, ecosystem services, the benefits to human wellbeing, and associated values. They are further expanded to include the co-production processes of whale ES as well as its main stages, inputs, and flows. These processes are illustrated using examples from ARCPATH case studies of coastal communities dependent on whale resources: Húsavík in Iceland, Andenes in Norway, and Ilulissat/Disko Bay in Greenland. The chapter aims to improve the understanding of the human dimensions of ES and the underlying processes that enable Arctic coastal communities to benefit from whales. It provides a starting point for further analysis of possible research and management approaches regarding whale resources in the Arctic.

Keywords Ecosystems services · Co-production · Marine mammals · Arctic coastal · Communities · Social-ecological systems

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9.1 Introduction

Interdisciplinary inquiry, synthesis of information from different scientific fields, and the articulation of community perspectives in the face of rapid social and environmental change are central to the ARCPATH project. In that sense, the interests of the ARCPATH project shares some key characteristics with the concept of ecosystem services (ES), commonly defined as the benefits that people obtain from natural capital that has become an important part of the global sustainability debate (Millennium Ecosystem Assessment (MEA) 2005). The ES concept is interdisciplinary in nature and links biophysical structures and processes to human values, benefits, and wellbeing. However, human agency in ES production has rarely been discussed in a way that makes a meaningful contribution to the understanding of the processes underlying ES (Fischer and Eastwood 2016). This has resulted in gaps in our understanding of how natural and non-natural capital inputs contribute to ES (Outeiro et al. 2017). This undermines, somewhat, the potential usefulness of the concept for analysing social perspectives on climate change within the ARCPATH project.

Having said that, this knowledge gap is being gradually filled as socioecological dimensions of ES receive increasingly more attention in the ES literature. This has been particularly the case with respect to one of the most commonly used ES classification systems, the Common International Classification of Ecosystem Services (CICES). To conceptualise how human beings, benefit from ecosystems, Haines-Young and Potschin (2010) designed an ES cascade model that follows a value chain-like sequence, defining and describing the different stages of ES formation from biophysical structure to human wellbeing benefits and values. The model has been used extensively in ES research, yet discussion of marine ES in this context remains limited.

One area of marine ES that is just starting to be explored is how marine mammals contribute to human wellbeing. This is being done by identifying and classifying whale ES (Cook et al. 2020; Roman et al. 2014). Whales continue to play an important ecological, sociocultural and economic role in Arctic coastal communities (Caulfield 1997; Roman et al. 2014). The region's historical reliance on marine resources for survival and the simultaneous existence of market and subsistence economies (Vammen Larsen et al. 2019) makes it an interesting study area to investigate the generation of benefits from whale ES. Most of the whale ES discussed in this chapter are co-created by human activities using different types of capital: natural, human, social, manufactured, and financial (Palomo et al. 2016).

Yet our understanding of the linkages between ecological functions, human inputs and the marine ES effects on human wellbeing within the Arctic continues to be somewhat limited. This is largely due to the existing disconnect between social and natural sciences that tend to study Arctic societies and ecosystems separately (Malinauskaite et al. 2019).

This chapter seeks to contribute an interdisciplinary discussion of the human dimensions of marine resource management. It applies the five-stage ES cascade model (Potschin and Haines-Young 2016) to whale ES. The stages – biophysical structure – function – service – benefit – valuation – are explained as human-nature co-production processes using examples from three ARCPATH case studies of coastal communities in Iceland, Norway and Greenland. In each instance whale ES provides an important contribution to human wellbeing in terms of livelihoods, cultural identity and social cohesion.

This chapter's inquiry is structured in four sections that complement this introduction. The first of these presents a theoretical framework. The next describes the research methods of the study and the location of its case studies. The third section provides both an analysis of whale ES in the Arctic and the utilization of an ES cascade model for those whale ES that include co-production processes. Finally, the last section of the chapter discusses possible policy implications and limitations of the model as well as areas for future research.

9.2 The Theoretical Framework

As mentioned above, the Haines-Young and Potschin (2010) ES cascade model distinguishes between the different stages in the formation and valuation of ES, including supply and demand-side occurrences (Martín-López et al. 2014). As indicated in Fig. 9.1, biodiversity and ecosystem functions are located within an ecosystem, while human wellbeing and values are located within a different social system, and ES are located at the intersection between the two. The conceptual framework of the ES cascade model distinguishes between different stages of the ES formation process and between biophysical, sociocultural and monetary value domains.

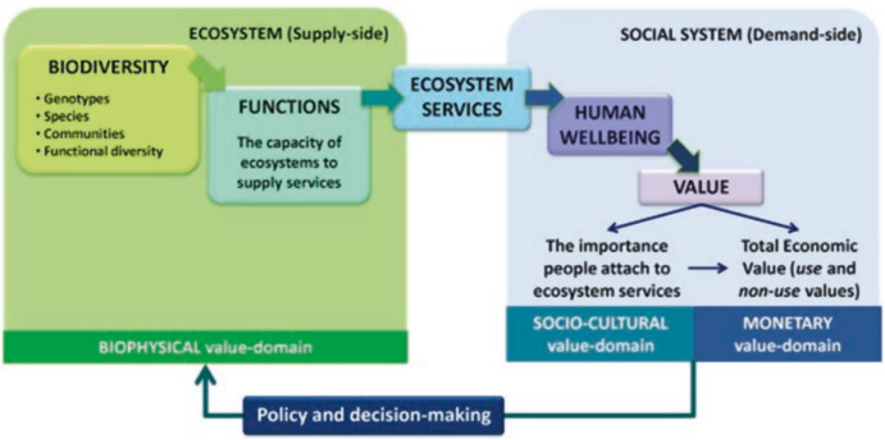

Fig. 9.1 Conceptual framework of ES cascade model and value domains embedded in social-ecological systems. (Sourced from Haines-Young and Potschin (2010) and Martín-López et al. (2014))

Figure 9.1 illustrates the flow of processes involving the five core stages of biodiversity, functions, ES, human wellbeing benefits, and value. An additional stage in the model, policy and decision-making, is presented at the bottom of Fig. 9.1 and represents the feedback coming from the social system, where human wellbeing benefits and values link into the biophysical domain through ES management.

Every stage of the ES cascade model requires inputs of natural capital and, in many cases, built and human capital. First, for a species of whales to be able to supply ES, their natural environment has to be relatively intact and well-functioning. Secondly, a decision has to be made about which characteristics of a whale have potential to increase human wellbeing, and this requires cognitive human inputs. Thirdly, built capital, such as whale watching boats or tracking equipment, is often required to mobilise whale ES. Finally, to measure ES values, human wellbeing is translated into some kind of metric, which requires human capital inputs (Spangenberg et al. 2014). This expanded the original ES cascade model of Haines-Young and Potschin (2010) to include social processes and human agency at every stage of the cascade process. The amended model focuses predominantly on the formation of ES with use values that require human and built capital inputs. The individual ES co-production processes as defined by Spangenberg et al. (2014) are listed and explained below.

Value attribution 'can be characterised as an intellectual act defining an ecosystem service potential, as a potential supply for an assumed societal (and thus group and culture specific) demand' (Spangenberg et al. 2014, p. 25). This implies a recognition by a group or an individual that a particular part of an ecosystem has a potential to enhance human wellbeing and therefore has value from an anthropocentric point of view. Value attribution is the first step towards co-production of ES and involves cognitive[1] and physical co-production on behalf of humans (Palomo et al. 2016). It is essentially a social construct that depends on human needs, preferences and values in a given natural resource context.

Mobilisation of ES potential (ESP) in the ES cascade model implies transformation of ecosystem services potential, which can be defined as a possibility for a certain group of individuals to enhance their wellbeing through its utilisation. Contrary to a portrayal of ES as free-flowing gifts of nature, they are similar to other production processes and have been described as 'anthropogenically defined and produced, the results of socio-technical systems activating the potentials offered by nature's functions' (Spangenberg 2014, p. 25). As in value attribution, ESP mobilisation requires cognitive and/or physical inputs.

ES appropriation is the process of getting access to ES that enables its users to receive benefits from them. It is at this stage of the cascade model that human wellbeing benefits from ES are generated. ES are appropriated when the products of ES

[1] It is important to distinguish between two types of ES co-production by humans here: physical and cognitive (Palomo et al. 2016). Physical co-production implies processes within material ES flows and measurable physical changes in ES supply, while cognitive co-production implies inherent cognitive processes and perceptions of an individual or a group related to the benefits of a given ES, either through direct or indirect interactions.

mobilisation are enjoyed by those who have access to them. It is usually, but not necessarily, the same group of individuals who facilitate ES mobilisation through investment of human, physical and financial capital that gain this use right (Spangenberg et al. 2014). ES appropriation in this model only accounts for ES with use values.

ES commercialisation occurs when appropriated ES are sold in markets, i.e. when those who mobilise and/or appropriate ES decide to exchange at least a part of them for money or other goods. A relatively high demand for ES increases its exchange value and gives an incentive for a higher rate of mobilisation and, at the same time, for the protection of the biophysical structure/function through management interventions and sustainable use. ES commercialisation is applicable to those ES that can be exchanged in markets.

This chapter combines the conceptualisation of the ES cascade framework depicted in Fig. 9.1 with the co-production theory by Spangenberg et al. (2014), seeking to overcome some of the latter's shortcomings, i.e. its failure to account for the full spectrum of ES values. The chapter thus seeks to make a contribution to ES theory by proposing an all-encompassing model of ES co-production specific to whale ES. This is then illustrated by outcomes from ARCPATH's case studies in three Arctic coastal communities.

9.3 Research Methods and Case Study Locations

9.3.1 Research Methods

This chapter builds a cascade model of whale ES that includes underlying co-production processes using examples from case studies in the Arctic. For this purpose, a mixture of research methods was used: a literature review, stakeholder mapping, participant and non-participant observations, and 49 semi-structured interviews. All interviews were conducted by the authors using best practice guidelines in qualitative research methods (Hennink et al. 2020). Grounded theory method was then applied in qualitative analysis of the interview data, with a purpose of eliciting the key ways in which respondents co-create and benefit from whale ES (Strauss and Corbin 1990). The fieldwork for the case study research took place in Húsavík, Iceland in June 2018, in Andenes, Norway in September 2018, and in Disko Bay, Greenland in August 2019.

9.3.2 Case Study Locations

Húsavík is a medium-sized town in Northeast Iceland with just over 2300 inhabitants (Statistics Iceland 2019). The most typical whale species in Skjálfandi Bay are humpback, minke, and blue whales and harbour porpoises. The abundance of these species in the bay has been attracting visitors since the 1990s, and whale watching has since become the main tourist attraction in town, drawing more than 100,000 visitors per year (Nicosia and Perini 2016). Húsavík is the self-proclaimed 'whale watching capital of Iceland', and cetaceans play an important role in its economic, social and cultural lives.

Andenes in northern Norway is a medium-sized town with around 2700 inhabitants (Statistics Norway 2019). The main species of whales are sperm, humpback, minke and orcas. Whale watching started in the late 1980s and has since become very important for the tourism industry in the Vesterålen region and for the town's economy in general. There are plans to soon commence 'The Whale' project in Andenes, which will consist of an interactive exhibition, conference venue and cultural centre (The Whale 2019).

Disko Bay in Greenland is the largest open bay in western Greenland, measuring 150 km north to south and 100 km east to west. The main town, Ilulissat, is the third largest settlement in Greenland with around 4500 inhabitants (Statistics Greenland 2019). The town has become a popular tourist destination in recent years, offering various tourist activities, including whale watching. The main species of whales in Disko Bay are bowhead, humpback, minke, beluga and narwhal. Unlike the residents of other case study sites, Greenlanders engage in indigenous whaling, which is important for the food security and cultural identity of the local population (Caulfield 1997).

The three case study locations were chosen because of their proximity to the Arctic Circle as well as their social, cultural, and economic similarities. They are all located on Arctic or sub-Arctic coastlines and share other geographical features that encourage the presence of whales. Furthermore, they have all experienced a shift in economic activities from extractive use of marine resources to service-based economic activities, especially tourism, and all three communities depend on whale ES for their livelihoods and wellbeing to some extent.

9.4 An Analysis of Whale ES in the Arctic and the Utilization of the ES Cascade Model

9.4.1 Whale ES in the Arctic

Quite recently, a literature review-based inventory of whale ES in the Arctic was conducted by Cook et al. (2020) where, following the CICES classification system (Haines-Young and Potschin 2018), whale ES were grouped into three types: provisioning, regulation and maintenance, and cultural ES. The examples of whale ES listed in the inventory and other literature are summarized below. These are complemented with examples from the ARCPATH case studies.

9.4.1.1 Food Products (Meat, Blubber, Skin and Intestines)

Whale food products, such as whale skin (mattak) and whale meat, contribute significantly to food security in many Arctic coastal communities (Cook et al. 2020), including those in Disko Bay, where they are used for sustenance and traded in both barter and market economies. Whale food products are sourced through local hunting restricted by nationally determined quotas. In Iceland and Norway, whale food products are also available, albeit to a lesser extent, and sourced through commercial whaling which is also regulated by quotas.

9.4.1.2 Whale Bones, Teeth and Baleen

Raw materials from whales – bones, teeth and baleen – have been historically important in all three case study countries before the introduction of petroleum-based alternatives (Cook et al. 2020). Some of these raw materials are still used by craftsmen in the case study locations to produce souvenirs, jewellery, traditional tools and other artefacts.

9.4.1.3 Enhanced Biodiversity and Evolutionary Potential

There is evidence in the context of whales that more biodiverse environments are more ecologically productive. Roman et al. (2014) discuss the pump and conveyor belt functions of whales, which lead to the vertical (via diving and surfacing) and horizontal (via migration) transfer of nutrients from areas of high to lower productivity. This ES is also discussed by Wilmers et al. (2012), indicating biodiversity decline in some areas that have suffered significant losses of great whales, which are associated with trophic cascades.

9.4.1.4 Climate Regulation (Carbon Sequestration)

The submergence of whale carcases contributes to the organic content of the deep sea and carbon sequestration, providing a limited but important role in global climate regulation (Roman et al. 2014; Smith and Baco 2003). A recent study estimates that a whale stores a mean of 33 tonnes of carbon dioxide in its carcass, which most often gets buried in the deep sea for centuries when a whale dies (International Monetary Fund 2019).

9.4.1.5 Tourism (Whale Watching)

Whale watching is the single most important tourist activity in both Húsavík and Andenes, and is emerging fast as a lucrative branch of tourism in Ilulissat. Over 100,000 visitors come to Húsavík every year to go whale watching (Icelandic Tourist Board 2020), generating direct and indirect income, boosting employment and ensuring a steady flow of visitors throughout the year. The same is true in Andenes but the interview data suggests that here visitor numbers are lower and that there are actually two whale watching seasons – summer and winter. There are no official statistics regarding the numbers of whale watching passengers in Disko Bay, but interviews and observations indicate that the sector is growing rapidly, generating livelihoods and adding to the overall development of the tourism sector in the area.

9.4.1.6 Music and Arts (Entertainment)

Whale-inspired art is found in Húsavík in artwork by local artists, photographs, books and whale song recordings in the town's Whale Museum. In Andenes, most of whale-related art can be found in the souvenir shop of the main tour operator, Whale Safari. This whale ES has another dimension in Ilulissat, where whales and other marine mammals play an important part in traditional art, including fine arts, storytelling and entertainment. There are multiple traditional tales and legends about whales in Greenland, some of which have been adapted into children's stories and translated into foreign languages (Futtrup 1996). Whale songs have been a part of Inuit culture for centuries, still inspiring music today (Sakakibara 2009).

9.4.1.7 Sacred and/or Religious

Whales play an important role in people's connection to nature in all three case study countries. In Greenland, it has to do with spirituality and subsistence hunting, while our interviews in Iceland and Norway suggest that the presence of whales is considered as a sign of healthy ecosystems and can facilitate a way to connect to them. It has been reported by whale watching guides and operators that seeing a whale for the first time can be a highly emotional and even spiritual experience due to the rarity and sheer size of these animals. This type of impact was mentioned during interviews in all three case studies, yet it appears to be most prominent in Greenland where spirituality before Christianity was nature-based, and being a part of the surrounding ecosystems is still very deeply felt among the local population (Caulfield 1997).

9.4.1.8 Education

The presence of whales, combined with the growth of whale watching, facilitated the increase in formal educational activities related to whales, targeting visitors, researchers and the local population in Húsavík and Andenes. The Húsavík Whale Museum and the local primary schools, together, organised a Whale School for the local schoolchildren, while the University of Iceland Research Centre in Húsavík attracts researchers and students from all over the world. In Andenes, there are plans to open a museum, research and information centre entitled 'The Whale', aimed at educating visitors and locals about whales and marine environment. In Ilulissat, educational whale ES are apparent in the local museum's exhibitions. Moreover, stories about whales are still very much an integral part of the Greenlandic culture. This means that educational whale ES are co-produced and enjoyed in informal settings through daily cultural practices.

9.4.1.9 Aesthetics

Whales have been described as 'charismatic megafauna', being large and majestic animals that appeal to the public (Kalland 1994). The size, rarity, physical appearance and apparent intelligence of whales are sources of great enjoyment for people around the world, making whales very popular species among visitors. Interviews with whale watching guides and operators affirm that wishing to appreciate the beauty and majesty of whales is a major motivation behind choosing to go on a whale watching trip.

9.4.1.10 Community Cohesiveness and Cultural Identity

In both Húsavík and Andenes, whales have become new symbols of these towns as a result of both the expansion of whale watching and the concurrent decline of previous employment opportunities such as fishing in the Húsavik and the military in Andenes. In both places, whale watching constitutes an important economic pillar, providing a basis for expanding tourism and counteracting a 'brain drain' of the younger generation. Whales are important for these communities' outside image and socially formed identity as whale watching is the main visitor attraction. In Greenland, the cultural identity aspect is deeply rooted as whales have been the basis of subsistence and cultural practices for Greenlanders since their settlement (Caulfield 1997). Most Greenlandic interviewees, when asked what would happen to their community should the whales disappear from their area, said they could not imagine it because whales represent a part of what they are as people.

9.4.1.11 Existence

Some of the ecosystem services of whales described above, such as inspiration for the arts, the provision of educational values or simply aesthetic enjoyment, do not necessarily involve direct interactions between whales and people in an environmental setting. For many people, just knowing that whales exist and are conserved provide wellbeing benefits, which are often labelled as non-use value (Harris and Roach 2017).

9.4.1.12 Bequest

Bequest is also an aspect of non-use value that may not be regularly considered. It is related to expectations that future generations will be able to enjoy whale ES. Neither bequest nor existence values are addressed by Spangenberg et al. (2014) model but they are discussed in the CICES classification outlined by Cook et al. (2020).

It is evident from the list above that whales provide people in the ARCPATH case study communities with multiple benefits through ES. It is also clear that even though whales and their habitat are the primary sources of ES, most of these benefits require active human involvement. The next section of this chapter presents a framework for theorising how it happens.

9.4.2 An Expanded Whale ES Cascade Model Including Co-production Processes

Table 9.1, below, follows the same CICES classification system of ES (Haines-Young and Potschin 2018) used above to list whale ES. It employs the Total Economic Value (TEV)[2] framework to identify different types of use and non-use values that are later presented in Fig. 9.2 below. It adds the value domains outlined in Fig. 9.1, and elaborates ES co-production processes involved in each whale ES as per the approach of Spangenberg et al. (2014). It is important to note that human co-production activities do not occur in all whale ES. The regulating and maintenance types of ES do not require active human involvement as they originate entirely in ecological structures and processes.

[2] 'A widely used framework to disaggregate the components of utilitarian value in monetary terms, including direct use value, indirect use value, option value, quasi-option value, and existence value' (Potschin et al. 2014). TEV framework is used to classify ES according to their type of utilisation and determine appropriate valuation methods. Use value includes direct use, indirect use and option value, and non-use value is derived from the knowledge that a resource is preserved intact for the future.

Table 9.1 ES cascade model specific to whale ES including co-production activities

Biophysical structure/ process/function (subject to pressures)	Ecosystem services (subject to co-production)	Co-production activity	Benefit	Values (ES value domains and types of TEV values)
Harvested whale	Food products	Hunting	Nutrition	Economic and sociocultural; direct consumptive use
Harvested whale	Bones, teeth, baleen	Hunting	Raw materials for arts and culture	Economic and sociocultural; direct consumptive use
Harvested whale	Blubber products	Hunting	Energy	Economic; direct consumptive use
Whale carcass	Enhanced biodiversity/ evolutionary potential	None	Maintenance/enhancement of life-supporting systems	Biophysical; indirect use
Whale carcass	Climate regulation	None	Regulation of geophysical environment	Biophysical; indirect use
Living whale	Tourism (whale watching)	Whale watching	Recreation, enjoyment and health	Economic and sociocultural; direct non-consumptive use
Living whale	Music and arts	Creation of art	Aesthetic experiences, entertainment and inspiration	Sociocultural, economic; direct non-consumptive use
Living whale	Education	Educational/research activities	Education and training	Sociocultural; direct non-consumptive use
Living whale	Sacred and/or religious	Human/whale interaction Contemplation	Spiritual enrichment	Sociocultural; direct non-consumptive use
Living whale	Aesthetics	Human-whale interaction/ contemplation	Aesthetic experiences	Sociocultural; direct non-consumptive use
Living whale	Community cohesiveness and cultural identity	Community/ecosystem interaction Social/cultural activities	Cultural heritage, source of social cohesion and identity	Sociocultural; direct non-consumptive use
Living whale	Existence	Cognitive co-production: knowing/ contemplating/having certain values	Sense of satisfaction and security	Sociocultural; non-use
Living whale	Bequest	Cognitive co-production: knowing/ contemplating/having certain values	Expectation of security for future generations	Sociocultural; non-use

The table above sets forth the biophysical structures and functions that provide the basis for ES, along with corresponding co-production activities, resulting benefits, and values.

The whale ES co-production model presented in Fig. 9.2, below, stems from the elaboration of whale ES noted above. The schematic, based on the ES cascade model by Haines-Young and Potschin (2010), was designed to incorporate involvement of whale ES producers and users into ES formation, following Spangenberg et al. (2014). It presents all the main stages of whale ES formation as well as the social-ecological processes that lead to them. Despite being based largely on the ARCPATH case studies, the model is generalisable and can potentially be applied to ES co-production in other contexts.

Figure 9.2 sets out to illustrate how people benefit from whales through co-production of ecosystem services. In the model, the anthroposphere, where these processes happen, overlaps with the biosphere, highlighting the dependence of humans on ecosystems. The different parts of the model are described in the next section using examples from the ARCPATH case studies.

9.4.3 *The Stages of Whale ES Cascade Explained*

The five stages of the whale ES cascade model in Fig. 9.2 – biophysical structure/process/function, ecosystem service potential, co-produced ES, benefits, and values – are explained in the following paragraphs. They represent the products of the co-production processes that occur between each stage and ultimately lead to human wellbeing and associated values.

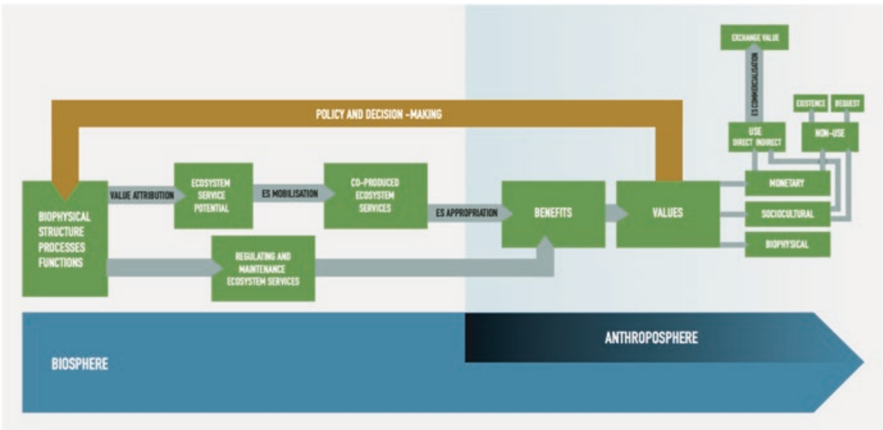

Fig. 9.2 Whale ES cascade model for whale ES. (Adapted from Haines-Young and Potschin (2010), Spangenberg et al. (2014), and informed by ARCPATH case study research)

9.4.3.1 Biophysical Structure/Process/Function

The schematic in Fig. 9.2 shows different stages of the expanded ES cascade model. A whale, its life cycle (living whale, dead/harvested whale, and whale carcass) and its biophysical processes and functions constitute the ecological infrastructure[3] of whale ES. Biophysical functions include the processes that make the whale ES possible. Whale feeding and breeding in different parts of the world provides people with possibilities to observe them in their natural habitat and gain recreational and other benefits. The whale pump facilitates nutrient cycling. Finally, whale carcasses enable carbon sequestration and enhance evolutionary potential in the deep ocean floor (Roman et al. 2014).

9.4.3.2 Ecosystem Service Potential

According to Spangenberg et al. (2014), ESP occurs as a result of recognition of the potential of ecosystems to enhance human wellbeing through value attribution. ESP is the midpoint between ecological infrastructure and the ES that require co-production. At this stage of the ES cascade (Fig. 9.2), potential users with the power and resources to do so, decide upon the ecosystem structures and functions which are valuable in a particular social, cultural and economic context, reflecting societal needs.

9.4.3.3 Co-produced Ecosystem Services

In the expanded model, there are two ways in which ES are supplied: either as regulating and maintenance ES, or as ES that require human co-production (Fig. 9.2). The model recognises that most whale ES (except regulating and maintenance) require active human involvement. For instance, for any of the provisioning ES to be enjoyed by humans, a whale has to be harvested, certain value has to be attributed to its products, and conditions provided for a whale to be hunted, and whale harvesting has to take place. Regulating and maintenance services, on the other hand, imply indirect use value and do not require any additional sourcing effort by humans. Cultural ES usually involve direct or indirect interaction between humans and whales and value attribution to the existence of a whale.

[3] [An ecosystem's] 'natural capital, its properties; and support functions that underlie other ecosystem services and are in a dynamic relationship with [that ecosystem's] processes and natural capital' (Jónsson and Davíðsdóttir 2016).

9.4.3.4 Benefits

Benefits denote an enhancement of human wellbeing. These can be direct or indirect benefits experienced individually or collectively and can occur as a result of direct or indirect human-nature interactions or market exchange with those who have access to ES. For instance, meat resulting from whale hunting in Greenland provides nutritional benefits, and the act of hunting itself – sociocultural and social benefits from the cultural practice and preserving of traditional way of life. These benefits differ between Iceland and Norway where whale meat is less significant for local food production and whaling is carried out by commercial companies. When considering benefits, one must ask the important question: Benefits for whom? This raises an array of issues concerned with needs, perceptions, conceptions of a good life, equity, and the distribution of power relations related to ES appropriation and commercialisation.

9.4.3.5 Value

In Fig. 9.2, above, the ES values are divided into the three domains first delineated in Fig. 9.1: biophysical, sociocultural, and monetary. The latter, in turn, is divided into use and non-use values, following the TEV framework (Cook et al. 2020). Non-use values can be accounted for in non-monetary terms through sociocultural valuation or in monetary terms through non-market valuation techniques. Use values can be accounted for in sociocultural or monetary terms. Given the anthropocentric nature of the ES concept, the biophysical value domain relates to the underlying ecosystem functions that translate into economic and sociocultural values (Gómez-Baggethun and Barton 2013). An example of how the value of whale ES can reside in all three of these value domains is subsistence whaling in Greenland, where some whale meat is sold or exchanged through bartering but most of it is consumed without any exchange of money. As it provides very important nutritional and sociocultural benefits, the monetary value of whale meat in Ilulissat alone is a poor indicator of the its contribution to the provisioning and the wellbeing of local communities.

The five stages of the whale ES cascade model represent the sequential transformation of certain characteristics of the ecological infrastructure into human wellbeing benefits. The processes that enable this transformation are described in the following paragraphs.

9.4.4 ES Co-production Processes, Actors and Power Relations: Case Study Examples

It has been argued above that various physical and cognitive co-production processes have to take place for ES to be possible: value attribution, mobilisation of ecosystem services potential, ES appropriation, and commercialisation (Fig. 9.2).

These processes enable transformation of different features of whales into the progressive stages of whale ES. They are heavily dependent on the context in which ES are co-produced. For this reason, ES co-production processes differ somewhat in each study location and generalisations are only appropriate to some extent.

9.4.4.1 Value Attribution

Value attribution is a context-dependent process, and it matters who participates in it and whose values and needs are represented. For example, carbon sequestration in whale carcasses is only attributed value by people if there is a perceived threat of climate change to human wellbeing. If this were not the case, there would be no perceived human wellbeing improvement from sequestering more carbon. Similarly, whale food products have a potential to enhance human wellbeing in those societal and economic contexts where whale meat is a desirable form of nutrition. One such example is found on Disko Island in Greenland where the demand for whale products is high. However, it is much less in Andenes and Húsavík, according to our interview data.

When considering the cognitive co-production process of value attribution within ES, it is important to consider who assigns values to different parts of the ecological infrastructure. Power relations between stakeholder groups in each case are also important because different ESPs often compete with one another. For instance, in the perceived trade-off between whaling and whale watching in Iceland, whose value attribution matters: citizens, scientists, the tourism sector or whaling companies? In Greenland, the whaling quotas are set by the National Institute of Natural Resources based in Nuuk, where most scientists are non-native. According to the interview data, even though the Greenlandic Hunters' Association is consulted, the hunters do not take ownership of management decisions on which their livelihoods depend, nor do they feel that their interests and values are given sufficient consideration.

9.4.4.2 Mobilisation of ESP

For whale watching to happen, first, whales have to be present and, second, a decision has to be made that whales are worthwhile seeing (cognitive process). Then, specific infrastructure is necessary to facilitate whale watching activities and make it possible for those interested to enjoy this recreational activity (physical process). ES mobilisation requires different types of capital and happens in an institutional setting where different rules can apply. The most prominent cultural whale ES in Húsavík and Andenes – whale watching – requires natural capital (whales and marine ecosystem), human and social capital (manpower, compliance with regulations, knowledge, etc.), and built capital (boats, harbour, security equipment, etc.) that is mobilised using financial capital.

The institutional settings that regulate activities related to whale resource utilisation dictate what is allowed in a certain context. In the case of whale watching within each of our study locations, there are very few formal institutional limitations. On the other hand, whaling is controlled by a number of strict rules. Social context and power relations also play significant roles at this stage of the ES cascade model. Those who provide the most inputs during the ES mobilisation processes – e.g. through human labour – do not necessarily reap the most human wellbeing benefits. An example that could be cited here are the whale watching guides. According to our interview data, they are often highly qualified, but tend to receive a relatively low wage that is characteristic of the hospitality industry.

9.4.4.3 ES Appropriation

To be able to hunt whales and get access to the provisional whale ES, requires whaling equipment that comes at a considerable cost. Whale watching operators in both Húsavík and Andenes have been able to repurpose some existing fishing boats or to secure new rib boats. This requires certain upfront investments and prevents some potential whale watching operators from entering the market. In Greenland, whale watching is conducted using either small privately-owned boats that have permits to carry up to ten passengers or bigger specialised vessels usually owned by larger foreign tourism companies. Greenlandic whaling is also operated using mostly small privately-owned boats and obtaining a recreational or professional hunting license is relatively straightforward. However, the whaling quotas tend to be rather small in number when compared to demand, which increases competition between hunters.

Who gets to enjoy the excludable whale ES is determined by those who have the use right (Felipe-Lucia et al. 2015). Those who mobilise ES gain use rights and benefits from ES, which they can choose to enjoy themselves, share for free, or exchange with others. Here the questions of equity, fairness and social power relations arise. For example, whale watching and whaling vessel owners are generally the only ones who can access provisioning and recreational whale ES, while others have to get access by purchasing them in markets. The relatively high market price of whale watching may price out low income visitors from the recreational benefits of whale watching.

9.4.4.4 ES Commercialisation

Use values of whale ES become exchange values through ES commercialisation as set forth in Fig. 9.2. This is when those who mobilise and/or appropriate ES decide to exchange all or a part of them for money or other goods. High demand for ES increases its exchange value and provides an incentive for higher rates of mobilisation and, at the same time, protection of the ecological infrastructure through management interventions and sustainable use. (Note the uppermost arrow in Fig. 9.2).

In Húsavík, there are relatively few whales compared to the amount of whale watching boats. However, the number of whale watching trips has grown almost exponentially since the 1990s. The potential negative effects of whale watching on whale populations (Christiansen et al. 2013) raise questions about whether they should be regulated. Responding to such concerns, the Icelandic Whale Watching Association created a code of conduct to provide whale watching operators with guidelines (IceWhale 2015).

Other examples of whale ES commercialisation can be seen when Greenlandic part-time hunters[4] decide to sell their catch in a local market instead of keeping it all for themselves and their families, or when small-boat owners start taking passengers out to sea and charge money for such tours. In both cases, those who mobilise ESP decided to exchange the resulting ES, which then becomes a market commodity. Commercialisation of education and related whale ES occurs through sales of whale watching tours, educational materials, and entrance fees to museums.

9.5 Discussion and Conclusion

9.5.1 Possible Policy Implications

The expanded model outlined above conceptualises human involvement in the co-production of whale ES. It challenges an existing view of ES as a one-directional flow of benefits from ecosystems to societies. Our alternative perspective that has been introduced in this chapter portrays humans as active co-producers of many whale ES through value attribution, mobilisation, appropriation, and commercialisation. Such findings have the potential to inform policy tools targeted at influencing these processes from ecological structures to market exchange. An example of this can be seen in the Icelandic Code of Conduct in Whale Watching where private actors with economic interest in recreational whale ES cooperate to protect the underlying ecological infrastructure.

The analysis of ES co-production processes reveals some power and equity issues that are also relevant for policymaking. For instance, in ecosystem-based management, they present a way of accounting for the human dimensions of marine ecosystem management (Christie et al. 2017). These dimensions play out through ES co-production processes as uneven influence over value attribution, differentiated access to capital that is necessary for ES mobilisation and appropriation, and disproportionate influence on ES management. This is apparent in the policy area of whaling within Greenland where those who depend the most on whale ES have little influence over the rules regarding their harvesting.

Of the three value domains highlighted in this chapter (Figs. 9.1 and 9.2), exchange values are the most commonly used in ES valuation, often detracting from

[4] There are two types of hunting licences in Greenland: for full-time and part-time hunters.

the biophysical and sociocultural value domains. However, in many Arctic coastal communities, whale ES constitute important biophysical and sociocultural values as they play a central role in local social-ecological systems. This is especially true with respect to Greenland's heritage where the relationship between humans and marine mammals is of great sociocultural significance. Some of these values cannot be accounted for by monetary valuation alone (Cook et al. 2020) and require alternatives, such as sociocultural valuation and deliberative ES valuation methods (Martín-López et al. 2014). The analysis of whale ES formation and evidence-gathering process via interviews in this chapter promote a stakeholder-focused approach to marine resource utilisation.

Focusing on whale ES and their contribution to human wellbeing alone is not sufficient, in itself, to ensure the protection of marine ecosystems and their necessary functions underpinning whale ES. The functioning of entire ecosystems need to be taken into account. Hence, a wider approach is needed to consider different aspects of socio-ecological systems, in particular sustainability, ecosystem dynamics and multi-species interactions (Granek et al. 2010).

Ecosystem-based management is an approach that fits well with the discussion of ES in this chapter because it includes ecological, economic and societal objectives in marine ecosystem management (Long et al. 2015). It is a preferred approach to marine ES management that is encouraged by the Arctic Council (2013). The view of society as an integral part of a social-ecological system rather than something external to nature accommodates the consideration of actors and processes outlined in this chapter.

9.5.2 Uncertainties, limitations and research needs related to whale ES cascade.

Unpredictability of whale resources is an important issue to consider in whale ES analysis and management. In all three case study locations, whale species and populations have been fluctuating in tandem with biophysical conditions, not least due to observed climate change. Whales are highly migratory species, and any changes in natural conditions and the distribution of prey species can cause them to leave their usual feeding areas. Data gained from interviews with experts in Norway indicate that this happened in Tromsø in 2018, leading to the near-total collapse of whale watching in the area and causing concern that something similar might happen in other Arctic locations. Therefore, improved knowledge of biophysical changes and anthropogenic activities affecting whale behaviour is crucial for reducing this uncertainty.

The ES cascade model presented in Fig. 9.2 was adapted to include sociocultural and biophysical value domains as well as non-use values. However, even when included in the model, the non-use values can be difficult to account for in policy making. Non-market valuation techniques have been applied in certain attempts to monetise non-use values of marine ES, but their results should be supplemented with information on other types of values for more comprehensive assessment (Chan et al. 2012). Multiple value domains might be affected simultaneously following impacts to whale ES in each of the case study communities. Value pluralism would have to be addressed through integrated ES assessment methods to account for these changes.

The ES cascade model has also been criticised for failing to take into consideration power relations and the socio-economic realities of ES co-production, access and use (Berbés-Blázquez et al. 2016). This chapter has strived to address these concerns in the context of whale ES in the Arctic. Moreover, even though the ES cascade model acknowledges the presence of synergies and trade-offs between ES, its ability to quantify them is rather limited due to many uncertainties and complexities that are at play between the different uses of marine ecosystems (Granek et al. 2010).

Another challenge relates to conducting ES valuation using methods that can be hard to apply in policy (de Groot et al. 2010). Monetary ES valuation methods often involve surveys that might not be able to reach a representative sample of a given population. Results might be affected by budget constraints or limited by an aversion to paying additional fees for environmental protection. For instance, the contingent valuation study on expanding the whale sanctuary in Faxaflói Bay, Iceland (Malinauskaite et al. 2020) captures some of the preferences of Icelanders regarding its size and reveals public division on the subject of whaling. However, it remains to be determined what this means explicitly for management of whale ES. Sociocultural valuation reflects non-monetary values, but their implications for management are harder to quantify due to complicated metrics that decision-makers are not familiar with in many cases.

Finally, considering that whales are highly migratory species that cannot be confined to one marine ecosystem, the ES approach has a limited ability to account for some of their regulating and maintenance and provisioning forms of ES during periods of time when they are not present in a given location. The question of whether whale ES are still valuable when not present in a certain location relates to perhaps the biggest philosophical limitation of the ES concept – its limited capacity to account for intrinsic ES values in the absence of a human presence.

9.6 Concluding Thoughts

In this chapter, an ES cascade model was developed for whale ES and expanded to account for co-production processes. The inventory of whale ES was informed by a literature review and illustrated using empirical examples from three ARCPATH case study coastal communities in Iceland, Greenland and Norway. The purpose of this exercise was to highlight the role that humans play in ES formation and to further our understanding of the contribution of whale ES to the wellbeing of people in the Arctic. The resulting model conceptualises where and how in the whale ES cascade human co-production occurs. It also includes some considerations of equity and power relations that are crucial to any analysis of natural resource use.

The purpose of ARCPATH has been to connect climate science to on-the-ground societal effects, highlighting community perspectives and possible pathways to action. The first link that ARCPATH has explored is that between climate change and environmental impacts (see Chap. 8 in this volume). The second link, which is the focus of this chapter, is between environmental change and human wellbeing (see also Chap. 10 in this volume). The conceptual framework for studying human-nature interactions presented here is a first step towards analysing how changes in marine ecosystems may affect local communities and how these effects might be best addressed. Whale ES represent an understudied area in Arctic and ES research, and the focus on co-production processes helps to identify much-needed local community perspectives within these fields.

The ES cascade model provides a conceptual bridge between ecosystems and societies that is needed for effective policy advice. The processes highlighted in this chapter can be targeted to ensure more socially and ecologically sustainable use of whale resources. Albeit, the unpredictable nature of these marine mammals and the scale of social-environmental change in the Arctic makes management more difficult and require adaptiveness and reflexivity on the part of policy makers.

In the context of rapid change in the Arctic and diverse uses of whale ES, there is a need for more primary ES valuation studies covering the full spectrum of value domains. Likewise, more research is needed on the biophysical and co-production processes that underpin ES values, and better understanding of power relations, determining who participates in co-production. Additionally, more attention needs to be directed toward who experiences whale ES benefits, and who has the decision-making power regarding their management. These research directions combined hold a potential to build better linkages between the disciplines in their inquiries into social-ecological change in the Arctic.

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Chapter 10
"Small Science": Community Engagement and Local Research in an Era of Big Science Agendas

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Abstract Community engagement in the research process is more than communication and outreach. It is a process of co-production of knowledge. The co-production of knowledge starts and ends at the "small" local level but is embedded in "big" processes that are nested in academic and research institution priorities. This chapter problematizes the issues of small-to-big science and reflects on limitations related to community engagement in research such as community research fatigue, un-standardized research ethics protocols across research institutions, and limitations in funding bodies' budget schemes. It considers lessons learned by theorizing a "sliding scale of community engagement" that can be used to conceptualize the definitions of community engagement activities within a large research project. The chapter also places emphasis on discussion of the community-engagement experiences of the Nordforsk-funded Nordic Centre of Excellence project *Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies (ARCPATH).* This project has facilitated excellent collaboration with our informants in our

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research communities and hence provides a significant example of the co-production of knowledge that we seek to encourage.

Keywords Community engagement · Co-production of knowledge · Knowledge mobilization · Outreach · Dissemination of knowledge · ARCPATH

10.1 Introduction

> The hunters and fishers know a great deal about what is going on. They live in and experience the coastal areas all year round. We believe that their knowledge, if collected systematically, can be a huge help to making decisions regarding management of these resources (Pâviârak Jakobsen, Konst. Fagchef, Aasiaat, (Chief Scientific Officer) Qaasuitsup Kommune.

The process by which research data are collected, particularly in relation to practices and methodologies of community engagement, is an important, yet often under-theorized aspect of research activities. The authors of this chapter are all involved in the *Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies (ARCPATH)* project. In addition to considering specific aspects of climate and sea-ice changes, the project has focused on socio-economic and social-ecological changes in specific locations in Iceland, Greenland and northern Norway. These locales include coastal communities that are highly dependent on marine resources. (The specific locations can be found on the map in Chap. 7 of this volume.)

The project's resulting variety and breadth of community-based experience has provided a platform from which to analyse our own field practices with the goal of developing a potential guiding template to assist other researchers contending with methodological and ethical concerns of field and community-based research. Such analyses could prove vital in an era of changing expectations of scientific funding agencies that often call for increased community engagement in social-ecological systems research. Within this particular context, this chapter considers the issues of small-to-big science and reflects on related limitations to community engagement in research. These include such issues as community research fatigue, the lack of standardized research ethics protocols across research institutions, as well as the absence of sufficient funding. The authors of this chapter provide a "sliding scale of community engagement" that can be used to better understand the nature of community engagement activities in a large research project such as ARCPATH. Working closely with local informants, the project thus aims to produce findings that aid in the responsible and sustainable development of the Arctic. Through community engagement and the co-production of knowledge, this ARCPATH analysis can aid in developing local and international climate-change adaptation measures and new pathways to sustainability throughout the Arctic and beyond.

10.2 Community Engagement and Knowledge Co-Production: Definitions and Considerations

> Co-production of knowledge between academic and non-academic communities is a prerequisite for research aiming at more sustainable development paths (Pohl et al. 2010).

Until recently, scientific research-derived knowledge has been viewed as being created by academics who then disseminate this knowledge in a one-way flow to other interested scientists and policy makers, primarily through scholarly journals. This view of knowledge production is now seen as increasingly problematic, particularly in research that involves people and their communities.

Within all of the science disciplines, the research practices of anthropologists, by definition, have always involved close contact and information-gathering activities with communities that have often had an unequal power and economic relationship with either the researchers or the countries from which they have traditionally hailed. This context may be seen as colonialist in character, with fieldwork practises that are now increasingly seen as involving the "extraction" or "legalized theft" of data from communities and families without their consultation or consent (Sillitoe 2007). Such practises were once disturbingly routine, with the data gathered being used for the consumption and benefit of the researcher and his or her society without regard for the people from whom the information was taken. Globalization and resulting concerns about such practises have led, in part, to a shift in practice by anthropologists and other social scientists. This has resulted in a new emphasis on working with field-site communities to jointly identify research needs and encourage their direct participation in the co-production of research designs and knowledge (Sillitoe 2007). This shift in approach includes the concept of knowledge production as a collaborative partnership that can include researchers and members of the communities most directly impacted by the research findings and the policymaking based on those findings (Jasanoff 2004; Djenontin and Meadow 2018). This creates a means for promoting dynamic, inclusive and legitimate research processes and outcomes. A community-engaged research approach is thus one that involves and facilitates collaboration with the field-site communities as integral components of the research endeavour that may incorporate both qualitative and quantitative research methods. This approach encourages recognition of the strengths of community institutions and individuals and is guided by enhanced research ethics principles and a more respectful relationship between the researchers and community.

Community-engaged research that leads to co-production of knowledge with community members and other stakeholders has become a central tenet or characteristic of transdisciplinary research, including the inclusion of different knowledge systems and knowledge holders, and a practical, problem-focussed approach (Max-Neef 2005; Hirsch-Hadorn et al. 2006; Lang et al. 2012; Patterson et al. 2013; King and Ogilvie, in Chap. 18 of this volume). Increasingly, knowledge co-production and, in particular, the inclusion of local and traditional knowledge holders, is now an important determinant of the success of co-management regimes that are being adopted as governance mechanisms in the Arctic (King 2004; Armitage et al. 2011; Berkes 2017).

An analysis of transdisciplinary co-production of knowledge in the development of organic farming in Switzerland found that a "transdisciplinary mode of knowledge co-production implies that problem-solving strategies have to be based on a close interaction between scientists and other involved actors" (Aeberhard and Rist 2008). Within Arctic research, incorporating local participation and collaborative approaches is now considered crucial in any research design. As Daniel Chartier (2018: 19) writes, "Ignoring the cultural and human aspects of the North leads to denying the complexity of circumpolar relationships and representations and can lead to the establishment of policies that are maladapted to the territory. One must reflect on the principles, the methodology, and the practices that set the definition of the North and Arctic in a sociocultural perspective, because they have fundamental political and ethical implications." ARCPATH has also taken such issues extremely seriously. The project strives for interdisciplinarity, an approach that takes multidisciplinarity (research that simply draws on different disciplines) one step further to integration. Hence "transdisciplinary" implies the combination of knowledge into a meaningful whole where individual disciplines are transcended (Petrie 1992). ARCPATH strives for transdisciplinarity and specifically uses the term to include local knowledge from stakeholders and others as well academics.

Within the field of environmental science, a commonly accepted definition of knowledge co-production has been "… the contribution of multiple knowledge sources and capacities from different stakeholders spanning the science–policy–society interface with the goal of co-creating 'usable' knowledge and information to inform environmental decision-making" (Lemos and Morehouse 2005). A definition of knowledge co-production that focuses on sustainability research suggests that it is the: *"interactive and collaborative processes involving diverse types of expertise, knowledge and actors to produce context-specific knowledge and pathways towards a sustainable future"* (Norström et al. 2020). The ARCPATH project, through its researchers' interactions with Arctic communities, has adopted transdisciplinary research approaches including an emphasis on knowledge co-production. Community engagement processes in ARCPATH have thus focused on working with community members to identify research issues and needs, to include local and traditional knowledge systems and knowledge holders, and to co-produce knowledge as research outcomes that will solve community problems and improve environmental governance for sustainability.

10.3 Considering Issues of Research and Community Engagement

There is a growing trend by funding agencies to support research that is transdisciplinary, centered on problem-solving, and has a community engagement component. But even when community engagement and co-production of knowledge is a stated research aim, a number of factors can hinder the ability of researchers to engage meaningfully with communities. One issue is that data gathered about, by, and within communities are often context-specific, and it can be hard to generate meaningful data concerning individual communities if the end goal of the research effort is the compilation of the data into a larger data set. Quantitative data concerning socio-economic trends are more easily separated from context, but other equally important qualitative data, on such topics as fisheries, can be difficult to aggregate (Lorance et al. 2011). Furthermore, trends in contemporary scientific inquiry seem to point toward the importance of meta-data and aggregate data sets, as researchers move from data-lacking systems to data saturation situations. This is for a good reason: global issues such as climate change and biodiversity loss necessitate the sharing of data across boundaries and from many disciplines. In the following section, we present some of the complexities faced by researchers trying to promote community engagement and avoid data extraction while conducting community-based research.

A. ***Community research fatigue***

The participation of local individuals and communities in academic research necessitates a voluntary contribution. Even in cases in which participants are paid for their time, they are still choosing to engage of their own volition. In the whale ecosystem services aspects of the ARCPATH project, community participants have generally been extremely open and willing to engage in both qualitative and quantitative research efforts. They often gave up more than an hour of their time to contribute to such undertakings. However, the willingness of participants to take part in future research efforts cannot be taken for granted. Researchers may also be confronted with the effects of over-research in an area, known as “community research fatigue” (Edwards and Holland 2013; Sukarieh and Tannock 2013). Particularly manifest in communities with a limited geography and population, academic research interest can exhaust or overwhelm local contributors, particularly if the community, in the past, has been disenfranchised from the results of research or has witnessed their views being misrepresented.

In addition to professional researchers and journalists, many higher education institutes have graduate and undergraduate students undertaking community-based research. With limited local knowledge or training, these students may exacerbate feelings of research fatigue within the community. In addition, when researchers make promises they cannot or do not keep, this can result in communities questioning the researcher’s true identity and agency. This can also result in community withdrawal or fatigue.

ARCPATH project researchers experienced this situation when they found they had overpromised with respect to the mutual benefit and eventual social change that would derive from their inquiries. Such unintentional actions by researchers will often make community members feel exploited in terms of their time and knowledge or betrayed when their contributions are incommensurate with the local needs. Community disengagement also often occurs when researchers make claims of reciprocity, for example, in the sharing of eventual research findings or in the supply of payments to research assistants and interviewees for time incurred and then fail to follow through on their promises. In all these examples, continued research fatigue will lead to strained relations between researchers and community members, or even animosity or open hostility to ongoing researcher demands.

Research fatigue can also emerge when research participants are truly uninterested in, or unfamiliar with, the topic of the research project. This may be especially the case if they feel that their own experience and knowledge has only a peripheral relationship with its themes. If there is little community interest in the topic from the start, then maintaining any real engagement will be problematic. In recent years, remote communities in Greenland have been the focal point of extensive research undertaken by scientists from multiple disciplines. International scientists increasingly visit the locale to gather better understanding of climate change, take samples, collect ice cores and set up monitoring equipment. These activities may or may not be of great interest to local residents. Other dimensions of climate change, however, including social-ecological and social-cultural issues may be of more relevance to Greenlandic communities. It is these topics that have been investigated by researchers in the ARCPATH project.

In spite of this fact, ARCPATH's scientists are non-Greenlandic. This entails the risk of their research representing an outside worldview in which Greenlanders have limited ownership or investment. This is particularly true when a research topic includes issues challenging or controversial to Greenlanders, such as whaling and fishing quotas, or climate policy. (See Chap. 9 of this volume.) It was evident during ARCPATH's interviews with Greenlandic stakeholders in Disko Bay (Qeqertarsuaq in Greenlandic) that there already existed some distrust between fishermen and biologists. This was because the biologists, who were neither local to the area nor, in most cases, Greenlandic nationals, had the power to make quota recommendations to the Greenlandic parliament. Because we were not seen as official biologists, we were more accepted by the fishers. Nevertheless, it must be conceded that community engagement was easier to secure in Iceland and Norway, which have cultures closer to those of the project researchers. Furthermore, several of the ARCPATH team members are Icelandic, Norwegian or Danish (Fig. 10.1).

In the case of our research in Greenland, in the Ittoqqortoormiit (Scoresby) and Tasilaq areas, the project was extremely fortunate to be able to include Janne Flora, an established Danish anthropologist/eskimologist who is deeply versed in the local cultures. Although this aspect of ARCPATH research is not highlighted here, Níels Einarsson also had several very successful interactions with hunters in his field work in Ittoqqortoormiit. In many of these cases, the cultivation of trust and rapport led to a 'snowball' effect, with each interviewee suggesting other useful people with whom the researchers might talk.

Based on our experience in the ARCPATH project, we present three core recommendations aimed at securing successful community engagement. These can help to override the potentially negative impacts of research fatigue. They are not distinct categorisations and can be mutually reinforcing given that each approach relates to the underlying issues of cultivating mutual trust, rapport, reciprocity and credibility. Each of these recommended approaches are explored below with respect to their potential for minimising the degree of community research fatigue.

Fig. 10.1 The photograph shows calving icebergs from the magnificent Sermeq Kujalleq (Jakobshavn) glacier adjacent to the town of Ilulissat, western Greenland (population 4905). Within the last ten years the glacier has doubled its speed. Today it moves at a speed of around 40 metres every 24 h (see http://www.kangia.gl/Fakta%20om%20isfjorden/Sermeq%20kujalleq%20-%20verdens%20hurtigste%20gletsjer?sc_lang=en). (Photograph: Astrid Ogilvie, May 2019)

1. *Align research interests with those of the interviewee(s) to emphasise mutual benefits*

In the parts of the ARCPATH project involving research on whale ecosystem services, careful attention was paid ahead of each field trip to Iceland, Norway and Greenland to identify the most suitable stakeholders to interview. This was done regardless of whether these individuals were whale watchers, hunters, government workers or local business owners. Stakeholders were split into economic and non-economic categories. In the case of the former, they were further identified according to whether they were direct or indirect beneficiaries from whale resources. In the case of the latter, they were split into regulatory and non-regulatory interests.

2. *Demonstrate the potential positive impacts of the research*

Sometimes community research fatigue will develop because of the perception of a lack of change attributable to previous involvements in such projects. This problem can be difficult to counter when interviewees have previously engaged in research with an expectation of a sizable impact, only to later find no discernible changes. Rather than emphasising policy or regulatory change as the inevitable outcome of a research process, the ARCPATH researchers who addressed whale ecosystem services were keen to stress the broader benefits of gaining greater understanding of the current social-ecological and socio-cultural situation, and how this had changed from the past, and might be expected to alter again in the future. In this way, the community interviewees became aware that they were a valued informant in the research process due to their accumulated knowledge and perspectives.

3. *Establish and build mutual trust*

Due to a desire to treat our informants with sensitivity and respect, considerable preparations were made in advance of the ARCPATH Greenlandic field trip to Ilulissat, Qeqertarsuaq and Aasiaat in August 2019. Emphasis was placed on clarifying the importance and topicality of the research, how the research information would be treated, and the mutual benefits of communicating research outcomes to a broad array of interested parties, including governance institutions, academia and NGOs.

No promises were made concerning how policies and regulation might change in the future, but the researchers were very interested in how stakeholders might perceive particular changes to be either disadvantageous or advantageous, for example in relation to whale-watching codes of conduct or hunting quotas. Through a consultative and, above all, collaborative approach focused on the building of societal knowledge rather than directly shaping national policy or instigation of social change, it was possible to overcome the negative triad of possible ailments that can hinder such research: prior misrepresentation, extensive knowledge extraction and failed promises. In particular, the researchers focused on the importance of multiple forms of knowledge and ways of knowing, with none considered superior to another. This was particularly the case in Qeqertarsuaq, regarding the co-existence of traditional subsistence whale hunting alongside the relatively recent, market-based economy of whale watching.

B. ***Participant Compensation***

The researcher has the luxury of studying the community as an object of science, whereas the young Indian, who knows the nuances of tribal life, receives nothing in the way of compensation or recognition for his knowledge, and instead must continue to do jobs, often manual labor, that have considerably less prestige. If knowledge of the Indian community is so valuable, how can non-Indians receive so much compensation for their small knowledge and Indians receive so little for their extensive knowledge? (Brugge and Missaghian 2006).

Therein lie some of the complexities, contrasts and challenges in the researcher-indigenous interviewee relationship, inequities which reinforce the importance of providing appropriate compensation for contributing to academic research projects including those in the Arctic. The practice of paying interviewees for their time and insight appears to have become increasingly common throughout the global research community, but is a sensitive issue as different cultures have different approaches to this practice. In Iceland, for example, it has been the case that interviewees might find an offer of payment for knowledge inappropriate and even insulting. This may have something to do with Iceland's exceptional standard of literacy where a local farmer or fisherman, for example, may well have a high level of education. Or perhaps also because Iceland has a long tradition of welcoming travellers interested in their country, starting as early as the eighteenth century (Ogilvie 2005). Certainly, the implications of paying local community members, and the terms for doing so in both the design of research and the reporting of results, appears to have been overlooked in most academic literature.

In the case of ARCPATH’s interviews in Greenland, which were focused on the topic of whale ecosystem services, there were several reasons why the researchers opted to pay Inuit hunters for their insights. These included, in no particular order of importance, the following: (1) to incentivise participation; (2) as an expression of thanks for the time spent during the interview; and (3) as a way of recognizing the challenging subsistence income of the hunters relative to other interviewees. As the initial quotation introducing this section suggests, there are a number of strong rationales for paying indigenous hunters for their interview contributions. Not the least of these is the fact that the researchers themselves are being compensated through generous salaries and have all of their trip expenses covered by the project’s budget. From this perspective, the act of payment could be seen as critical to overcoming, in a small way, some of the power imbalances between the interviewers and the interviewees. It can be seen as an act of recognition and respect that can also lessen the potential for community research fatigue.

C. ***Ethical Considerations***

In recent years, academic research involving human beings is generally required by universities or funding agencies to address ethical elements which guide the formulation and undertaking of its methods. Ethical dilemmas in qualitative research methods, such as the semi-structured interviews undertaken in the ARCPATH project, occur due to the moral and ethical complexities of researching private lives and determining which aspects of accounts can be placed in the public arena. Non-professionals, including most community members, do not generally set “on” or “off the record” boundaries for themselves. So, for example, they may reveal tensions between their private opinions and the public standpoint of the institution which they represent. This may have a negative impact on them should this be made public. Although each academic institution varies in its approach to the ethics of academic research and will have its own internal protocols, there is merit in developing a standardised protocol for research involving human subjects conducted across the Nordic region (see for example, ACUNS 2003; NSF 2018).[1]

In the ARCPATH project, no specific protocol was relied upon, although the five core principles suggested by the Interagency Arctic Research Policy Committee (IARPC) were followed. These principles include the direction that researchers should: “*be accountable; establish effective communication; respect indigenous knowledge and cultures; build and sustain relationships; [and] pursue responsible*

[1] It may also be noted that guidelines are freely available for those who wish to conduct research in the Arctic (and elsewhere). It is possible, for example, to undergo training such as with the Collaborative Institutional Training Initiative (CITI) programme on Research Ethics and Compliance Training (see https://about.citiprogram.org/en/homepage/).

environmental stewardship".[2] (IARPC 2018) There are also several additional common ethical considerations relating to qualitative research methods such as issues of confidentiality, treatment of culturally sensitive information, and collaboration. These were considered carefully in relation to the first four stages of the semi-structured interviews used in our ARCPATH investigations at each stage of the research: thematising; designing; the interview; and transcription and analysis. Each of these are now briefly considered in Table 10.1, below. It sets forth the core ethical questions that were considered by the project's social science researchers during each stage of the process. A brief commentary on ARCPATH's approaches in response to these dilemmas is then outlined in the subsequent text.

Thematising

In this stage, the aims of the investigation were defined and a summary made of the main content of the topics for the semi-structured interviews. With regard to the ARCPATH case studies addressing the subject of whale ecosystem services, the thematic focus of the investigation was to examine the benefits that societies receive

Table 10.1 Ethical considerations in semi-structured interviews

Interview stage	Core ethical questions
Thematising	What are the beneficial consequences of the study?
Designing	How can the study contribute to enhancing the situation of the participating subject? Or the group they represent? Or the human condition?
The interview	How can the informed consent of the participating subjects be obtained?
	How much information about the study needs to be given in advance, and what can wait until a debriefing after the interviews?
	Who should give the consent? Was it the subjects or those for whom they work?
	How can the confidentiality of the interview subjects be protected?
	When is it important that the subjects remain anonymous?
	How can the identity of the subjects be disguised/protected?
	Who will have access to the interviews?
	Can legal problems arise concerning the protection of the interviewees' anonymity?
	What are the consequences of the study for the participating subjects?
	Will the potential harm done to the subjects outweigh potential benefits?
	When publishing the study, what consequences may be anticipated for the subjects and for the groups they represent?
Transcription and analysis	How did the researcher's role affect the study?
	Was a broad enough array of stakeholders secured in order to obtain meaningful representation for the specific case study?

[2] See the guidelines on the Principles for Conducting Research in the Arctic published by the Interagency Arctic Research Policy Committee (IARPC). This organisation emphasises five core principles: be accountable; establish effective communication; respect indigenous knowledge and cultures; build and sustain relationships; pursue responsible environmental stewardship (see https://www.iarpccollaborations.org/principles.html).

from marine mammals. An effort was made to look at how these benefits are altered by intensifying climate change (Arctic Report Card 2019) and rapid economic development, especially with regard to tourism and hunting. The study also looked at how marine ecosystems are managed currently and how they could be managed more sustainably in the future.

Designing

This stage involved careful evaluation of the moral and ethical implications related to the intended knowledge sought from the semi-structured interviews. Interviewees were provided with a detailed briefing about the aims of the overall ARCPATH project and the specific objectives of the semi-structured interviews. They were introduced to some basic technical content fundamental to the research and the researchers' strategy concerning data management and participant anonymity.

Participants were informed about the concept of ecosystem services as a way of understanding the various human well-being benefits that can be obtained from environmental resources. This conceptual understanding was then placed into a management context. Those interviewed were then told about the researchers' commitment to participant anonymity and confidentiality throughout the research process, including its analysis, the dissemination of results through the writing of articles and reports, and ultimately the conclusion of the ARCPATH project. In accordance with the requirements of the European Union's General Data Protection Regulation (2016/679),[3] it was explained by the researchers that all recorded interviews would be stored on secure servers and password protected computers. It was noted that the data from the study would be used only for the purposes of the ARCPATH project, and following its completion, all recorded data would be destroyed. In addition, interviewees were asked to give their verbal agreement for the interview to be recorded, stored, transcribed and analysed. As part of a debriefing session at the end of the interview, participants were provided with the opportunity to inform the researchers about any issues or questions that they had not been asked, but which they thought to be relevant to the overall purpose of the interview.

The Interview

Each of the 51 semi-structured interviews conducted by ARCPATH researchers on the topic of whale ecosystem services was conducted with the aid of a pre-prepared interview framework. The interview frameworks for the case studies in Húsavík, Iceland and Andenes, Norway were identical in design. However, the framework used in Greenland was adapted to account for the Indigenous hunting aspect of the community. In addition, the Greenlandic interviews were also prepared in Danish. At all times during the questioning, a reflective approach was undertaken with respect to the knowledge sought and in the interpersonal relations of the interview situation. This helped to inculcate trust and develop rapport between the interviewers and the respondents. The researchers emphasised during the briefing phase, at the outset of the interview, that there were no "right" or "wrong" answers to any of

[3] See https://eur-lex.europa.eu/eli/reg/2016/679/oj/eng

the questions, merely viewpoints to be heard. Some of the key questions asked in the interviews were as follows:

1. Do you think that you derive any benefits from whales personally, and if yes, what are they?
2. In your experience, has the way that people perceive whales in [X] changed in the last couple of decades? If so, how? Has your perception changed over time? If yes, how and why?
3. Have you noticed any major changes in the way whales are utilised/and what people do to benefit from whales in [X] over the last couple of decades? If so, what have been the main drivers?
4. How would you evaluate the present situation of whale populations in [X]?
5. Who do you think has the most/least influence over what is happening in whale management in [X] at the moment?

A variety of sub-questions were then asked depending on the particular responses to these initial questions. In addition, if participants found it difficult to answer a question, "probes" of inquiry were developed and these formed additional parts of the interview guide. This ensured the smooth flow of the interview and helped maintain the ease of the interviewee.

Transcription and Analysis
For each of the semi-structured interviews, a transcription was made using MAXQDA software. In the analysis of the project, the researchers were asked to reflect once more on the initial aims of the project as determined during the thematising phase. In addition to the preparation of a general written summary of the content of each interview, this process will help to determine the coding that will be applied to the data. In order to ensure the most accurate representation of the interview content, the researchers will undertake a verification process. This will ascertain the reliability, generalisability and validity of the interview findings. In so doing, the consistency of the results and the extent to which the interviews investigate what was meant to be investigated will be determined.

Based upon the experiences of the ARCPATH project, it may be useful to develop a standardised ethics protocol applicable to all research institutions operating in the Nordic Arctic related to the study of human subjects. As noted above, both ACUNS and the NSF have developed such research guidelines for the Canadian North and for the USA as a whole. The aim of this brief chapter is not to create such a protocol, here and now, but it might be helpful for future efforts to highlight some of the main ethical and moral observations pertaining to this type of qualitative research that emerged from ARCPATH's experience. These include the following views:

- Co-production of knowledge involves close interactions between interviewers and interviewees, necessitating careful attention to the ethical implications of these involvements.
- The ethical issues relating to an interview with a human subject go beyond merely the interview itself, encompassing preceding and post-interview stages.

- Establishing informed consent on the part of the interviewee is an important part of the process, helping interviewees to also understand the implications of their participation in the study and the researchers’ role.
- Even if an ethics protocol is developed, it must be recognised that maintaining ethical standards in qualitative research methods involves a lot of on-the-spot judgments by researchers concerning the implications of an answer, how to follow-up, and what issues might be deemed too sensitive or inappropriate for further questioning.
- The interviewer acts as the instrument of the interview, meaning that their personal integrity as a researcher is critical to the ethical standards of its inquiry.
- Consideration of research ethics goes beyond the interview design and process itself, but also includes recognition on the part of the researchers of the value of co-produced knowledge in a broader societal context, such as the Arctic as a whole.

10.4 Implementing Collaborative Research Design Between Researchers and Field Site Communities

The co-design of research is a significant pre-requisite for the co-production of knowledge and research outcomes. It is at this stage that the perspectives and priorities of the communities, individuals and other stakeholders should become clear. This is also possibly the most difficult and neglected aspect of transdisciplinary research, since research design is often decided at the proposal stage to meet the requirements of academic institutions and funding agencies long before researchers visit a field site or community. For implementation of a collaborative project involving the co-production of knowledge, the people within the community being researched need to be able to determine the relevant area(s) of investigation and design questions in collaboration with researchers. One technique for establishing this type of early collaboration is to establish a community research institution or committee that identifies community priorities for research and trains community researchers (McDonald 2003; Murray and King 2012).

As part of the ARCPATH project, a case study on fisheries governance in Iceland used co-design and co-production practices in determining the original research questions to be posed to newcomers and current participants in fishing regarding the future of the fishery. Through multiple subsequent meetings, the ARCPATH researchers and their local informants have worked together on a variety of issues. Thus, the co-production of knowledge represents engagement in activities from all stages of research, not least because the original research questions of the future for newcomers in fisheries came from current fishers themselves. Through multiple meetings, ARCPATH members and fishers, together, designed several research questions. Fishers were also instrumental in the data-collection phases of the research effort, guiding the direction of interview instruments and providing feedback as the project progressed. Below, we include an example of the way in which the local community was engaged in the topic of the establishing a Marine Protected Area (MPA) in Skjálfandi Bay off Húsavík in Iceland.

10.5 A Marine Protected Area for Skjálfandi Bay: An ARCPATH Case Study in Community Engagement

Co-production and community engagement were at the core of our work in introducing a Marine Protected Area in the sea space of Skjálfandi Bay. The ARCPATH project has had a strong focus on two interconnected issues of Arctic social-ecological change. The first of these is marine tourism. As discussed earlier in this chapter, marine tourism is a booming enterprise in the Arctic but carries with it problematic social and environmental consequences for the marine mammals and societies who rely on the practice. The second is Marine Protected Areas (MPAs) which are rare in the Arctic but because of increasing pressures from exploitation, fishing, hydrocarbon extraction, shipping and tourism, communities in the region are calling urgently for sustainable management arrangements like MPAs. These two issues, marine tourism and MPAs lend themselves well to cross-cultural comparisons and knowledge sharing through the conduct of empirical cases studies.

We have discovered that there is significant experience of MPAs in the Mediterranean, and in other coastal and marine resource dependent regions in Europe, such as Spanish Galicia, with which ARCPATH researchers are familiar. These examples provide lessons of much value for researchers concerned with governance design and implementation in northern contexts (Vidal 2017) (Fig. 10.2).

This research component of ARCPATH has been carried out by a team of anthropologists and geographers who are not only experts on the complex and pertinent issues of Arctic change, but who were also able to bring to the table valuable lessons learned from studying the consequences of mass marine tourism in sub- and non-Arctic regions. ARCPATH research has involved fieldwork in Icelandic communities that several of the participants are intimately familiar with through previous experience. In Húsavík, whale watching has gradually become a major industry over the past 25 years (Einarsson 2009; Huijbens and Einarsson 2018). The surrounding areas of Skjálfandi Bay and the island of Grímsey have also been of high interest due to changes these areas have faced in fishing and in the development of marine and other forms of tourism. The subtleties of the relationship between marine and fisheries policies, have framed the research to be undertaken. The current politicizing of environmental issues in Iceland has led to the promotion of a Marine Protected Area or similar regulatory arrangement in Skjálfandi Bay, primarily due to concerns about the intense and unregulated multiple use of the bay's seascape and marine ecosystems. ARCPATH researchers found that to be true to the subtleties of complex stakeholder involvement and ecosystem dynamics, any successful conservation process needs to be solidly grounded in local grassroots and

Fig. 10.2 This shows the town of Húsavík in northern Iceland. Population 2307. (Photograph: Astrid Ogilvie, April 2019)

bottom-up activities. Here co-production of knowledge and community engagement has been key.

As researchers we have been keenly aware that it would have been a mistake for us to solicit an MPA without firm support from the local community. Thus, we have attempted to anchor the project in the combination of local aspirations and expectations for use of the bay and local understandings of its ecosystem dynamics. Through the research process, we have looked for the much-needed legitimacy and credibility that efficient new management systems and structures call for. There are countless examples of the introduction of MPAs where they have failed. This is often due to the perception of local people and users that such practices are an alien arrangement, introduced from above and without consultation and knowledge of local needs. We have also been aware that globally, conflicts between stakeholders are believed to be a major reason for the high rate of MPAs failing to achieve their management goals (ICF Consulting Services 2018). The differing perspectives that emerge from these conflicts reveal opposing economic interests, conceptions of heritage, and understandings of appropriation and protection of marine resources (Gómez 2018).

Our role as researchers in designing and introducing an MPA in Skjálfandi Bay has been to offer advice, support and knowledge, based on existing international literature on MPAs, as well as empirical and comparative experiences from other regions. We also draw on our own research, ranging from cultural perceptions of the bay to observations on interactions at sea between human and marine mammals, some of which can lead to disturbances for the animals. However, we have not wished to spearhead what many locals would perceive as essentially a foreign and alien idea. This was the reception given to the introduction of whale watching in 1995 (Einarsson 2009; Huijbens and Einarsson 2018). Understanding the social, economic and cultural context of marine tourism in the community of Húsavík, and engaging with key actors, calls for co-production of knowledge that might form the basis for nimble, responsive and socially responsible governance.

Such governance must also take into account local observation and response to other challenges and opportunities that the community will face. Not least of these are related to equity issues in the fast-growing tourism industry. Tourism can provide job opportunities for young educated women. These women might otherwise leave the fishing villages, a migration pattern which undermines community viability in the long term. Other processes at work in these communities such as a changing use of local resources with trade-offs for ecosystem services related to multiple use of cetaceans, discussed in this paper, warming waters around Iceland, and fisheries policy have profound impacts on coastal communities.

The development of local tourism in the form of whale watching builds on the emerging image of these animals as powerful and intelligent creatures worthy of protection and key symbols for the environment. This has been a particular focus of our case study work (Einarsson 2011a, b). In contemporary Iceland there are, as well, strong lobby groups who argue for the resumption of whaling and against the value of, or need for, the non-consumptive use of cetaceans. An added aspect of our case-study efforts was to contribute to an informed dialogue, locally, nationally and internationally on the whale controversy. As seen from the local level, and from a bottom up co-produced knowledge perspective, bringing these lessons and perspectives based on local realities to the attention of the policy community is a significant contribution made by our research.

10.6 An ARCPATH Scale of Community Engagement

The continuum of ARCPATH community engagement can be illustrated in a graph (Fig. 10.3). The right side of the figure denotes the “outreach” or dissemination of research findings aspect of community engagement.

In the middle of the continuum is stakeholder consultation and participation in research, where the majority of ARCPATH community engagement activities take place. As an example, a large-scale stakeholder mapping exercise was conducted by the University of Iceland’s researchers prior to undertaking fieldwork in Húsavík (Iceland), Andenes (Norway) and Qeqertarsuaq (Greenland). This involved a desktop-based evaluation of direct and indirect beneficiaries and national and local regulatory bodies linked to whale resources in the study sites. This was combined with a further, more extensive discussion during interviews with identified

Fig. 10.3 This shows ARCPATH’s conception of the continuum of community engagement activities

stakeholders. The purpose of the latter stage was to ascertain whether stakeholders considered they had been categorised correctly on a stakeholder map, and to find out whether there were additional stakeholders that were relevant and had been missed during the initial desktop-based evaluation. Stakeholders were identified as: whale-watching companies, tourist organisations, hunters and hunting licensing bodies, local municipalities, harbour management bodies, museums, tourists and local businesses benefiting indirectly from the whale watching industry. The aim of the researchers was not to determine in advance of their fieldwork who was the most powerful stakeholder or the one obtaining the greatest amount of financial benefit due to the presence of whales, but rather to discover this through an elucidative process in the interviews. Equally significant, the underlying ethical topics of gender quality and social justice and equity were all integrated into the questioning about who benefited the most and least from whale resources, and what this ultimately implied in terms of their sustainable management. A comparative analysis of regional developments in the ARCPATH case-study areas of Húsavík in northeast Iceland; Qeqertarsuaq in western Greenland; and Skjervøya in northern Norway may be found in Ogilvie (2019). Figure 10.3 summarizes our approach to research co-production, community engagement, outreach and the mobilization and application of ARCPATH research results. The following sections provide some examples of that research dissemination and our conclusions about ARCPATH community and stakeholder engagement.

10.7 Dissemination of Findings

> The extent of sea ice is rapidly changing. This has an impact on almost everything we do. During our hunting and fishing trips we see a lot of birds and seals and other resources. We write down what we see and we discuss what it means. We hope our records and knowledge can help the Government make wise decisions… Karl Tobiassen, Qaarsut (http://www.pisuna.org/uk_index.html).

The ARCPATH project has disseminated its findings in the usual manner through scientific publications, in conference presentations, and in outreach efforts with the general public. A few examples are provided here. The Stefansson Memorial Lecture of 2018 was presented at the University of Washington by Leslie King. The title for her talk was *Learning from Northern People* and it described some of the rich local and traditional knowledge contributed by people and communities at the ARCPATH research sites and in other Arctic and sub-Arctic regions (King 2018). In September 2019 Margaret Willson gave a keynote presentation for the International Maritime Organization on gender and maritime policy as part of a panel introduced by Guðni Th. Jóhannesson, the President of Iceland. Dissemination to the general public is of course also of great importance, and an example of this was a presentation by Astrid Ogilvie in November 2019 to some 100 members of the Boulder chapter of the Rotary Association on Arctic climate change and the ARCPATH project.

However, in order to spread information about ARCPATH's work to an even wider community, other, more novel means of dissemination have been used. In particular, we have collaborated with artists and photographers who are closely involved with local informants in their work. These have included work with Kerry Koepping and Andrea Sparrow from the Arctic Arts Project that is dedicated to visually communicating the science of climate change.[4] It was fortuitous that Koepping and Sparrow were in Ilulissat and Qeqertarsuaq in May 2019 at the same time as one the project leaders, Astrid Ogilvie. Among other things, their work during this visit resulted in a telling summing up of the situation in Greenland in video form by Sparrow in which the unusually warm temperatures the region is experiencing were highlighted.[5]

Many of the discussions between ARCPATH researchers and local informants have focused on the melting of sea ice and glaciers. A chance meeting at a conference on climatic change and anthropology between ARCPATH co-leader, Astrid Ogilvie and her distant cousin, the environmental artist, Elizabeth Ogilvie, has serendipitously resulted in dissemination of ARCPATH findings in the latter's film, *Out of Ice* and her book of the same name (Ogilvie 2017a, b). Both film and book consider the effects of melting sea ice from the perspective of local people in Greenland. The film, in particular, is largely focused on voices from stakeholders in Ilulissat. The results of such collaborative efforts have been repeated on several occasions including at the Arctic Assembly conference in October 2018.

Other, non-traditional methods of communication have also been used by ARCPATH, for example, Astrid Ogilvie has posted an account of local effects of sea-ice loss in Iceland and Labrador drawn partly from local knowledge contributions on the website of BIFROST (an environmental humanities intervention on climate change led by educators and researchers from the Nordic Network for Interdisciplinary Environmental Studies (NIES) working in close collaboration with numerous partners from civil society.[6]

In 2019 we initiated another dissemination and outreach initiative entitled *Seawomen of Iceland/The Arctic*. This project, based on Dr Margaret Willson's work, (Willson 2016) will be led by the Stefansson Arctic Institute and the Institute

[4] See https://www.arcticartsproject.com/

[5] See https://vimeo.com/347149339

[6] See https://bifrostonline.org/sea-ice-stories-from-iceland-and-labrador/

of Arctic Studies at Dartmouth College. This international travelling media-based exhibit presents a graphic and engaging glimpse into the lives of strong and resilient women who for centuries have braved the Arctic waters in search of fish. In first-hand accounts, these women detail their excitement, accidents, trials, and tribulations in fishing in Iceland, from the historical times to the present. Through this exhibition, the voices of these seawomen speak directly to the viewers, reflecting strength, intelligence, and – above all – knowledge on how to survive. The exhibit is designed to offer a gender empowering and inspiring visual narrative of experiences of extraordinary women, bringing them to life through ethnographic and historical insights. The material addresses gender impacts of marine management policies on participation and recruitment of women to fishing, a profession that has increasingly become a male-dominated activity in spite of obvious potential for gender equality measures. Gender equality in all aspects and sectors of society is a key policy issue in Nordic cooperation, including the Nordic Arctic but fishing has, until now, not been part of this central discourse. Through this ARCPATH outreach activity we hope to help rectify this omission.

10.8 Summary and Conclusions

In this chapter, ARCPATH researchers have outlined the role of community engagement in the ARCPATH project. Community engagement is viewed as a part of our transdisciplinary research approach and a means of knowledge co-production. Through community engagement we seek to ensure research outcomes that are understandable and useable by the case-study communities of ARCPATH. We also discuss in this chapter the lessons learned from community engagement during the ARCPATH project including limitations as a result of research fatigue. We have also discussed the necessity for developing trusting relationships with community members. We identify a range of ethical considerations related to community engagement in research. We present a table of ethical questions to be asked at each of the four stages associated with the interview of local resident. We then suggest a continuum of community engagement ranging from typical research outreach activities, through a range of engagement mechanisms involving the co-design and co-production of knowledge along with other research outcomes.

In conclusion, we offer an ARCPATH approach to the co-production of knowledge. When we visit our communities, we listen attentively and focus on relationship-building. We also give back in terms of our findings and connections with other communities. We seek to create networks of communities who can learn from each other’s experiences. Wherever possible, we share the interpretation of our findings with our communities. Personal meetings and discussions are the best way to create trust. It is important that the providers of information understand the needs of the users, and the users clearly understand what information can be provided. Only a two-way interaction can create trust.

We also must keep in mind the importance of respect for the partner communities in which we work. It is noteworthy, that many local people who have been interviewed by our researchers state that they are looking forward to hearing the results of the ARCPATH study. It is, of course, our intention to impart this information when it is finalized, as we did during the research process. It is also vital to be aware of initiatives by the stakeholders themselves such as that of the PISUNA project noted above.

As a final comment, however, the essence of the ARCPATH approach can be summed up very briefly. In research, as in life, communication is crucial, and all successful communication hinges on respect and mutual understanding. Although the planned activities and approaches of the project are essential, perhaps the most important element that ARCPATH team members can bring to communication with all involved—stakeholders, colleagues, students and the general public—is the nebulous but vital concept of respect.

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Part IV

Chapter 11
Project ReiGN: Reindeer Husbandry in a Globalizing North–Resilience, Adaptations and Pathways for Actions

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Abstract Fennoscandian reindeer husbandry represents ecological, social-economical and institutional gradients reflected in different adaptations and management regimes. This provides for an interdisciplinary comparative research approach, between and within countries. By integrating perspectives from natural and social sciences, ReiGN engages in (1) identifying key drivers, (2) their effects on this pastoral system, and (3) how they are linked to ecological, social and political differences. In this chapter we outline the main challenges confronting this diverse and dynamic social-ecological system within a globalization and climate change perspective. This enables us to evaluate its adaptive capacities as well as its potential to stimulate policy decisions, societal responses and management actions

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for a viable reindeer husbandry. In this chapter we present reindeer husbandry in a historical context and introduce key concepts of Sámi reindeer husbandry to ease the understanding of our findings presented and discussed. We also offer an overview of the main research areas in which the ReiGN NCoE has conducted its work over the past several years.

Keywords Reindeer husbandry · Resilience · Sustainability · Transdisciplinary research

11.1 Introduction

Reindeer husbandry[1] has a long-shared history with, and is an integrated part of, the Sámi culture in Fennoscandia. Reindeer husbandry is also linked to the northern Finnish farming system and more locally within Norwegian and Swedish farming societies. This production system contributes to an array of ecological services such as food and other animal products, in addition to offering a variety of biodiversity, cultural and aesthetic benefits.

Although northern Fennoscandia may be regarded as a single natural geographical region there are differences between and within the Nordic countries in terms of natural and climatic conditions. The countries also exhibit some institutional variations in their governance systems and the manner in which they provide legal recognition of indigenous rights. These variations can be seen to be reflected in the reindeer herders' management and coping strategies.

The ReiGN initiative is a multisite and multidisciplinary Nordic research centre (NCoE). We aim to contribute to a resilient Fennoscandian reindeer husbandry by creating a better understanding of how the interaction between globalization and climate change affects this socioecological system at different scales. Further, we investigate how these drivers are linked to ecological, economic and socio-political differences between and within three countries; Finland, Sweden and Norway. Through six interrelated work packages (see Table 11.1 below) we address different dimensions of resilience, adaptations and future pathways for reindeer husbandry. These include concerns related to: (1) Genetic resources and breeding; (2) Living landscapes – ecologic and social foundations of mobility; (3) Tipping points and pasture resilience; (4) Strategies for different climatic scenarios; (5) Bioeconomics; and (6) Governance. Our research centre provides networking opportunities in the conduct of scientific research and natural resource management. It also facilitates interactions between scientists and reindeer herders in the development of new ideas and research approaches related to reindeer husbandry.

[1] Here, we conceptualize reindeer husbandry as a unifying concept that bundles the social-ecological relations between humans, animals and landscape.

Table 11.1 ReiGN is organized into six work packages (WPs) and a networking cluster all with specific objectives embracing our vision to *establish an interdisciplinary multisite Research Centre for holistic understanding of drivers connected to globalization and climate change that affect reindeer husbandry in Fennoscandia*

Work packages	Main objectives
WP1 – Genetic resources, biodiversity & breeding	To identify drivers of genetic diversification and evolutionary changes of herds in Fennoscandia for sustainable and flexible management strategies in a changing Arctic
WP2 – *Living landscapes Ecologic and social foundations of mobility*	To investigate differences of mobility and cooperation in Fennoscandia and how it may be impacted by climate change and land tenure systems
WP3 – *Tipping points and the resilience of pastures – critical transitions in reindeer husbandry*	To examine the role of changing winter pasture quality or quantity on the risk of system changes between and within the countries
WP4 – *Optimal harvesting strategies in a changing world*	To assess how human strategies, like feeding and selective harvest, might either mitigate or aggravate possible climate impacts
WP5 **–** *Reindeer husbandry as bioeconomy*	To develop and refine an economic-ecological model, and to assess how stochastic weather conditions, climate and various institutional setups influence the bioeconomy at different scales.
WP6 – *Governing systems of reindeer husbandry and compromised sustainability?*	To compare, contrast, assess and evaluate the governing systems in the Nordic countries to promote governance structures and practices that contribute to increased problem-solving capacity
Networking – *research Communication and mutual learning*	To establish a meeting arena for researchers at all levels within the Centre to link together and foster inter-disciplinary thinking, cooperation for developing new ideas and actions

We begin this chapter by providing a historical overview of Sámi reindeer husbandry in Fennoscandia and introduce key concepts that frame our research efforts. We then present some of the specific findings that have emerged from our research inquiries within ReiGN. First, we address the domestication process and what seem to be the limits of reindeer adaptability and flexibility within a climate changing environment. Second, we look at land use competition as captured in past and current forest practices and how the winter strategies of herders have changed accordingly. Third, we consider the institutional dimensions of reindeer husbandry and scrutinize its governance on different scales, focusing on the central question of "what governs the governors"? Fourth and finally, we put these findings into an overall perspective on current realities of reindeer husbandry within the region. This chapter will provide readers with a broad introduction ahead of three in-depth presentations by our colleagues in ReiGN. (See Chaps. 12, 13 and 14 of this volume).

11.2 Reindeer Husbandry Within the Fennoscandian Region

Reindeer husbandry is practiced today by about 20 ethnic groups along the northern fringe of the Eurasian continent and is tightly connected to their socio-economic and cultural identity. This one-species pastoralist system has diversified over the centuries. In contemporary Russia, it includes both an extensive nomadic tundra form characterized by large herds as well as a hunting-based community form found in the taiga region where small numbers of reindeer are kept primarily for transportation. Most of the about 1.5 million semi-domestic reindeer in Russia are found east of the Urals, centered in and around the Yamal Peninsula (Klokov 2012). In northern Europe, Sámi, Komi and Nenets people are heavily involved in reindeer husbandry. Both indigenous Sámi and non-Sámi Finns practice reindeer husbandry in Finland. In Sweden and Norway, however, this is an exclusive right of the Sámi within Sapmi.

In the Fennoscandia area we find around 600,000 semi-domesticated reindeer in the winter herd equally distributed between Norway, Sweden and Finland. Altogether, around 40% of the three countries' land area is utilized for reindeer grazing. However, at present a substantial part is functionally unavailable to reindeer husbandry. Meat production, about 6000 tons per year, provides the main source of income for those involved. In addition, various state subsidies may, in varying degree, contribute to the local economy. Other sources of livelihood include hunting tourism and handicraft, fishing and berry picking, as well as external earnings and employments, provide additional income support.

We can distinguish three major forms of reindeer herding[2] in contemporary Fennoscandia (Riseth et al. 2019). The first is an alpine tundra form characterized with relative long seasonal migrations found in Norway and Sweden. The second type is a coastal form with local seasonal migrations that is found in the mid part of Norway. The third is a taiga form found in Sweden and Finland which encompasses year-round grazing in the forest zone and is confined to relatively small areas with limited possibilities for pasture rotation.

11.3 The Pastoralists of the North

11.3.1 The Historical Emergence of Reindeer Husbandry

The depletion of wild reindeer populations in the late Medieval age was probably a precondition for the expansion of extensive forms of Sámi reindeer husbandry in northern Fennoscandia (Vorren 1973). This triggered ecological adaptations and

[2] Here, we defined reindeer herding as the herders' operational work and their interaction with a herd at different temporal and spatial scales in order to secure their wellbeing in an ever-changing environment.

specialization (Lundmark 2007). Vorren (1973) argues that Sámi communities in Fennoscandia started shifting from a hunting-based economy to reindeer pastoralism around 1600 AD. Some scholars, e.g. Aronson (1991) and Salmi and Heino (2019), claim an earlier emergence. In the early phase, herders practiced intensive control over small, tame herds with transportation and decoys for hunting as the primary purposes.

Over time, reindeer herds became larger and a more extensive nomadic pastoral system developed where transportation, meat, hides, and antlers were the main products. This subsistence-based economy was closely integrated into the surrounding local economies encompassing sedentary Sámi and non-ethnic Sámi engaged in farming and different resource extraction activities. It also became part of the early national economies of the region through trade and taxation (Hansen and Olsen 2014).

11.3.2 The Early Years of Reindeer Husbandry

Sámi reindeer husbandry goes back in history well before the Nordic states were fully fledged. The practice was recognized as a legitimate livelihood with customary rights. It moreover had a recognized value as a subsistence exchange economy between settlers and herders, providing mutual benefits. The Lapp Codicil of 1751, part of the border treaty between Norway and Sweden, formally clarified and recognized the established rights of Sámi herders', including the free seasonal cross-border migration of their reindeer.

In confined areas within the Fennoscandia taiga zone and along the coast, intensive small-scale Sámi herding practices developed. These were based on the provision of transportation and food products (including milk) in combination with small scale farming, hunting, fishing and other resource gathering (Lundmark 2007). Finnish settlers were also to adopt this system (Kortesalmi 2008).

11.3.3 Traditional Sámi Reindeer Husbandry

A key to understanding reindeer husbandry is an awareness of the dynamic and highly adaptive nature of the trilateral environmental – human – reindeer interaction on which it is based. A model of this interaction is presented in Fig. 11.1 below. The contributing elements of each side of this triangle are worthy of some consideration.

The environment side of the triangle encompasses both biotic and abiotic elements. The landscape resources (e.g. pastures, firewood, construction material, berries, plants, wildlife, and fish) vary in time and space and their utilization is adjusted to the reindeer's requirements and the herders' needs. Effects of predators and

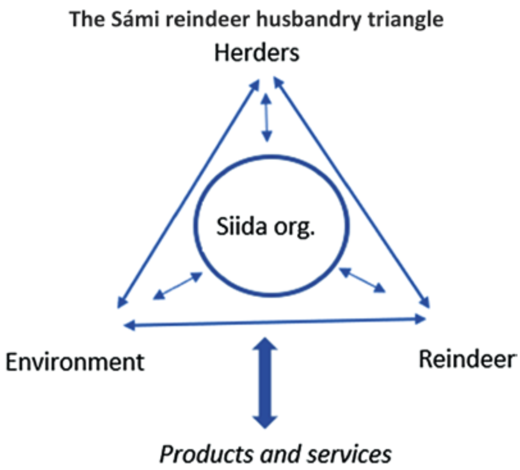

Fig. 11.1 A conceptual framework of the traditional nomadic Sámi reindeer husbandry system and the interacting and self-adapting relationship between the reindeer herd, the herders and the environment linked together by the siida (The reindeer siida is a group of independent households, normally with family bonds, working together to "balance" the triangle and secure their members' interest and rights (Sara 2009)) organization and the exchange of products and services with other sectors (modified after Paine 1994)

insects on reindeer herds are also biotic environment factors in reindeer herding as well as outbreaks of infectious diseases. Climate and weather with a clear seasonal and stochastic dimension are integrated parts of the environment and influence vegetation growth and phenology as well as availability of food and reindeer behavior. The operational environment also includes a social dimension connecting neighboring siidas.

The herders and their households compose the second side of the triangle and represent the basic subsistence economic unit of the reindeer husbandry. The privately-owned reindeer form their capital. The slaughtering and selection practices performed by the households reflect their aims and strategy and will influence their production output and future capital. The traditional pastoralists' ideology is to buffer and withstand losses by having big herds (Paine 1994). Controlling big herds was labor intensive and labor resources were probably the most important limiting factor for expansion, in addition to available ranges. However, a big herd gave, and still gives, a competitive advantage in conflicts between households within a siida, as well as between siidas.

The reindeer represent the third side of the interactive triangle transforming green biomass into products for human use and consumption (e.g, transportation, meat, hide, antler. etc.) as well as cultural assets. As the households' production aims are dynamic and may vary, e.g., according to labor resources, needs and aspirations, their herd size and composition will vary accordingly. Indeed, a family herd is composed of different age and sex structures, as well as of animals with desirable and functional behavioral and morphological characteristics. Reindeer are highly gregarious and form herds. Keeping control of their capital necessitates therefore cooperation between households.

The herd control and transfer of knowledge are organized and exercised through the siida. Although the animals are privately owned, the landscape resources are herded in common within the siida's traditional boundaries. The reindeer herders within the siida try to monitor the environment and buffer, if possible, the seasonal and spatial variations and fluctuations in range resources by flexible movements, herd size regulation, intensive herding and predator control at different scales. Also labor-intensive operations, such as gathering and round-ups during calf marking and slaughtering, are common activities. The siida is a dynamic, locally adapted, body and may vary seasonally in size (both in number of animals and households) and spatial distribution and accordingly in management operations and actions. There is a delicate balance between animals' performance and their natural behavior and the herders' ambition to keep control of a coherent and separated herd (Sara 2009). Indeed, the siida represents the hub in the triangle and is an adaption to a nomadic large-scale herding practice (Sara 2009). It connects the herders, households and herds as well as the common landscape resources and infrastructures. The intimate relationship between the households' strategies and decisions and the collective practice influences the siida's herd size, composition and productivity.

The triangle is still vibrant today. However, it is surrounded by a cloud of interlinked and potential cascading external drivers. Land use practices and rights, governance, legislation, conservation (especially predator management), the economy (including governmental incentives and subsidies and technology) are all interacting with the reindeer husbandry triangle at different scales. Globalization is overarching force on top of this band of drivers, interacting and amplified by climate change, which also influences the triangle directly.

11.3.4 States Taking Control

During the nineteenth century, Sámi pastoralists were exposed to a number of external shock waves as the result of international unrest and the intensified colonization within northern Fennoscandia. The national states expanded their control through the establishment of military strongholds, the church, and imposition of strict taxation regimes on the Sámi. Conflicts between states culminated in the closing of borders in the North: between Norway and Russia in 1826; Norway and Finland in 1852; and between Sweden and Finland in 1889 (Aarseth 1989).

The restriction and eventual blocking of traditional cross-border migration routes of the reindeer led to a buildup of animals in northernmost Sweden and deteriorating winter pastures there (Riseth et al. 2019). An alternative and partly forced north-south migration path followed, which created new turbulences and conflicts between and among Sámi reindeer herding communities (Aarseth 1989). Many families were either forced to relocate or permanently pushed out and eventually settled down as farmers often in combination with other employment activities. The level of unrest within the region was amplified by the transfer of Sami traditional land rights to state control during the same era (Tuori 2015). This created conflicts both within and between Sámi and non-Sámi settlers.

Further expansion of these types of farming and settlement practices were followed with additional state legislation in the last part of the nineteenth century and the start of the twentieth century that put further restrictions on reindeer husbandry (Kortesalmi 2008). Indeed, this reindeer husbandry legislation partly dismantled the siida organizations and drew new administrative borders for herding that reduced the remaining autonomy of the Sámi herding communities (Labba 2016). In Norway, a conscious assimilation policy was implemented (Minde 2003). In Sweden, a dual approach characterized by assimilation and separation became the chief features of its national Sámi policy. Through legislation, the Swedish state constructed and limited the Sámi identity in relation to reindeer herding as a livelihood. This has caused long-lasting controversies and divisions within the Sámi society and placed a constraint on Sámi rights (Lantto and Mörkenstam 2008; Löf 2016). In Finland, the interaction between the state and the Sámi was more bidirectional in character. The Finns did not grant the Sámi a special status (Nyyssönen 2013). However, in the late nineteenth century, the Finnish authorities started to supervise and administer more strictly Sámi lands and enlarging what were deemed to be state-owned lands (Lehtola 2015).

Such state policies, aimed at controlling traditional Sámi lands and dismantling their reindeer husbandry, led to growing protests and a counter movement among the Sámi in the twentieth century. These took the form of demonstrations, national and pan-Sámi meetings and the formation of Sámi organizations (Lantto 2000). Perceived and treated as culturally "inferior" or "backward" by existing national policies, reindeer herders faced an uphill struggle against the practices and projects of modernization and rationalization that characterize the era.

11.3.5 Growing International Recognition of the Rights of Herder Communities

The shift toward ideas of international humanism following World War II has gradually altered these once prevailing attitudes towards the Sámi people and their role in reindeer herding. The 1948 UN Human Rights Declaration proclaimed the end of discrimination based on ethnicity. The adoption in 1989 of the Indigenous and Tribal Peoples Convention has expanded understanding of the needs and aspirations of such communities. The 2007 International Convention on the Rights of Indigenous Peoples has heightened awareness of their ability to claim a voice and an agenda for action to meet their needs.

Such international influences on national policymaking have helped to improve the institutional and legal positions of the Sámi within Norway, Sweden and Finland, especially with respect to their land development policies and practices (Riseth et al. 2019). Sámi parliaments were also established in the 1980s and 1990s in all three countries, thus giving the communities their own political voice and a stronger sense of representation. However, the full recognition of Sámi rights and self-determination remain contested issues across the Fennoscandia region. (See Chap. 13 of this volume). This is especially the case in the context of the growing competition for access to land and resources within Sápmi[3] and the other northern regions.

Today we are dealing with a complex social-ecological system, which remains strongly impacted by both historic and current events. Below we explore some of the complexity, diversity and dynamics of reindeer husbandry – as well as the responses that develop within this system in relation to its contemporary context.

11.4 Research Glimpses

The ReiGN project has been engaged in research on a wide variety of topics. Here we present some glimpses into the research that has been fully or partly supported by NCoE resources. Each section below examines how progress in research on reindeer husbandry has been advanced by ReiGN investigators. Our overall purpose here is to raise awareness of the challenges, and possibly opportunities, facing Fennoscandian reindeer husbandry today and in the future.

11.5 Semi-Domestic Reindeer – Coping with Climate Change

The globe is warming, and its pace is particularly fast in the Arctic, causing unprecedented ecosystem changes. One of the pressing questions for reindeer husbandry within the region is whether reindeer and herders are able to track and respond to these changes? Indeed, semi-domestic reindeer have a wide geographical distribution suggesting a diverse domestication history and a flexible lifestyle. Their risk-averse life strategy (Bårdsen et al. 2008) has allowed them to adapt themselves to the short plant growing season and the harsh and unpredictable winter conditions of the North. However, rapid climate change may constrain their future adaptive capacity.

[3] Sápmi, the Sámi homeland stretching over northern Norway, Sweden, Finland and the Kola Peninsula.

11.5.1 Domestication

The origins of the domestication of reindeer has been debated since the early 1900s (see e.g. Laufer 1917 and Wiklund 1918). Røed et al. (2008) have suggested a polycentric origin, in accordance with Wiklund (1918). This was based on differences found in the genomic signatures between current semi-domesticated reindeer in Fennoscandia and in Russia. This theory suggests that wild reindeer were domesticated separately within each region.

This does not necessarily concur with recent ReiGN findings. Røed et al. (2018) obtained ancient mitochondrial DNA from around 200 reindeer samples at several sites in Finnmark county, northern Norway. This was compared with similar data from more recent archaeological sites, including present semi-domesticated reindeer samples from the same region. The archaeological samples provide evidence both temporally and spatially, of a *Rangifer* population with high genetic variation and ahomogeneous genetic structure up until the late Medieval period.

Subsequently, the reindeer went through massive genetic replacement during the sixteenth and seventeenth centuries. This accords with the suggested transition of the Sámi economy from a mainly hunting and gathering economy to reindeer pastoralism (Vorren 1973) and coincides well with the period of extensive mass trapping and the reduction of wild reindeer (Hansen and Olsen 2014). However, Røed and his coworkers conclude that the spread of reindeer pastoralism in Fennoscandia involved the translocation of a genetic signature of non-native animals that suggests an eastern origin of the introduced new type. Domesticated reindeer in Fennoscandia may have come from that region. However, that does not rule out the possibility that the domestication and active management of local small reindeer herds may have taken place earlier.

Recent genetic analyses initiated by ReiGN participants, of extant semi-domestic reindeer from 31 herding areas in Norway, Sweden and Finland suggest a common ancestral population which later evolved into the two main gene pools characterizing domestic reindeer in respectively Finland and Sweden/Norway. The further substructuring of the Swedish/Norwegian gene-pool follows socio-cultural gradients (Røed et al. n.d.). Indeed, the two main sub-clusters follow the traditional language borders with South Sámi dominating the southern and Central Sámi region (Røed et al. ms). The ongoing fragmentation and loss of pastures may lead to spatial reshuffling of animals. Indeed, the pressure to increase productivity may disrupt this genetic variability and structure. To maintain the genetic diversity of semi-domestic reindeer is vital in sustaining their adaptive and plastic capacity within an ever-changing environment. With this in mind, a future breeding program should therefore aim to encompass the remaining genetic resources by implementing a common, but locally adapted, Nordic breeding program.

11.5.2 Adaptive and Plastic Responses

Juvenile survival is the most critical component of reindeer population dynamics and is closely connected to the condition of females within the herd. Obviously, this will affect the herds' growth and hence their harvesting potential. The short Arctic growing season suggests strong selection pressure for an optimal timing of birth. The right timing of birth will safeguard early calf growth and survival and viable autumn calves. Further, this will enable females to build up their body reserves before the start of a new reproductive cycle in autumn. Indeed, the timing of calving in respect to plant phenology during spring may have fitness consequences, and due to the effects of climate change, the mismatch between parturition time and the emergence of spring vegetation can increase.

ReiGN researchers drew on the input of Sámi herders over three consecutive calving periods in 13 Norwegian districts. Their observations together with vegetation phenology measures using the Normalized Difference Vegetation Index (NDVI) as a proxy, resulted in a finding that the peak date of calving happens just before the mean spring green up and is positively correlated with it (Holand and Bårdsen n.d.). It was seen as being adapted to match the specific district's mean vegetation phenology. However, the anticipated high rate of climate change accompanied by increased fluctuations in temperature and precipitation between years and seasons may limit their adaptive tracking.

We therefore argue that adjustment via phenotypic plasticity will be the dominating short-term response to climate change in Rangifer. Indeed, our results suggest that the timing of calving is flexible and related to the females' body condition at conception. Females in good condition during the preceding autumn, which is indirectly influenced by summer and autumn forage quality, will conceive early and hence give birth early the following year. Further, we can suggest a shorter gestation length in good spring condition females, indirectly influenced by favorable winter/early spring conditions during pregnancy.

To dissect this further, ReiGN participants have identified phenotypic responses to weather parameters and vegetation phenology utilizing the Kutuharju long time series data base. The Finnish experimental herd was established in the late 1960s and is composed of around 100–120 winter animals with known life history and pedigree. In this herd, the calving season has advanced by ~ 7.6 days between 1970 and 2016 (Paoli et al. 2018). The advance is linked to warmer March to May temperatures which again induce earlier breeding the following autumn (Paoli et al. in review). However, favorable early life condition will enhance females' ability to realize their phenotypic plasticity (Paoli et al. 2019a). Paoli and coworkers argued that the onset of estrus in females is influenced by their body condition near breeding. Also, males in good body condition will contribute to an early onset of the breeding season followed by early parturition (Paoli et al. in review). Indeed, an early calving may cascade into improvement of females' condition in autumn, resulting in early conception, followed by earlier calving the year after and an increase in calves' first summer survival (Paoli et al. 2019b).

We have also investigated the strength and shape of selection on the birth date and weight in the Kutuharju herd. Holand et al. (2019) showed that the advance in birth date includes both a phenotypic plasticity and a micro-evolution component. The ongoing adaptive evolution advances the question if the herd can adapt fast enough to maintain an optimal phenotype as the environment changes. We found directional and stabilizing selection towards a combination of earlier birth date and heavier birth mass. Indeed, calving phenology is unlikely to be under pure directional selection, meaning that breeding too early or too late could both be detrimental.

11.6 How Forestry Affects Herders' Strategies toward Winter Pastures

During the last century, reindeer husbandry has faced increasing disturbances from other land use practices including forestry, energy development, mining, and tourism (Uboni et al. n.d.). In addition, the successful conservation of large predators has increased predation pressures on reindeer herds (Åhman et al. 2014). The effects of climate change on snow, icing events, and grazing conditions are also having a growing effect on reindeer husbandry.

Winter pastures are commonly considered to be a bottleneck in the system as forage during the winter is a strong determinant of both reindeer number and animal condition. The cumulative effects of the disturbances described above result in both fragmentation of pastures and reduced forage quality. This is affecting the total forage available and also the possibility of using remaining pastures as they may be small and far apart.

The dominant form of disturbance caused by other land use practices in Sweden and Finland is forestry. Both countries practice clear-cut forestry, where even-aged cultivated forest stands are harvested every 80–120 years. Such harvests remove older trees and thus reduce the amount of arboreal lichens. Ground lichens can also be disturbed by both the harvesting machines themselves, and by subsequent soil scarification that takes place during the planting of new tree seedlings. In addition, harvesting residue along with changes in light and moisture conditions can also have a negative effect on ground lichens (Kumpula et al. 2014).

In addition to the changes found in single forest stands, the broader fragmentation of the forest also affects the structure and mosaic of grazing landscape. This further reduces the options for reindeer herders to make use of their seasonal pasture areas and this, in turn, undercuts the resilience of reindeer husbandry (Moen and Keskitalo 2010). Clear-cut forestry practices have resulted in an increasing proportion of even-aged young stands and a scarcity of old- growth forests (Berg et al. 2008). The remaining areas of old-growth coniferous forest stands are relatively small, and they are becoming increasingly isolated as forests are harvested.

Within the ReiGN project, we have used data from the Swedish National Forest Inventory that shows a significant loss of ground lichens from forest plots inventoried from the 1950s to 2010s (Horstkotte and Moen 2019). It is difficult to assess the exact amount of forage-loss as the data is based on classifications of lichen abundance rather than exact amounts of lichens. However, the data show that between 36% and 70% of the plots with once high coverage of lichens now show a loss of lichens. The data also show that the negative impact of forestry on lichens is becoming more pronounced in recent years. This is due to direct impacts of harvesting machinery, but also because the replanted forest stands are very dense. This reduces the sunlight reaching the forest floor, which reduce growth of the remaining lichens. A reduced growth rates of lichens will also reduce their competitive ability and the forest floor tend to be dominated by mosses over lichens. Taken together, forestry reduces both the amount and the availability of lichen forage (Sandström et al. 2016; Uboni et al. 2019; Horstkotte and Moen 2019).

Using official statistics, the ReiGN project has also analysed how herders have responded over time to the disturbances brought about by other land users and the loss of winter forage (Uboni et al. n.d.). Rationalization and motorization have increased the possibility of using the remaining unaffected pastures. However, this can be done only with increased economic and environmental costs. Supplementary feeding of reindeer with pellets or hay has also increased as a response to forage loss. While this has been a practice in Finland for some time, it is a relatively new phenomenon within Sweden. Again, however, this causes substantial new economic costs to the reindeer herders.

Herd structure and harvest strategies have also changed within the Fennoscandian region from the 1950s onwards. ReiGN researchers have also examined these trends from the perspectives of forestry and reindeer husbandry professionals. They have also looked at the relations and interactions between these two types of livelihoods in Finland (Turunen et al. 2019).

A typical response to reduced quantity and quality of winter pastures in both Finland (Kumpula et al. 2000, 2014; Pekkarinen et al. 2015) and Sweden (Uboni et al. n.d.) is an increased grazing pressure on the remaining lichen pastures. Since lichens have slow growth rates, an intense grazing frequency does not allow for the regrowth of the lichen biomass before the reindeer next return to the pasture. The possibility for a rotational grazing scheme is lost. Data on lichen abundance from Sweden and Finland suggest that the current grazing pressures on the lichen pastures are higher than what is allowed by their present state and recovery potential (Uboni et al. n.d.; Kumpula et al. 2014; Pekkarinen et al. 2015). This suggests that the current grazing pressures on winter pastures are not sustainable in the long run.

Interviews with reindeer herders confirm the problematic situation regarding winter pastures (Axelsson-Linkowski et al. n.d.). In comparing pasture-use strategies between the current generation of herders with those of their fathers, the herders explain that strategies that the older generation practiced, such as rotational grazing schemes where pastures where allowed to lie fallow and encouraged lichens to regrow, can no longer be used. All of the interviewed herders state that all available pastures are currently used every year. In some areas, the same pasture may even have to be used a second time during the same winter. Earlier generations thus had the option to save some pastures for more critical times, such as during a bad winter. This is no longer possible for the current generation (see also Löf 2014). The understanding of the dynamics between reindeer and pastures, and their wish to graze only on so-called *aevis laante*[4] is an important part of the traditional ecological knowledge of the herders. As one of the younger herders observed:

> That is something you wish for and dream about, to have such an opportunity. To allow some pastures to rest, one or a couple of years. It was easier before when everything was not so heavily exploited. There were more pastures then, so it was more common to save pastures.

The increased grazing pressure on the remaining pastures, together with the growing disturbances of these pastures from other forms of land use, has led several researchers to consider the long-term sustainability and resilience of reindeer husbandry in Sweden in its current form (e.g. Moen and Keskitalo 2010). Herders have tried to buffer the reduction in pasture quality and quantity by, for instance, buying commercially available supplemental food or by actively moving reindeer between pastures. However, these buffering strategies are costly, economically by requiring more work and resources. A continued increase in costs is likely to be unsustainable for the herding companies. When this happens, traditional reindeer husbandry will either collapse or change into a different form of pastoralism, such as farming or ranching (e.g. Landauer et al. n.d.).

Such a change may have already happened in parts of the reindeer husbandry area, although it is not as yet prevalent throughout the entire area. In Finland, for instance, supplementary feeding of reindeer on winter pastures has increased in the Sámi reindeer herding area. Many herding districts in the southern and middle part of the Finnish reindeer husbandry area have already been forced to shift from a pastoral system based on natural pastures to a more ranching-like system based on keeping and feeding reindeer in fences during the main or hardest part of winter (Helle and Jaakkola 2008; Turunen and Vuojala-Magga 2014). Such changes may be especially serious in pastoral societies that are as much rooted in culture as in the monetary aspects of herding.

11.7 Governance of Reindeer Herding in Fennoscandia: What Are the "Problems" and the "Solutions"?

Governance entails the interaction and actions of state and non-state actors embedded in governing structures. Governance is essentially geared toward collectively formulating and addressing societal issues (Kooiman 2003). Governing issues represent the "problems to be solved" in a governing system – such as reindeer husbandry – and "solutions" gain policy standing through the interactions between different sociopolitical actors. How "problems" and "solutions", including the identified desirable directions for societal development, are negotiated and how those interactions are structured become fundamental to consider in a governance

[4] South Sami: untrodden or ungrazed land, i.e. pastures that had not been used that particular winter.

perspective. Put differently, an important part of the analysis of governance entails investigating whose perspectives are heard, whose are not, and through what mechanisms. Governance as an empirical development is sometimes misread as a diminishment of the state (Stoker 1998), rather than as recognition of the changing roles and demands on the state.

Regarding reindeer herding in Fennoscandia we find that the Swedish, Norwegian and Finnish states maintain the relatively firm hold they have exercised over reindeer husbandry governance since the beginning of the last century. Today, a number of resource regimes and sectors also operate in the reindeer herding area. Many of these have experienced decreasing governmental control. One illustrative example is the Swedish forestry model based on "freedom under responsibility" (Lindahl et al. 2017). Thus, when it comes to the governance landscape at large – from the local to the global level – we find that state dominance in governance is challenged by new actors, new drivers, new demands and new discourses that shape and reshape how humans interact with each other and the land.

For well over a century, views on what constituted the "problems" relating to reindeer husbandry and how they should be best addressed – the "solutions" – were framed, almost exclusively, from the perspective of the states or majority actors within it. The views, voices and standing of herders were rarely acknowledged within formal governance and implementation proceedings. Over the past decades we have seen a growing recognition and support of the indigenous Sámi and their reindeer herding rights (Lantto and Mörkenstam 2008; Lantto 2012; Torp 2011). Yet current research suggests that herders' influence over how reindeer herding, and the reindeer herding area, itself, is governed remains limited (see for example Löf 2016; Benjaminsen et al. 2015). In fact, across Fennoscandia, reports on increasing land use conflicts, diminishing lands available for reindeer herding, and violations of indigenous rights are becoming an increasing matter of concern (for a recent example see OECD 2019). Our research in ReiGN similarly finds that reindeer herders often occupy structurally marginalized positions in governance, interactions and negotiations. The imbalance is reflected in the lack of practical opportunities and resources, a lack of input into the institutional design of consultation procedures and in the way governing interactions, specifically herders' participation, are framed (Larsen et al. 2017; Löf 2016; see also Chap. 13 of this volume).

In ReiGN we have looked closer at these dynamics and how governing issues and suggested solutions are embedded in institutional and normative governance structures. We have paid particular attention to the role of meta-governing principles, or "what governs the governors" (Kooiman 2003). By adopting a critical approach informed by a social equity perspective we have, for example, exemplified how meta-governance is clearly path-dependent and (mis-) informed by preconceived ideas in the form of myths relating to reindeer husbandry and reindeer herders (Sarkki et al. 2018).

Another example, concerns supplementary winter-feeding where herders and other state and private actors have quite divergent views on the phenomenon. Using participatory methods, we demonstrated in our inquiries how by proposing and institutionalizing supplementary feeding as an individualized "solution" to the loss of grazing area, such efforts can cloud alternatives that are institutionally and politically more challenging. These measures would be directed at maintaining or restoring the natural grazing regime. They reduce the impacts of competing land use practices and are almost always favored by the reindeer herders who regard routinized supplementary feeding an undesirable development (Horstkotte et al. n.d.). Above all, our research demonstrates how certain dominant meta-governing norms, such as "being adaptive" may, in fact, reduce the adaptive space that is available (see Löf 2013).

In a case study on Saarivuoma/Sárevuopmi reindeer herding community, we took a closer look at the present institutional messiness regarding transboundary herding practices. By operating from Sárevuopmi's perspective, rather than the state's, we were able to nuance and challenge the commonly held view that the primary "problem" relating to transboundary herding is the failure of the Swedish and Norwegian states to negotiate a new bilateral reindeer grazing convention. From Sárevuopmi's perspective, with traditional lands on both sides of the Swedish-Norwegian border, the "failed" negotiation is regarded, instead, as a success or part of a "solution". Without modern conventions limiting their land use, it has been possible to return to more traditional and flexible land use practices in accordance with principles laid down in the Lapp Codicil of 1751. This legal instrument has thus provided the community with an opportunity to challenge established meta-governing principles by returning to historically established rights of transboundary herding practices and reinterpreting them in the present context (Grönvall and Löf 2020). Our study thus actualized questions such as: Who has a right to govern? How can we evaluate what successful governance is and for whom it operates? It should be noted that the study did not include reindeer herders on the Norwegian side whose position on this matter is quite different. This highlights the reality that governing interactions that are favored by one reindeer herding community are not necessarily favored by other communities.

Taken together the above examples demonstrate the need to continuously challenge and to complement established problem-descriptions (and solutions) with herders' perspectives, knowledge and viewpoints. It calls on us to recognize differences and diversity both between and within herding communities and districts. These insights carry relevance also for the way we do research. In our view, they demand us to reflect critically about how we conduct our own research practices. Below, we wish to highlight some examples of collaborative research practices as a structured way of reinterpreting and understanding problems and solutions in accordance with the herders' perspectives.

In ReiGN we have, for example, utilized participatory methods and tools such as fuzzy cognitive mapping to better understand and reflect the herders' practice-based knowledge (Horstkotte, Löf and Moen ms). To achieve a more holistic understanding of recent environmental changes, we have also made efforts to combine scientific and practice-based knowledge (Rasmus et al. 2018, 2020). We have, moreover, established structured arenas for knowledge and experience exchange by facilitating and organizing meetings between herders from different communities and parts of Sápmi; between herders and researchers; and between herders and state officials. We have organized workshops on issues recognized as pressing by the herders, such as supplementary feeding, climate impact and adaptation, and their visions for the future of reindeer herding. While enabling exchange is an important first step, we recognize that this is not sufficient if we wish to challenge known asymmetries such as whose views and knowledge counts. We have therefore tested different techniques to address such asymmetries, for example by carefully choosing meeting venues (e.g. it is possible to meet in the reindeer herding forest); rearranging the order of who presents their perspective first (e.g. herders before researchers or officials); and by physically placing herders and their perspectives in the center of the room while others (researchers, state officials etc) are placed at the fringes. Such ways of (re)structuring dialogue and exchange can potentially have a large impact on what “issues” and “solutions” are reflected in governance interactions.

An important part of our work within ReiGN has been similarly to reflect critically upon the role which we, as researchers, play in the governance system. We need to uphold certain views and norms and suggest how different ways of knowing, based either on the scientific method or from experience, can inform policy and practice (Sarkki et al. 2019). We have, therefore, engaged in developing methodologies for participatory scenarios as a way to facilitate how reindeer herders and other local actors can engage in knowledge co-creation with researchers and scientists (Nilsson et al. 2019) or together with land use administrators and local decision-makers (Sarkki et al. 2019). All of these examples are part of our efforts to provide a better understanding of “what governs the governors” and how governance solutions can better fit with the herders’ lived, local and different realities. It also demonstrates how research can take a more active role in decolonizing not only state-Sámi relations but also research itself.

11.8 Perspectives

The impacts of globalization and climate change on reindeer husbandry are difficult to predict due to the complex relationships existing between herders, the herds, the environment and external drivers. Here, we try to put our research findings into perspective, bearing in mind how the uncertainty of future climate scenarios, as well as social-economic development and institutional frameworks, may alter them even over a short period of time.

It seems clear that continuing globalization combined with climate change will intensify the pressure on all northern natural resources. The extensive nature and area of reindeer husbandry along with the state’s failure to clearly regulate the interactions with competing land users, result in continuing controversies. Indeed, this ongoing “piece by piece” loss of grazing land leads to a variety of detrimental impacts. This is the unifying challenge for reindeer husbandry in Fennoscandia. Conflicts are fueled by never-ending disagreements among the participants over resource use and the need for economic compensation and mitigations arising from such practices.

We have shown that views of what constitutes conditions and prerequisites for a sustainable reindeer husbandry differs between herders and other actors. Thus, when we talk of challenges, opportunities and a sustainable reindeer husbandry in the future, such discussion is ultimately dependent on the particular frames of reference and the issues of concern that are presented. For example, where some resource actors may advocate supplementary feeding as a solution, herders may emphasize an alternative view of husbandry based on natural pastures. In this instance, the need to restore and protect grazing areas and resources becomes a higher priority. Where a state may advocate reducing reindeer herds in order to avoid overgrazing, herders may instead advocate reducing and removing the pressure arising from other competing land use practices. All of the states of the region have demonstrated, to varying degrees and in different ways, a reluctance to realize and incorporate Sámi rights and calls for self-determination. In the future, herding communities, on their part, will demand recognition of their status as rights holders and influence over matters that concern them. They will require that respect for the established principle of free, prior and informed consent be observed by the state.

Supplementary feeding is a means to compensate herders for lost pasture, especially where the lichen resources are reduced. Indeed, intensive forestry has reduced the lichen resource, fragmented pastures, and led to overstocking of the winter range. The higher frequency of extreme winter weather events as well as increased depredation rate have also intensified feeding. Finnish herders claim that although supplementary winter feeding increases their expenses, giving supplementary feed is, nowadays, the only way to gain a regular income (Rasmus et al. 2020). Winter supplementary feeding is spreading rapidly in Sweden and Norway. This may push reindeer husbandry into static and confined herding systems where, in the future, it will resemble farming more than pastoralism. This could be seen as a critical tipping point for reindeer husbandry. Reindeer husbandry based on natural pastures in winter has as one of its most important preconditions the securing of both ground and arboreal lichen ranges within a reasonable and sustainable pasture rotation system.

In our ReiGN research, we found that the mitigating effect of environmental stochasticity by supplementary winter feeding may change the reindeer's life history strategy, favoring allocation of females' available resources towards growth and reproduction (Paoli et al. ms.) as compared to survival. This change may tailor reindeer for an intensive farm-based production. Breeding strategies that maintain the genetic potential and diversity of semi-domestic reindeer is vital in sustaining their adaptive and plastic capacity on year-round natural pastures within an ever-changing environment. The importance of maintaining genetic diversity is also clearly seen by the genotypic variation in probability of being affected by Chronic wasting disease (CWD) (Güere et al. 2019). CWD poses an imminent threat to reindeer husbandry, and as for combatting many diseases a diverse genetic makeup may be important.

Reindeer seem more resilient to climate change than previously acknowledged. However, phenological mismatches in reproductive events may degrade the autumn body conditions of the reindeer. This may be amplified by higher levels of insect harassment and new vector borne diseases. (See Chaps. 4, 6, 12 and 13 of this volume). According to herders' perceptions, documented by ReiGN researchers, frequent snow icing events may cause temporally locked winter pastures that add to degrading spring body conditions (Rasmus et al. 2018, 2020). Warming may also affect reindeer positively, by advancing and prolonging the growth season, and hence reducing the length of the harsh winter period. These effects, both positive and negative, may interact and are expected to be area-specific. Knowledge of the coping mechanisms is essential in order to predict how semi-domestic reindeer will be affected in a changing environment and whether their phenotypic plasticity is capable of adaptation.

During the coming decades, ongoing warming in the North will likely induce a latitudinal and altitudinal tree line expansion. This expansion will most likely reduce forage quality in summer ranges and lichen resources in winter ranges. Reindeer behavioral plasticity along with enhanced management and herding practices may buffer some of these long-term negative habitat effects. A requirement for such responses is access to diverse and adequate grazing ranges. Likewise, strengthening the herder's local and internal autonomy, extending collaboration over national borders, as well as over siida or co-operative borders, is important to meet the conditions of a changing environment.

Fennoscandian reindeer husbandry is today integrated within the market economy and the nation states. This integration has weakened the autonomy of reindeer husbandry by increasing the dependency on external economic inputs and giving the states more opportunity for top down regulations. The state's policy for rationalization and its requirement of a higher meat production output per reindeer unit, combines with the continuing mechanization to push many herders with small herds out of business. Yet all viable livelihoods need a critical mass of practitioners. Ways must be found to stem the decline in participants. New initiatives must be undertaken in combination with innovative and viable reindeer husbandry solutions developed within the herders own societal and organizational structures. They must be based on practice-based knowledge as well as new scientific findings and feasible technology.

It is our hope that the interdisciplinary and multiperspective research in ReiGN will add to the development of a sustainable reindeer husbandry. This development must, of course, be done by the actors themselves. Our research highlights the complexity and place-based variations of reindeer husbandry in an attempt to reach a more holistic understanding that there are no panaceas, no one-size-fits-all solutions, to the challenges that reindeer husbandry faces in a globalising world where climate change is re-writing the rules.

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Chapter 12
What Drives the Number of Semi-domesticated Reindeer? Pasture Dynamics and Economic Incentives in Fennoscandian Reindeer Husbandry

Antti-Juhani Pekkarinen, Jouko Kumpula, and Olli Tahvonen

Abstract All Nordic countries regulate the maximum number of reindeer. However, long-term grazing pressure by reindeer together with the effects of forestry and other land uses raise concern regarding the possible overgrazing of the important winter lichen pastures. Understanding the dynamics between pastures and the reindeer population is imperative for determining the size of sustainable reindeer populations. Governmental regulation and subsidy systems additionally create economic incentives and set restrictions on reindeer management. Current herd sizes are, thus, based on both biological and economic factors. In this chapter, we provide an economic-ecological model of a reindeer herding system that can be used to analyze how the various forces drive reindeer numbers. We first show how ecological and economic factors affect model results. We then use Finland as an example to demonstrate how bioeconomic analysis can be used as a tool for understanding the reindeer herding system. Finally, we discuss how current restrictions on the maximum number of reindeer relate to economically and ecologically sustainable model solutions.

Keywords Economic-ecological model · Optimal harvesting · Overgrazing · Natural resource management · Herbivore-plant interactions

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12.1 Introduction

The reindeer (*Rangifer tarandus* L.) is one of the key species in the Arctic and subarctic. Reindeer herding is also an important income source for local people in these regions and an intrinsic part of the Sami culture in Fennoscandia (Forbes et al. 2006). However, long-term grazing pressure by reindeer together with the effects of forestry and other land use practices have led to a significant reduction and fragmentation of the most important natural ground and arboreal lichen pastures used in winter (Väre et al. 1996; Kumpula et al. 2009). Several reasons have been given for the loss, deterioration, and fragmentation of reindeer pastures (Kumpula et al. 2014; Sandström et al. 2016). However, questions concerning the sustainable size of reindeer populations and the possible overgrazing of ground lichen pastures have been at the center of this debate. The impact caused by reindeer numbers on pastures have therefore formed the main concern during the most recent decades (Kitti et al. 2006). In this chapter, we present an economic-ecological analysis of the drivers that affect reindeer numbers in Fennoscandian herding. We conclude with a case study estimating the current situation in Finland, where maximum reindeer numbers for the next 10-year period are decided by the Ministry of Agriculture and Forestry.

The existence of adequate winter pastures is critical for reindeer numbers in most parts of the Fennoscandian reindeer herding area (Pape and Löffler 2012). Lichen pastures, in particular, are essential for the productivity of the reindeer population in many areas. Thus, reindeer population and lichen pastures form a dynamic system, where reindeer numbers affect lichen biomass and lichen growth conditions and lichen pasture availabilities affect the number of reindeer that winter pastures can support. During recent decades, high reindeer numbers along with changes in lichen growth conditions have raised serious concerns about possible overgrazing of lichen pastures (Forbes et al. 2006).

National governments regulate reindeer numbers because of concern that reindeer herders operating under no restrictions may let reindeer populations levels rise too high. Ensuring pasture productivity and preventing overgrazing are the main reason for this regulation. As an example, according to Finnish law, the Ministry of Agriculture and Forestry has to evaluate and determine the maximum reindeer number for each reindeer herding cooperative during each 10-year period. This is done so that reindeer grazing does not exceed the sustainable production capacity of winter pastures (Finlex 1990). Thus, in addition to being of scientific interest, a clear understanding of the ecological dynamics between winter pastures and reindeer population is also necessary for policymakers, as they determine what will be reasonable sizes of reindeer populations in various areas within the country.

From the perspectives of the reindeer herding industry and many local people, the desired herd size and its economically sensible management should not be based solely on biological factors. They emphasize that social and economic factors should also be considered (Kitti et al. 2006). Also important in determining correct reindeer numbers are the impacts of forestry and other land use practices (Kumpula et al. 2014). Governmental regulation and the establishment of subsidy systems for herders may also influence reindeer numbers by producing economic incentives and setting certain management restrictions. Thus, we must consider all aspects of the reindeer husbandry system when determining what are sustainable and economically optimal herd sizes.

Reindeer husbandry within in Fennoscandia is a complex system of economic, ecological, and cultural interactions (Pape and Löffler 2012; Pekkarinen et al. 2018). The ecological importance of reindeer is evident in Arctic and sub-arctic areas, where reindeer are a keystone species and reindeer grazing shapes many plant communities. Indeed, nearly 40% of the total Fennoscandian land area is used as reindeer pasture (Pape and Löffler 2012). The importance of the reindeer for the northernmost cultures and economies is also undeniable. Reindeer herding forms a cornerstone of the Sami culture (Forbes et al. 2006). Furthermore, Sami culture is of special importance to the European Union (EU), as it is the only indigenous culture recognized within the EU as a whole and within the national constitutions of specific member states (Finlex 1990; European Union 2005). Sami culture and reindeer herding economics are tied together, and as noted in the EU constitution: "Traditional Sami culture depends on primary economic activities, such as reindeer husbandry" (European Union 2005).

Reindeer herding is also greatly affected by other forms of land use in the Arctic. This has caused disputes between reindeer herders and other land users. Major disagreements, especially between foresters and reindeer herders, have been ongoing within Finland for decades (Jokinen 2019). However, the effects of forestry are typically not considered when decisions are made concerning maximum reindeer numbers. Although the final decision on this is, ultimately, a political question, this decision should be based on the best available understanding of the reindeer herding system and its needs. For this, we need a solid scientific understanding of all aspects of this complex system, together with useful practitioner knowledge. The interdisciplinary research approach carried out within the ReiGN project enables us to integrate perspectives from both the natural and social sciences. In addition, the wide network of people within the NCoE provides multiple opportunities for contact with both herders and policymakers. This helps us as researchers to produce practically relevant research and take part in ongoing policy discussions regarding reindeer husbandry in the Nordic region.

12.1.1 Understanding the Reindeer Herding System

The reindeer herding system is an economic, ecological, and cultural system. However, most research on reindeer herding has focused mainly on the biology and ecology of reindeer (Pape and Löffler 2012). In their review article, Pape and Löffler (2012) concluded that reindeer research needs to include more interdisciplinary approaches. This need for interdisciplinary system analysis is not limited to the reindeer herding system. According to Gordon et al. (2004), the future management of all wild large herbivores, in general, will require ecologists to cooperate with sociologists, economists, politicians, and the general public. ReiGN aims to contribute to interdisciplinary reindeer research by bringing scientist from various fields together and by cooperating with herders and policymakers.

Within the broad interdisciplinary framework of ReiGN, Work Package 5 aims, in particular, to develop mathematical system models that seek to combine economic and ecological knowledge of reindeer husbandry. Mathematical system models are an apt method for describing and analyzing complex system dynamics. Among others, Schmolke et al. (2010) concluded that they should be used more widely in the future for informing and supporting public policy decision-making. As such, it can be suggested that interdisciplinary mathematical system models may also prove valuable for studying the sustainable management of the reindeer husbandry system.

12.1.2 Model Development

Gaare and Skogland (1980) proposed one of the first system models for the reindeer-lichen system. They developed a simple reindeer-lichen population model that also accounted for lichen wastage caused by trampling. Danell and Petersson (1994) also constructed a detailed model of the reindeer herding system but did not include within it either pasture dynamics or the economics of reindeer husbandry. The first system model for the Fennoscandia reindeer-lichen system, that aimed at including both the ecological and economic dimensions of reindeer herding, was a two state-variable bioeconomic reindeer-lichen model provided by Virtala (1992). Moxnes et al. (2001) utilized a similar approach in their model and included a description of energy intake from various energy resources. They also included summer pastures and lichen wastage but no description of the population structure within their model. Coming a bit later, both Skonhoft et al. (2017) and Johannesen et al. (2019) developed a stage-structured reindeer population model to study the effects of predation. They found that predation may improve the economic output of reindeer herders in an unmanaged setting. However, the model only includes three stage classes (calves, adult males, and adult females) and no mating function or resource dynamics.

None of these models, however, described the reindeer population in necessary detail or took into account all the relevant ecological, economic, and management aspects required to describe the reindeer herding system as a whole. These deficiencies in modeling had to be addressed by others. Pekkarinen (2018) showed that the inclusion of pasture dynamics, the age and sex structure of a reindeer population, and the economic optimization framework are highly important features required for a model to be able to properly describe economically rational and sustainable reindeer herding. In Tahvonen et al. (2014) and Pekkarinen et al. (2015, 2017), we aimed to overcome the shortcomings of previous models by presenting an age- and sex-structured bioeconomic model of a reindeer-pasture system. In this essay, we aim to show how this complex interdisciplinary model may be used as a tool for understanding the current situation within Finnish reindeer husbandry.

12.1.3 *Aims of This Chapter: System Analysis with a Bioeconomic Model*

In order to understand the current situation in reindeer husbandry and its prospects for sustainable development, we must account for economic factors in addition to ecological knowledge (Pape and Löffler 2012; Pekkarinen et al. 2018). Bioeconomic system models are an apt way to describe the complex economic-ecological interactions (Getz and Haight 1989). In this chapter, we use such bioeconomic modeling analyses to study the operation of various mechanisms and drivers in the reindeer herding system and how they direct economically sensible reindeer numbers in various situations. We use the economic-ecological model of the reindeer herding system first presented in Tahvonen et al. (2014) and Pekkarinen et al. (2015). It describes an age- and sex-structured reindeer population, the growth and consumption of lichen, and the economics of reindeer herding. The model includes the various natural winter energy resources of reindeer and incorporates supplementary feeding along with the effects of a seasonal pasture rotation system and government subsidies. Within the model we first examine how various ecological and economic factors affect economically sustainable solutions and reindeer numbers. We then use reindeer herding in Finland as an example to show how such bioeconomic analysis can be used as a tool to understand various reindeer herding systems and sustainable reindeer numbers in different areas of the country. Finally, in light of our research findings, we discuss what might be the maximum number of reindeer within different Finnish reindeer herding areas.

12.2 Models and Methods

12.2.1 *A Bioeconomic Model of a Reindeer Herding System*

The ecological-economic reindeer-lichen model we use in our research combines three widely utilized perspectives (age-structure, predator-prey dynamics, and bioeconomics) into an interdisciplinary description of the reindeer herding system. The ecological component of the model is based on a description of the development of the age- and sex-structured features of the reindeer population. Age-structured matrix models (Caswell 2001) have been used in ecology for decades, as models describing populations only as a biomass do not include the internal structure of the population or time delays associated in reproduction and other life history events. The description of the internal age and sex structure is especially important when studying the management of reindeer or other long-lived polygamous species (Gordon et al. 2004; Gerber and White 2014; Pekkarinen 2018).

The reindeer population model we utilize includes 17 female and 13 male age classes and a detailed description of winter energy resource utilization by the reindeer population. In the model, winter mortality increases as the winter weight of the reindeer decreases. The weight decrease of reindeer depends on energy intake during winter. This is determined by the availabilities of ground lichens, arboreal lichens, other cratered food resources (dwarf shrubs, mosses, and graminoids), and supplementary food. The number of calves born and their weights depend on the weight decrease of adult females during winter. In addition, the mating success during the previous autumn affects the number of calves born. Mating success is specified by a modified harmonic mean mating system (Bessa-Gomes et al. 2010), which gives the fraction of females mated as a function of population age and sex structure.

Additionally, our ecological model is rooted in analysis of predator-prey systems and plant-herbivore systems in our particular case. These systems are commonly studied using mathematical system models based on coupled difference or differential equations (Begon et al. 2005). These equations describe how predators affect prey populations (in our case lichen) and how prey density affects predator populations (in our case reindeer). We use this approach to study a reindeer-lichen system where reindeer population dynamics depend on winter food resources, mainly ground lichens (Kumpula 2001), and where the reindeer population is the main factor affecting lichen biomass (Kumpula et al. 2014). Within this model, reindeer population density is endogenously affected by lichen biomass. Thus, the model may be used for studying economically reasonable lichen biomass in addition to the optimal management of reindeer populations. This feature is necessary for studying how many reindeer current pasture conditions can support and what economically rational restrictions may exist for reindeer population size.

In addition to lichen, the model describes the use of other food resources by reindeer. The description of the diet choice between different energy resources (arboreal lichens, ground lichens, other cratered food, and supplementary food) follows the principles of the optimal foraging theory (e.g. Stephens 1986). See Pekkarinen et al. 2015 for a detailed description of energy intake and population models.

The model also describes the seasonal pasture rotation system used in many parts of the reindeer herding area in Fennoscandia. When a seasonal pasture rotation system is used, reindeer consume winter lichen pastures only during the winter season. However, without pasture rotation, lichen is also consumed during the spring, summer, and autumn. In the model, lichen growth depends on the areas of lichen-dominated habitat types and their lichen biomass after winter and spring consumption. Arboreal lichen consumption is affected by the availability of natural old-growth coniferous forests and their arboreal lichen biomass per hectare.

To account for the total lichen reduction coming from grazing reindeer, the model we have used also includes lichen wastage by reindeer in addition to what is ingested and converted to energy. Pekkarinen et al. (2017) estimated two wastage functions (constant and linear). By incorporating either one of these functions, the model is able to describe measured changes in lichen biomass with a high degree of accuracy. Of these two estimated wastage functions, we used the constant wastage function in this study, as it is simpler and reduces the computing time.

The economic component of our model follows the approach presented in the seminal book by Colin Clark (1976), entitled *Mathematical Bioeconomics: The*

Optimal Management of Renewable Resources. It describes bioeconomics as a study of the economically optimal utilization (also including other values besides monetary income) of biological resources. Bioeconomic models solved by dynamic optimization are at the center of bioeconomic research. Development of an economic model often begins by defining the resource user/owner and his/hers objective. In our case, we assume that a reindeer herding district is the decision maker concerning activities relating to reindeer herding in the district area. However, this is not always the case, as for example, maximum reindeer numbers in Finland are decided by the Ministry of Agriculture and Forestry despite being defined at a district level.

Thus, we assume that a reindeer herding district makes the slaughter and feeding decisions and aims to maximize the present value of net revenues as suggested in the following equation:

$$\max_{\left\{b_t, h_{s,t}^i, s=0,\dots n_i, i=f,m, t=0,1,\dots\right\}} \sum_{\infty}^{t=0} \left(R_t - C_t\right)^{\alpha} \left(\frac{1}{1+r}\right)^t .$$

In this equation, decision variables are the number of animals chosen for slaughter ($h_{s,t}^i$) from the age (s) and sex (i) classes and the quantity of supplementary food given (b_t). R_t are the annual revenues from slaughtering, r is the annual interest rate, and C_t the total annual costs for year t. Total costs include constant and variable management costs, slaughtering costs, and feeding costs.

For our basic analysis of economically optimal reindeer husbandry, we used the costs and prices for years 2015–2016. For our case study examining the current situation of reindeer herding in Finland, we define costs, prices, pasture conditions, lichen biomasses, and reindeer numbers from new data developed for years 2015–2018 in conjunction with the ReiGN project. See Tahvonen et al. (2014) and Pekkarinen et al. (2015) for the complete description of the optimization procedure. All optimizations are computed using the AMPL programing language and Knitro (versions 7.0.0 and 10.3) optimization software (Byrd et al. 2006). The optimization codes are available as a supplementary data for Tahvonen et al. (2014) and Pekkarinen et al. (2015), on the website of the Economic-Ecological Optimization Group (www.helsinki.fi/en/researchgroups/economic-ecological-optimization-group/codes), and upon request.

12.3 Results and Discussion

12.3.1 Dynamic Solutions and Steady States

Lichen pastures are the most important winter energy resource for reindeer in many areas of Fennoscandia. The long-term balance between reindeer numbers and pastures may be studied by analyzing the steady states in the reindeer-lichen system model. However, Tahvonen et al. (2014) and Pekkarinen et al. (2015) showed that without harvesting by humans, predation, or significant alternative energy resources a reindeer-lichen system does not seem to stabilize. This result is based on dynamic model solutions, but it has also been empirically observed on predator-free islands when reindeer were introduced (Klein 1968).

However, although natural stable steady states are not typically found in reindeer-lichen systems, human influence often leads to a more stable situation. Thus, our analysis of economically optimal steady states considerably increases our understanding of the reindeer husbandry system. However, in addition to steady-state analysis, dynamic model solutions are needed for solving transitions from various initial states to these steady states. This is especially important in a reindeer herding system, where the transitions to a steady state may take a long time because of the slow recovery of lichen pastures and the fairly long-life span of reindeer. Figure 12.1, below, helps to explain the meaning of the initial state (= initial biomass of lichen and size and structure of the reindeer population), steady state (= long-term stable biomass of lichen and size and structure of the reindeer population), and the dynamic transition to the steady state from the initial state. Dynamic solutions are also necessary because it is not possible to compute optimal steady-state solutions with a positive interest rate without solving the transition to a steady state. Thus, to fully understand the reindeer herding system with bioeconomic model analysis, we need to study both steady states and dynamic transition solutions.

In Fig. 12.1 the initial states of the system are chosen so that they represent high and low reindeer densities as well as high and low lichen biomasses. The dynamic solutions show the economically optimal transitions from these four initial states to the two optimal steady states. Steady State 1 represents an economically sustainable state where it is optimal to base reindeer population management on natural pastures. In this given example, a 0% interest rate, the use of a pasture rotation system, and a high abundance of old forests with high-quality lichen pastures are all factors causing this steady state to produce the highest possible net revenues over a long-time horizon. In solutions leading to Steady State 2, the interest rate is 5%, no system of pasture rotation is used, and lichen pastures are located in lower-productivity commercial young forests. Using supplementary feeding as a main energy resource for reindeer and letting lichen biomass fall to a very low level is optimal under these conditions. The reindeer numbers in Steady State 2 are also much lower than in Steady State 1 because lichen pasture productivity is also lower.

It should be noted, however, that both the optimal slaughtering strategy and population structure of the herds are similar in both steady states. Tahvonen et al. (2014) has showed that it is economically beneficial to rely on intensive calf slaughtering and on a minimum number of adult males needed for efficient reproduction. Therefore, more than 60% of female calves and more than 95% of male calves are slaughtered during their first autumn. Many adult females are kept alive until 9.5 years of age while remaining adult males live only until they are 5.5 years old. The number of adult males is kept as low as possible without significantly lowering the fertilization rate of females and the reproduction rate of the population.

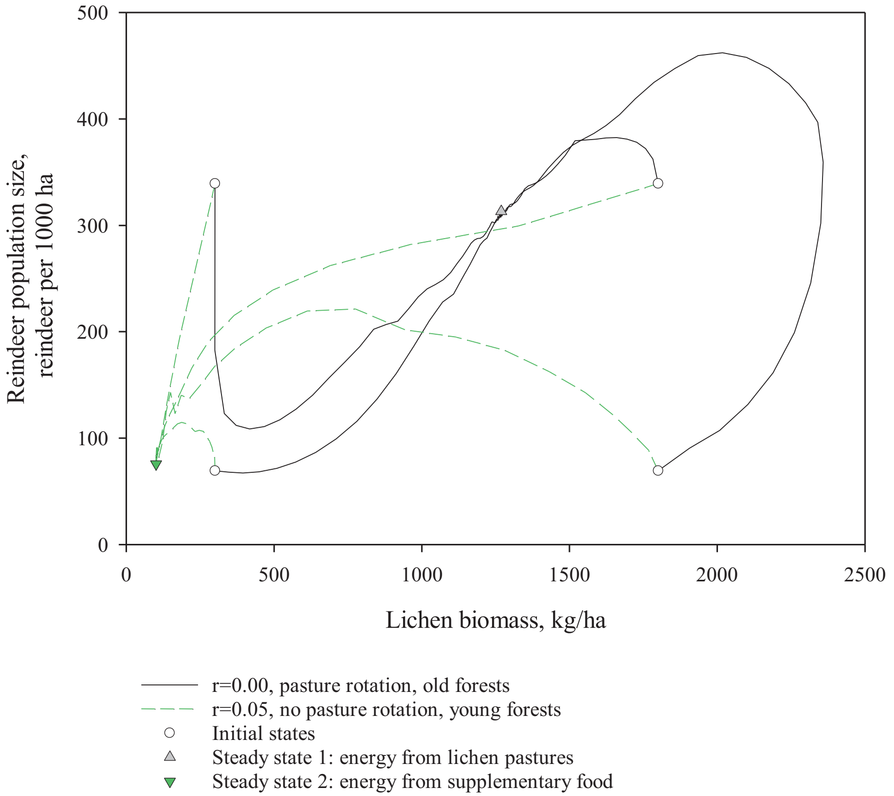

Fig. 12.1 Examples of economically optimal dynamic solutions and steady states in different situations. Eight dynamic solutions from four initial states that lead to two steady states are shown. Solid black lines represent solutions leading to steady state 1, where reindeer herding is based on natural pastures. In these solutions interest rate is 0%, a pasture rotation system is used, and the abundance of old forests with good lichen pastures is high. Dashed green lines represent solutions leading to steady state 2, where reindeer herding is based on intensive supplementary feeding. In these solutions the interest rate is 5%, no pasture rotation system is used, and lichen pastures are located in young forests

With this in mind, it should be noted that although the steady-state solutions of this study are presented in terms of total reindeer population sizes, it is necessary to understand that the internal herd structure and slaughtering strategy in these steady states correspond with the structure presented above. This herd structure and slaughtering strategy are also very close to the ones used in practice by contemporary herders in Finland (Tahvonen et al. 2014).

12.3.2 Economically Optimal Steady-State Solutions in Various Situations

The results presented in Fig. 12.1, above, clearly demonstrates that we need to consider ecological, economic, and management factors when seeking to specify economically rational reindeer numbers and lichen biomass in various situations. The steady-state solutions provided in Table 12.1, below, show that higher interest rates, the use of pasture rotation, the existence of large area of old-growth pine forests, and governmental subsidies all contribute increasing the economically optimal reindeer population size. Usually, with similar pasture conditions, a higher reindeer population size implies lower lichen biomass. Thus, it is suggested that lichen biomass declines when interest rates are higher or when governmental subsidies are paid for each reindeer kept alive within the herd. However, the use of pasture rotation and the high availability of old pine forests also increases the production capacity of the system. Thus, the steady-state lichen biomass increases in those cases in spite of the fact that reindeer populations may also increase.

Both Table 12.1 and Fig. 12.1 suggest the two main optimal steady-state operating regimes. In the first regime, reindeer herding is based on natural pastures and in the second on using intensive supplementary feeding. When the optimal solution is based on intensive supplementary feeding the lichen biomass falls to a very low level. However, reindeer still gain energy from other crater food resources and from arboreal lichens if available. The factors promoting the use of supplementary feeding are high interest rate, governmental subsidies, lack of pasture rotation, and lower growth rate of ground lichens.

Table 12.1 Economically optimal steady-state solutions under various economic and ecological conditions

Forest age	Pasture rotation	No subsidies 1 %	No subsidies 3 %	No subsidies 5 %	Reindeer subsidy *(28.5€)* 1 %	Reindeer subsidy *(28.5€)* 3 %	Reindeer subsidy *(28.5€)* 5 %
Old	Yes	**311** / *1051*	**321** / *801*	**341** / *703*	**346** / *924*	**352** / *691*	**409** / *100**
	No	**88** / *860*	**119** / *102**	**119** / *102**	**93** / *808*	**126** / *100**	**126** / *100**
Young	Yes	**192** / *914*	**206** / *688*	**248** / *101**	**209** / *757*	**250** / *101**	**252** / *100**
	No	**52** / *858*	**72** / *151**	**72** / *101**	**73** / *102**	**74** / *102**	**74** / *101**

Number of reindeer (per 1000 ha lichen pastures) / *Lichen biomass* (kg per ha)
* Supplementary food used as a main energy resource, lichen biomass very low

The shaded shells represent the solutions where supplementary food is used in optimal steady state as a main energy resource for reindeer during winter. Lichen pastures are their main energy resource in other solutions. The first number (in **bold**) gives the number of reindeer in a steady state (per 1000 ha of lichen pasture) and the second (*italicized*) gives the corresponding lichen biomass. The percentages indicate different interest rates (1%, 3%, 5%)
Number of reindeer (per 1000 ha lichen pastures)/*Lichen biomass* (kg per ha)
*Supplementary food used as a main energy resource; lichen biomass very low

12.3.3 Qualitative Analysis of Current Drivers and Economic Incentives in Finnish Reindeer Herding

With this discussion as background, we next aim to understand the sources of present reindeer numbers in Finland by studying the current drivers and economic incentives. In the section above we showed that economically rational reindeer numbers are driven by ecological, economic, and management factors of the system. In Table 12.2, below, we show how these drivers have changed within the Finnish reindeer herding system over time.

Here in Table 12.2 we considered how both ecological and economic changes have affected the rational size of reindeer populations, lichen biomass, net revenues, and supplementary feeding. The information shown in Table 12.2 is based on bioeconomic model solutions presented by Pekkarinen et al. (2015) except for the effects of predation mortality (Pekkarinen et al. ahead-of-print) and stochastic winter conditions (Pekkarinen et al. submitted).

From Table 12.2 it is clear that the pasture conditions in the Finnish reindeer herding area have clearly changed over recent decades. The areas of natural

Table 12.2 Drivers in Finnish Reindeer Husbandry over Recent Decades

	Reindeer numbers	Lichen biomass	Net revenues	Supplementary feeding
Changes in pasture conditions				
Decreasing area of old pine forests	–	–	–	+
Decreasing area of old spruce forests	–	+[a]	–	–[a]
Increasing stochastic variation in winter conditions	?	?	–	+
Increasing predation mortality	+[b]	–	–	?
Changes in mangement and economics				
Increasing management costs	–	+	–	–
Increasing meat price	+	–	+	+
Decreasing costs of supplementary feeding	+	–	+	+
Increasing governmental subsidies	+	–	+	+
Increasing use of pasture rotation system	+	+	+	–

+ driver increases the target variable
– driver decreases the target variable
? unsure direction or not studied
[a]effect during transition phase may be opposite to steady-state effect
[b]number of reindeer left alive after slaughtering increases, but the number of reindeer before slaughtering decreases
A plus sign indicates that the driver in question increases the optimal steady-state value of the given variable and a negative sign indicates a decrease in the optimal steady-state value

old-growth pine and spruce forests have decreased in number (Kumpula et al. 2014) over the same period, and the stochastic variation in winter conditions has increased (Turunen et al. 2016). The number of reindeer killed by large predators has also increased during the last decades (Kumpula et al. 2017).

Looking at our findings, it appears that all of these changes have negatively affected the net revenues gained from reindeer herding. These changes have also reduced the size of the economically sustainable reindeer population. Increasing predation pressures reduce the number of reindeer before the autumn slaughter. However, according to our solutions (Pekkarinen et al. ahead-of-print), a larger winter herd size is needed to compensate for the high predation occurring throughout the year.

Changes in pasture conditions from previous decades have also affected the economically optimal lichen biomass and the use of supplementary feeding. Decreasing the area of natural old pine forests clearly reduces the economically optimal lichen biomass and favors the use of supplementary feeding in both long-term (steady state) and short-term (transition to steady state) scenarios. However, decreasing the area of old spruce forests has an opposite effect in the long term. A decrease in the area of old spruce forests increases the economically optimal steady-state lichen biomass, as arboreal lichens are no longer available as an additional energy resource. This increase in ground lichen biomass then makes supplementary feeding more unprofitable. However, in the short term, a decreasing area of spruce forests increases the need of supplementary feeding until a new stable situation is reached.

Changes have also occurred in the economics and management of reindeer husbandry during past several decades. Costs of operation have increased but so has also the price of reindeer meat. Certain forest-dominated districts in northernmost Finland have adopted a seasonal pasture rotation system. Other changes in the system include a reduction in supplementary feeding costs due to subsidies paid to farmers. The Finnish government also now pays subsidies for reindeer herding according to the number of reindeer left alive after autumn slaughtering. According to our analysis, most of these changes in the management and economy of reindeer husbandry have been favorable to reindeer herding and have increased the net revenues and herd sizes. However, the increasing management and slaughtering costs have had the opposite effect, decreasing the optimal herd size and net revenues. Many of the changes both in reindeer herding economics and pasture conditions have also favored an increase use of supplementary feeding of the reindeer.

12.3.4 *Case Study of the Maximum Number of Reindeer in Finland*

Finally, in our analysis we considered the current numbers of Finnish reindeer within specific herding area and how they relate to our economically sustainable model solutions. Such analysis was made to provide background information for the

Finnish Ministry of Agriculture and Forestry, as it decides the maximum numbers of reindeer for the next 10-year period from 2021 to 2030. This type of work clearly demonstrates the policy relevance of the work conducted at the ReiGN NCoE. It produces and uses high-level scientific research to communicate matters of relevance to the public, policymakers, and the herders. While this work provides some practical policy recommendations, our main aim is to understand and show how various aspects of this complex bioeconomic system are linked together and how they affect the outcomes of different selected actions.

With this in mind, we studied how close the current reindeer numbers and lichen biomasses within various parts of Finnish Lapland were to the economically optimal model solutions discussed above. Our first step was to divide the 54 Finnish reindeer herding districts into four groups representing the average features of each district. One of the groups reflected conditions found in mountainous districts, while the other three represented forest districts with different availabilities of lichen and arboreal lichen pastures. The division of the 54 Finnish reindeer herding districts into four "average districts" is presented in Fig. 12.2 below.

After engaging in this classification effort, we moved on to consider the specific features of these districts. Table 12.3, below, provides the average values for current pasture conditions and maximum reindeer numbers within these four "average districts".

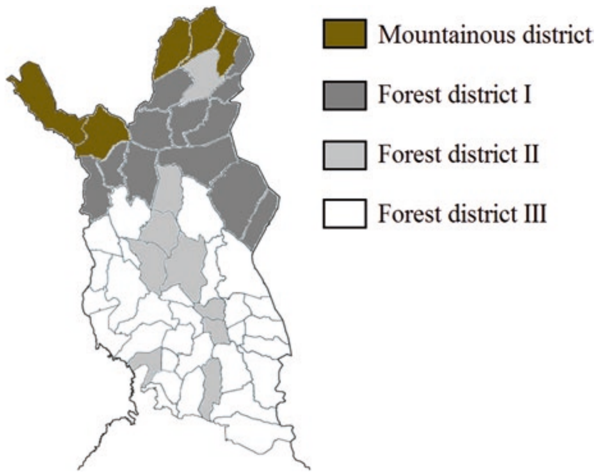

Fig. 12.2 The 54 Finnish reindeer herding districts divided into four groups with each representing the average main aspects of their pasture conditions. Mountainous districts have at least 45% of pastures located in mountainous vegetation types. Forest district I represents districts where ground and arboreal lichen pastures are largest and most productive due to large conservation areas. Forest district II represents districts where average ground lichen and arboreal lichen pasture availability and productivity is moderate, and Forest district III represents districts where the availability and productivity of these pastures is lowest. The age and size structure of the forests and forest pasture quality has been greatly affected by forestry in the two last districts

Table 12.3 Average values for current pasture conditions and maximum reindeer numbers in different "average districts"

	Mountainous	Forest I	Forest II	Forest III
The average land area of herding districts, km^2	3005	2789	2124	1979
Total area of lichen pastures, km^2	1200	643	277	101
lichen pastures in old/mature pine forests, km^2	72	276	77	26
lichen pastures in other forest areas, km^2	744	315	194	74
lichen pastures in mountainous areas, km^2	384	51	6	1
[a]Area of arboreal lichen pastures, km^2	66	471	177	104
Lichen biomass, kg/ha	153	169	100	<100
Arboreal lichen availability, kg/ha	6	12	9	9
Maximum number of reindeer allowed	6700	5892	3822	2325

[a]Includes only those old/mature coniferous forests where the availability of arboreal lichens was estimated to be sufficient (6 kg/ha or more on average). We assumed that sufficient arboreal lichen availabilities were in 50% (Mountainous and Forest I), 40% (Forest II) and 30% (Forest III) of old/mature coniferous forests

Total land areas and pasture areas were obtained from the classification of satellite images, while lichen biomasses for the 20 northernmost herding districts were obtained from field measurements made during 2016–2018 (Kumpula et al. 2019). The lichen biomasses have not been measured for the southern herding districts, but according to general observations they are clearly lower than in the northern districts. Arboreal lichen availability is assumed to be highest in herding districts where the area of old coniferous forests is highest.

In our study we determined that Mountainous Districts are those where at least 45% of pastures are located in mountainous vegetation types. The area of lichen pastures is high (28–57%) relative to total land area in all of the districts belonging to this group. Most lichen pastures in mountainous districts are located in dry mountain birch forest areas or on mountain heaths. The effects of forestry are very small in these districts, as coniferous forest areas are low. Only five districts in the Finnish reindeer herding area were classified as mountainous.

In our study, all other 49 districts are classified as forest-dominated and are called Forest Districts in this analysis. These districts are divided into three groups according to ground and arboreal lichen pasture availabilities. Forest District I represent those areas where ground and arboreal lichen pastures are largest and most productive on average. Mature/old-growth forests cover more than 20% of the total land area in these districts and ground lichen pastures cover more than 15%. On average, lichen pastures cover 23% of the total land area in these districts and old/mature coniferous forests cover 33%. The ground lichen and arboreal lichen pasture areas overlap significantly, as the best ground lichen pastures are located in old or mature pine forest.

Forest District II represents districts with moderate quantities and productivity of lichen pastures and Forest District III represents districts with low quantities and productivity. Forestry has considerably changed the age structure and quality of ground and arboreal lichen pastures in these two districts. In the following analysis, we mainly focus on Forest District I, but we also discuss results from the other "average districts". The available data are most sufficient for Forest District I, and the model was also originally developed for describing this area. In addition, this area is also of special interest because all the districts are located in an area specifically reserved for reindeer herding. Finnish law therefore dictates that state lands in the area should not be used in a manner that may significantly hinder reindeer herding (Finlex 1990).

We additionally estimated the meat price and average costs of reindeer herding based on the data from the Reindeer Herder's Association from years 2015–2016. We used 10€/kg for meat price, while the estimated variable management costs were 39.5€ per reindeer, slaughtering costs 16.7€ per slaughtered reindeer, and feeding costs 0.5€ per kg of supplementary food delivered to the pastures. Fixed management costs were estimated separately for each "average district", as the number of reindeer per land area differs significantly between the districts. The estimated fixed costs per ha of land area were 2.2€, 1.4€, 1.3€, and 0.9€ for the Mountain district, Forest District I, Forest District II, and Forest District III, respectively.

12.3.5 Steady-State Analysis of Current Maximum Numbers of Reindeer

According to Tahvonen et al. (2014), the maximum quantity of lichen in the climax stage (carrying capacity) is ca. 6400 kg/ha and highest annual production is achieved when lichen quantities reach approximately 2400 kg/ha. Table 12.3, above, shows that the current lichen biomasses found in pastures under year-round grazing conditions are very low on average in all parts of the Finnish reindeer herding area. It also shows that reindeer numbers relative to total the land area are clearly higher in northern parts of the Finnish reindeer herding area (Mountainous District, Forest District I) than in southern districts (Forest Districts II and III). However, the number of reindeer relative to the area of lichen pastures is lower in northern districts. Still, without an economic-ecological analysis it is unclear whether or not reindeer numbers and lichen biomasses are close to economically sustainable levels in different parts of the reindeer herding area.

Our proposed model solutions in Fig. 12.3, below, show that current maximum reindeer numbers in northern districts (Fig. 12.3, Table 12.3) are close to economically sustainable solutions. With a 3% interest rate, the model steady-state solutions proposed for a reindeer population are ca. 7000 for the Mountainous District and 6000 for Forest District I. However, economically sensible reindeer numbers are only ca. 2400 and 1000 for Forest Districts II and III, respectively. Thus, according to our steady-state analysis the current maximum numbers of reindeer in the southern districts of Finland (Table 12.3) are clearly higher than the economically sustainable solutions. However, we must note that due to corral feeding, the reindeer

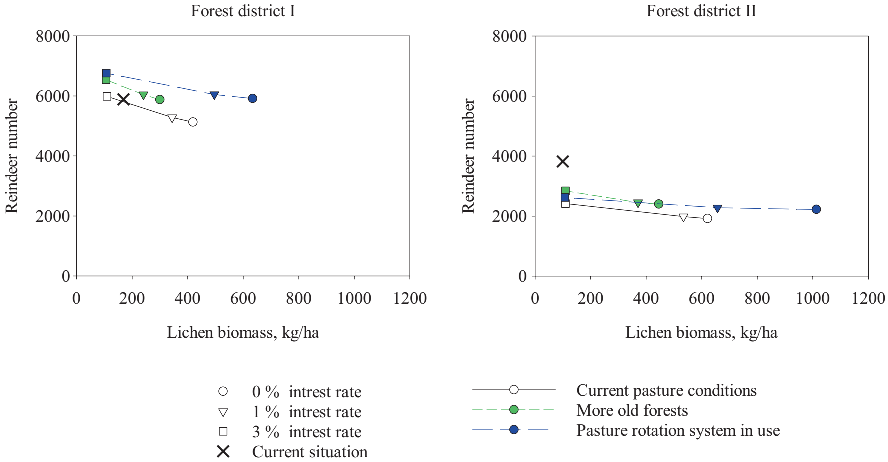

Fig. 12.3 Economically optimal steady-state solutions for average Forest districts I and II with three interest rates (0%, 1%, 3%). Symbols on the solid black line represent solutions with current pasture conditions without pasture rotation. Solutions on the green dashed line are computed with higher old forest availability (50% of the area of young and clear-cut forests is assumed to be old forest). Solutions on the blue dotted line are computed assuming seasonal pasture rotation (30% of all lichen pastures used only during the winter season). Additionally, the figure shows the current average lichen biomass and maximum number of reindeer in these districts

are no longer kept on natural pastures in many of the southern districts for the entire wintertime. The economic profitability of such a feeding system cannot be fully studied with our model, as the model is based on the assumption that natural pastures always form a significant winter energy resource.

Figure 12.3, above, shows the economically sustainable steady-state reindeer numbers and lichen biomasses for Forest Districts I and II. Additionally, it shows the current average lichen biomass and maximum number of reindeer in these districts.

The symbols on the black solid line of Fig. 12.3 show the economically optimal steady-state solutions with 0%, 1%, and 3% interest rates, with current pasture conditions, and without pasture rotation. Even in this situation, current maximum reindeer numbers can be seen to be close to model solutions in Forest District I. Figure 12.3 also shows that if old-growth forest availability were higher, or if a pasture rotation system were used, the current maximum number of reindeer would actually be lower than the economically optimal population size. In contrast, neither increasing old forest area nor using pasture rotation would alone improve natural pasture conditions in Forest District II enough to support the current maximum numbers of reindeer in an economically sustainable way. Thus, most areas in Forest Districts II and III have to rely on very intensive supplementary feeding.

Finnish law states that the maximum number of reindeer should be based on pasture capacity. Thus, it is imperative to understand the differences between the northern and southern parts of the Finnish reindeer herding area. Current reindeer numbers in the southern districts are based on supplementary feeding, not on natural pastures. However, the situation is the opposite in northern districts, despite these areas also using feeding during difficult winter conditions. Next, we continue exploring the relation between the reindeer population size and pasture capacity also outside steady states.

12.3.6 Dynamic Analysis of Various Options for Increasing Lichen Biomass

The steady-state analysis provided in Fig. 12.3 showed that the current number of reindeer and lichen biomass existing in Forest District I are close to an economically sustainable steady-state situation. In addition, our analysis suggest that the current lichen biomass could be increased either by reducing the number of reindeer, increasing the area of old-growth forests, or by using a pasture rotation system. However, dynamic solutions are needed to study how long it would take for lichen to recover from current grazing pressure.

Figure 12.4, below, shows simulation solutions of how different management actions affect lichen biomass and the need for supplementary feeding in Forest District I. It suggests that decreasing the maximum number of reindeer by 10% (from 5892 to 5303) has a similar effect to increasing the area of old growth forests. Although expanding the area of old-growth forests would take a long time to accomplish, the results suggest that forestry practices clearly has affected the grazing potential of winter pastures even in the northernmost forest districts of Finland. Thus, if half of the areas of current young forests and logging areas had remained old-growth forests, the current maximum number of reindeer would have enabled a clearly higher lichen biomass than we currently see.

Figure 12.4 also shows that developing the pasture rotation system may be the most efficient way in many areas to increase lichen biomass even without decreasing the maximum number of reindeer. In that case, it would be economically beneficial to keep using supplementary feeding for almost 30 years, despite most of the energy coming from natural pastures.

12.4 Conclusions

12.4.1 Using Detailed Bioeconomic Models in Natural Resource Management in the Arctic

Bioeconomic models have been widely used in fisheries and forestry to study sustainable management and to inform policymakers (Clark 1976; Getz and Haight 1989). Earlier studies (Pape and Löffler 2012) and reports from reindeer herders

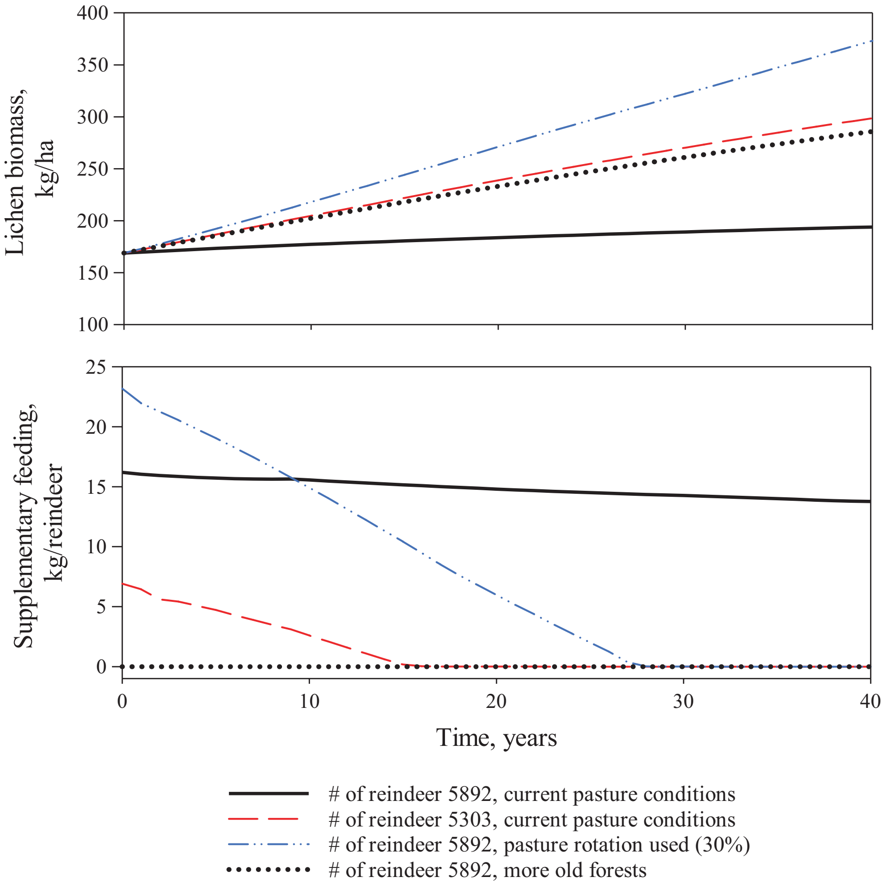

Fig. 12.4 The effect of management strategies on lichen pastures and supplementary feeding. Management strategies presented for the next 40 years for the herding districts in northernmost Lapland with high availability of lichen and arboreal lichen pastures (Forest I district). The solid black line represents a simulation with current pasture conditions and reindeer numbers and without pasture rotation. The red dashed line is computed with a lower reindeer density and with current pasture conditions. The solution with a blue dash/dotted line is computed with a higher availability of old forests (50% of the area of young or clear-cut forests is assumed to be old forest). The solution with a black dotted line is computed assuming that a seasonal pasture rotation is used (30% of the lichen pastures used only during the winter season)

themselves (Kitti et al. 2006) have suggested the need for interdisciplinary analyses of the reindeer herding system and sustainable sizes of reindeer populations. Thus, ReiGN researchers have focused on an interdisciplinary and comparative research approach that aims to identify key drivers and their effects on this pastoral system. Understanding current herd size and structure, slaughtering strategies, and time delays inherent in the population dynamics of long-living mammals needs an approach that includes the age and sex structure of the ungulate population within the modeling efforts. Indeed, previous research has shown that the management of large ungulates should be tailored to the age and sex structure of the population (Gordon et al. 2004) and that previous population models have underestimated the importance of including details of the mating system and male reproduction rates (Gerber and White 2014). As a part of an interdisciplinary NCoE, Work Package 5 in ReiGN has focused on the economic-ecological analysis of the reindeer herding system using a detailed dynamic age- and sex-structured model.

All previous economic-ecological models of reindeer herding tend to describe the reindeer population only by a single-stage variable (biomass or total number of individuals) or by an oversimplified stage structure. Also, none of the previous reindeer models include a description of the polygamous mating system of reindeer. However, it is not only the reindeer population that should be considered as a central resource in the Arctic reindeer herding system. The availability and quality of pastures are equally important. The study presented in this chapter is the most detailed bioeconomic model analysis of the economically sustainable management of the reindeer population or any other similar herbivore. This study combines the age and sex structure of the reindeer population, different winter energy resources, and the economics of a sustainable reindeer herding livelihood into one modeling approach describing the optimal management of a reindeer population. The model solutions of this study further underline the importance of an interdisciplinary approach to research. They show that sustainable population sizes cannot be evaluated solely from either ecological or economic perspectives. Indeed, economically rational solutions differ greatly according to the ecological, economic, and management conditions encountered.

12.4.2 Sustainable Numbers of Reindeer in Finland

In addition to conducting high-level interdisciplinary research, ReiGN also aims to have an impact on Arctic communities by producing tangible results and useful knowledge. In Work Package 5, we have used and further developed our bioeconomic model so that we may analyze the sustainable use of natural pastures and economically rational reindeer numbers within northern areas. We have extended this analysis to provide background information for the Finnish Ministry of Agriculture and Forestry as they determine the maximum numbers of reindeer for the 2021–2030 period.

We have shown that the long-term changes in the quantity and quality of pastures in Finland have reduced the productivity and grazing capacity of pastures. This has been seen to negatively affect the economics of reindeer herding.

Reindeer herding has adapted, in the past, to many of these unfavorable changes by developing new management strategies including pasture rotation, calf slaughtering, and supplementary feeding. Also, it has been shown that the development of certain economic conditions have been beneficial for the profitability of the reindeer herding. However, it has also been shown that pasture conditions, economic circumstances, and the impacts of these drivers can vary greatly between the herding districts and areas. Our study attempts to show that despite negative developments in pasture conditions, current maximum reindeer numbers in the northernmost districts of Finland are now close to economically sustainable levels. At the same time, however, our study suggests that present natural winter pastures cannot support current reindeer levels in the southern parts of the Finnish reindeer herding area over the long term due to many unfavorable changes occurring there within the pasture environment. Many of these districts have therefore had to resort to intensive supplementary feeding for decades.

Current Finnish law maintains that state-owned land should not be used in a manner that may significantly hinder reindeer herding in a specific area. Furthermore, Finnish law states that reindeer numbers should not exceed the sustainable production capacity of winter pastures. However, the research results that we have discussed in this essay imply that significant changes arising from current forestry practices have already decreased the grazing capacity of winter pastures and affected the reindeer herding economy.

As a result of these and other land use practices within reindeer herding area, the grazing capacity of pastures is likely to decrease even more in the future. If this should be the case, then adapting reindeer numbers according to reduced winter pasture resources may lead to a situation where reindeer herding may no longer be feasible. This would be an alarming and problematic situation, as reindeer herding represents a traditional livelihood in the Arctic area and is seen an intrinsic part of the indigenous Sami culture. Therefore, we suggest that future management plans for reindeer pastures should not only address consequences of the herding system, but also consider the results of other land-use practices in the northern and Arctic areas. As we have seen in our research these are interactive with one another and must be dealt with in a holistic and comprehensive manner.

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Chapter 13
Reindeer Herders as Stakeholders or Rights-Holders? Introducing a Social Equity-Based Conceptualization Relevant for Indigenous and Local Communities

Simo Sarkki, Hannu I. Heikkinen, and Annette Löf

Abstract The stakeholder concept has dominated academic discussions for a number of years and has functioned as a normative guide for natural resource management. However, there are at least three characteristics in stakeholder approaches: (1) all-inclusivity; (2) prioritization of economic interests; (3) ahistorical view on rights, which risk continued marginalization of indigenous people and the practitioners of traditional livelihoods despite of the intention to nurture indigenous and local participation by acknowledging them as stakeholders. We propose, in the context of natural resource governance, to address these biases by recognising indigenous and local traditional livelihood practitioners as rights-holders. We examine in turn: (1) how to conceptualise rights-holders in governance through a social equity perspective (2) why indigenous and local traditional livelihood practitioners should be considered as rights-holders instead of stakeholders, and (3) some of the implications and tensions associated with considering traditional livelihood practitioners, including both indigenous and non-indigenous groups and individuals, as rights-holders. We illustrate and examine these questions in a case study of reindeer herding in Finland. In Finland, today, reindeer herding is practiced by both Sámi and Finn herders and, based on a social equity perspective, both groups can be considered rights-holders if we acknowledge reindeer herding as a traditional livelihood practice. As traditional livelihood practitioners, herder have their whole way of life at stake and ultimately depend on access to land. In addition, herders have (had) detailed systems of customary rights preceding effective state-based governance in the north. Such institutions are particularly pronounced for Sámi reindeer herders

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but are applicable to both groups. Our conceptualisation of rights-holders thus recognises herders as categorically different from stakeholders, whose stakes are typically economic. It provides an incentive to increase the efforts of recognizing and treating herders as rights-holders in land use governance and thereby addresses some of the apparent gaps when it comes to implementation of indigenous rights and rights to participation in environmental governance. In this essay we also discuss differences in rights between Sámi and ethnic Finn reindeer herders and some of the conceptual and practical tensions that arise as a consequence of our approach. We conclude that efforts to recognise and reframe herders as rights-holders rather than stakeholders in land use governance are important and a potential tool to increase social equity of land use for reindeer herders.

Keywords Reindeer herding · Sámi people · Social equity · Land use · Rights-holders · Stakeholders

13.1 Introduction

How can we govern our natural resources in responsible and sustainable ways while ensuring the acceptance of those immediately concerned and dependent on said resources and lands? This delicate matter lies at the heart of political discussions on development – globally, regionally, nationally as well as locally. The idea of a "stakeholder" is one of the most widely used and policy relevant concepts to inform who should take part in decisions on natural resource governance (e.g. Reed et al. 2009). However, how to determine exactly who has a legitimate seat at the table has proven a difficult task (Billgren and Holmén 2008; Luyet et al. 2012). In this paper we introduce an alternative concept of *rights-holders* that can be used in the context of land use governance. We discuss why reindeer herders in Finland should be considered as "rights-holders" rather than "stakeholders" and how this can help us to understand both the rationale for who should have a legitimate seat at the table in land use governance and decision-making and how land use governance can move in a direction of increased social equity for reindeer herders.

13.1.1 A Critical View on the Stakeholder Concept

The concept of a "stakeholder" is used to identify actors to be included in negotiations characterised by deliberative democracy (Elster 1998) and in various forms of collaborative management and participatory practices (Senecah 2004; Reed 2008; Luyet et al. 2012). As an established approach, informing theory as well as policy practice, it includes various forms of stakeholder theories and their application, notably in so-called "stakeholder analysis" (SA) (Grimble and Wellard 1997;

Billgren and Holmén 2008). Here, stakeholders are broadly defined as anyone with an interest in and/or power over certain decisions (Howlett and Nagu 1997; Reed et al. 2009). While SA has contributed with tools to map diverging interests and stakes of actors, thus bringing power asymmetries and societal diversity to the fore in natural resource management (Billgren and Holmén 2008), SA provides little advice on how to deal with such differences and disagreements when they emerge. In the words of Grimble and Wellard: *"Whilst SA is a powerful tool for problem analysis and for illuminating the interests of the under-represented, it cannot, in itself, provide answers to problems or guarantee representation. In fact, SA mirrors the groupings and interests of society and in itself does not try to make changes…"* (1997, pp. 188–189).

Indigenous and local communities are increasingly considered as stakeholders with an objective to promote their interests and opportunities for participation in environmental governance (e.g. CIFOR 15 Oct 2018; CBD 17 Jan 2020; UNFCCC 2020). Yet, this stakeholder perspective on indigenous and local participation is clearly not sufficient in itself for at least three reasons. First, assuming that all stakeholders have similar types of interests and degree of influence entails a risk of making the idea of a stakeholder an "all-inclusive" concept without sufficiently addressing the different situations and positions of the diverse stakeholders (e.g. Howlett and Nagu 1997; Reed et al. 2009). The position of indigenous peoples in environmental governance is typically characterised by large power asymmetries, structural oppression and discrimination need specific attention and redress (see also Banerjee 2000; von der Porten and de Loë 2014). Second, the concept of a stakeholder tends to prioritise economic interests and suggests that such interests can, without great difficulty, be quantified, compensated and weighed against each other (Grimble and Wellard 1997; Billgren and Holmén 2008). However, indigenous and local communities typically have multiple interests that go beyond simply economic ones. In particular, they include socio-cultural interests and values associated with lands and land use along with economic interests (Daskon and Binns 2010). Third, necessary historical contextualisation and understanding of indigenous and local customary rights is occasionally neglected when identifying "stakeholders" and in considering their positions in land use negotiations (see Ojha et al. 2010; FAO 2016). Therefore, a reconceptualization of indigenous and local communities as relevant actors in land use governance is needed.

13.1.2 Indigenous and Local People as Rights-Holders

To address these shortcomings, we propose to use the concept of "rights-holders" instead of "stakeholders". We argue that this is one way of highlighting the particular status of indigenous people and local communities in the context of land use governance. In this context, it is important to note that indigenous people have recognised rights and are, thereby, formally considered as rights-holders (Ulfstein 2004; Wiessner 2011; Larsen et al. 2017). The United Nations Declaration on the

Rights of Indigenous Peoples (A/RES/61/295) adopted on 13 Sep. 2007, defines these indigenous rights as follows:

1. Indigenous peoples have the right to the lands, territories and resources which they have traditionally owned, occupied or otherwise used or acquired.
2. Indigenous peoples have the right to own, use, develop and control the lands, territories and resources that they possess by reason of traditional ownership or other traditional occupation or use, as well as those which they have otherwise acquired. (UNDRIP, Article 26)

While UNDRIP is a "soft law" declaration, and thus not a binding legal instrument, it is commonly held to reflect a globally recognized minimum level of indigenous rights that can serve as a guide for nation-to-nation negotiations (Wiessner 2011). Explicit efforts to highlight previously unacknowledged rights are plentiful throughout the globe as well as in the Nordic region. They occur at highest possible political levels, including within the UN Permanent Forum on Indigenous Issues (UN PFII 2016), but many challenges still remain in terms of how indigenous rights are implemented in policy and governance practices throughout the globe.

In environmental policy and legal discourses *"indigenous and local communities"* (e.g. CIFOR 15 Oct 2018; CBD 17 Jan 2020; UNFCCC 2020) are sometimes treated in tandem. Typically, this discourse suggests that indigenous and other local groups strongly and explicitly depend on natural resources and land. It suggests that they often live in rural and marginalised conditions and usually within small-scale local communities. This clearly demonstrates certain difficulties in the categorization of different types of land user groups. In this essay, we explore the rights-holders concept in the context of reindeer herding in Finland where we approach reindeer herding as a specific case of a traditional livelihood practice. Reindeer herding, which in Finland is practiced both by indigenous Sámi and ethnic Finns, is thus used here as an example to develop the idea of "rights-holders" in conjunction with indigenous and non-indigenous traditional livelihood practitioners. We also critically reflect upon some of the challenges associated with our traditional livelihood-based definition of rights-holders.

13.1.3 Reindeer Herders as Stakeholders or Rights-Holders

An important justification for recognizing reindeer herders as rights-holders is linked to their extensive historical and cultural continuity in land use. The Arctic has, for centuries, been inhabited by peoples and communities that have successfully adapted their livelihoods to local environmental conditions. These livelihoods are typically diverse, intimately linked to nature and rely on the use of rather large land and water areas. The combination of different subsistence practices, such as reindeer herding, hunting and fishing, has also been, and still is, of utmost importance for many Arctic peoples, including the indigenous Sámi (Larsen and Fondahl 2015).

When it comes to land use governance in northern Fennoscandia, most of the land there constitutes reindeer grazing area where herders have recognised land rights to graze their animals. From an established stakeholder-based view, herders, thus, should naturally be considered as stakeholders in land use discussions and decisions. Yet, we know from cases across Fennoscandia, that the actual participation of herders in such discussions, and their ability to influence decisions on matters that concern them, has been quite limited. In fact, Sámi actors and reindeer herders often remain marginalised in relation to other land users in many natural resource planning and decision-making processes (Sandstöm and Widmark 2007; Naum and Nordin 2013; Lehtola 2015; Ojala and Nordin 2015; Löf 2016; Sarkki et al. 2016; Larsen and Raitio 2019). The explanations offered for this situation are multifaceted in character and include, for example, poor institutional design (Sandstöm and Widmark 2007), colonial path dependency (Lawrence 2014; Löf 2016) and the continuing tensions between the economic interest of states and indigenous rights, cultures and livelihoods. These are often accompanied by an assumption that herders are not particularly impacted by other land use activities (e.g. Koivurova et al. 2015) or when they are, that they are able to adapt (Löf 2013, 2014). The growing number of unresolved land and natural resource related conflicts (Larsen and Raitio 2019) as well as repeated and outright violations of Sámi and human rights in northern Fennoscandia suggest otherwise (e.g. United Nations, 9 August 2016).

Reindeer herding is often recognised as *traditional,* which emphasises the strong link to cultural and territorial continuity. For indigenous peoples, the concept of traditional livelihood also entails specific legal recognition.[1] A necessary foundation for the continuation of these locally valued practices, is the widespread recognition of their rights of access to land and water – both on paper and in practice. When these rights are compromised, it creates profound difficulties for indigenous people seeking to practice and sustain livelihoods that their people and communities have relied on for generations (Oskal et al. 2009). Reindeer herding as a traditional practice is of particular importance for the indigenous Sámi people. It is also a traditional livelihood practiced by some ethnic Finns in northern Finland.

Reindeer herding has developed over long periods of time, and through its practice various land rights have been established. This means that today, compared to many other land uses, reindeer herding operates under special legal circumstances (Allard and Skogvang (eds.) 2015). However, many private and public actors often fail to recognise these. There is, instead, a strong tendency to treat reindeer herding as an interest on par with other land use practices in usual governance interactions (e.g. Löf 2014). This failure to recognise the herders' special rights and their

[1] See for example the United Nations Human Rights Committee and its stance reflected in General comment No. 23:3.2. The enjoyment of the rights to which Article 27 relates does not prejudice the sovereignty and territorial integrity of a State party. At the same time, one or other aspect of the rights of individuals protected under that article for example, to enjoy a particular culture may consist in a way of life which is closely associated with territory and use of its resources. This may particularly be true of members of indigenous communities constituting a minority.

historical use of the land, alongside existing power asymmetries and differences in vulnerabilities and dependency among different actors in the governance landscape, can partly be attributed to a stakeholder norm. It also risks, in our view, increasing and continued marginalisation of the herders.

In this chapter, we will use the concept of social equity (McDermott et al. 2013) to develop justifications for why indigenous Sámi and ethnic Finn herders should therefore be conceptualised as rights-holders instead of stakeholders in governance interactions. The concepts of social equity and rights-holders work well with one another because both concepts emphasise that assuming equal rights and positions among all actors can actually marginalize the disadvantaged groups even further.

13.1.4 Objectives, Research Questions and a Road Map

The overall objective of this essay is to provide justifications for why reindeer herders should be considered as rights-holders in land use governance. From the outset of this inquiry we wish to make clear that when we talk about rights-holders we do so primarily from a conceptual and governance perspective and not as legal scholars. We seek to provide new points of departure for analyses of natural resource policy and practice, but do not in any way intend to question or downplay the importance of established legal rights. From a reindeer herding livelihood point of view, we recognise however that the formal legal recognition of such rights has hitherto produced only limited results when it comes to influence over land use policy and governance practices. We thus stress the need to complement the formal legal understanding and recognition of rights-holders with one based on governance praxis.

This paper considers three conceptual research questions: (1) What does it means to conceptualize rights-holders from a social equity points of view? (2) Why should indigenous and local traditional livelihood practitioners be considered as rights-holders instead of stakeholders? and (3) What are the implications and tensions associated with considering both indigenous and non-indigenous traditional livelihood practitioners as rights-holders? These questions are examined through a case study of both Sámi reindeer herding and ethnic Finn reindeer herding in Finland.

Section 13.2 of the chapter develops our conceptual understanding of rights-holders based on social equity. The section concludes with identifying three empirical research questions to help address the shortcomings associated with the stakeholder concept. Section 13.3 of this essay outlines how formal governance of land use treats reindeer herding in Finland. It suggests why both Sámi and ethnic Finn herders should be considered as rights-holders instead of stakeholders. Section 13.4 of this chapter discusses the two conceptual questions: (1) What is the justifications for using the concept of rights-holder in the case of traditional livelihoods? and (2) What are the tensions between indigenous based and traditional livelihood-based definitions of rights-holder? Finally, Sect. 13.5 concludes the essay and provides some additional food for thought regarding the further application and development of the rights-holders concept.

13.2 Conceptual Background

13.2.1 Normative and Instrumental Rationales for Identifying and Engaging with Stakeholders

There are two dominating rationales for defining who is a stakeholder: the normative and the instrumental (Reed et al. 2009). The normative rationale is often based on the idea of justice as distributive result (the fair distribution of benefits and burdens) and a procedural process (actors can influence on decisions concerning their lives) (see Rawls 1971). Traditionally, the idea of who is to be considered as a stakeholder rests, according to Reed on two linked concepts: interest (Distribution) and influence (Procedure). Thereby, anyone who has an interest regarding a certain decision and who or can or should influence the decision, is to be considered as a stakeholder (Reed et al. 2009). The normative rationale, in the case of indigenous and local traditional livelihood practitioners, implies that they have a right to participate in decisions concerning their lives, and that they have a right to enjoy the benefits derived their indigenous homeland or lands where the local communities have lived often for generations. The instrumental rationale for engagement is linked to policy makers recognizing certain actors as rights-holders in order to satisfy high-level political principles in the making of legitimate decisions (see Wesselink et al. 2011). In conclusion, the normative rationale stems from a fundamental requirement in governance for enhanced social justice and social equity. The instrumental rationale emerges from the needs of decision makers. In this chapter we focus mostly on the normative rationale, but also discuss certain tensions between normative and instrumental rationales later in Sect. 13.4.1.

13.2.2 Social Equity and Rights-Holders

The normative rationale for treating an actor as a stakeholder or as a rights-holder can be seen to be linked to the idea social equity. The notion of social equity is both relative and context specific, meaning that those more impacted by decisions should also enjoy more rights (McDermott et al. 2013). The social equity concept proposes that groups who are not responsible for producing impacts (e.g. by land use change and climate change), but who are affected by the impacts, should be compensated or have the possibility of influencing decision making so as to mitigate these impacts. This can be done through affirmative governance actions on par with the level of impact. Affirmative governance actions aim to enhance position of disadvantaged groups by giving them more power in decision-making, by using compensation schemes, or other means to empower the minority groups by “positive discrimination” or “positive actions” (McDermott et al. 2013; McKendry 2016; Sarkki et al. 2017). As a consequence, the concept of social equity is sensitive to asymmetric histories, values, cultures, dependencies and livelihoods. It points out that social equity does not emerge by considering all actors and interests similarly. Social equity is commonly based on three key dimensions: recognition, distribution and procedure (McDermott et al. 2013; Pascual et al. 2014). The three dimensions of social equity have been applied also to examine reindeer herding in Finland (Sarkki et al. 2018). We apply these dimensions to fit to our consideration of reindeer herders as rights-holders as explained below.

First, the dimension of recognition as applied to rights-holders aims to cope with the challenge of all-inclusive definition of stakeholders by realising that some actors, like reindeer herders, should be recognized as having special rights to the lands. This recognition is justified via the traditional livelihood the herders practice, and due to having particular interests dependent on access to land making herders particularly vulnerable to competing land uses. The dimension of recognition answers the question of *how r*ights-holders are acknowledged in governance practices. As such, recognition is an additional dimension to those of interests and influence (Distribution; Procedure) that are central to developing rationales for *who* is to consider as a stakeholder or as a rights-holders, and *why*. Adding the *how* question has an added value by also suggesting that political recognition may be instrumental. For instance, states may be pressured to politically recognize indigenous rights advocated by international agreements. Therefore, visible political recognition can help policy makers to tick a box and argue that indigenous rights are well covered.

Second, the dimension of distribution, as applied to rights-holders, stresses that prioritization of economic interests while neglecting various dependencies and socio-cultural aspects associated with relations to land that may be relevant to indigenous and local communities. Traditional livelihoods, such as reindeer herding, are by definition, linked to cultural values. It has been noted that: *"The key characteristic of traditional culture is the 'generational-transformation' of knowledge, beliefs, values, customs and norms. This is fundamental for preserving societal values for the future and strengthening a community's sustainability and security"* (Daskon and Binns 2010: 497). Here we emphasize that traditional livelihoods are part of indigenous and local ways of life and highly dependent on access to land.

This particular dependence on land is also linked to the reality that many indigenous people do not have an "exit option". This means that they cannot move to other areas if their homelands or practice of traditional livelihood become unavailable (see Oskal et al. 2009; Löf 2013). As a consequence, the interests in land use on the part of traditional livelihood practitioners are far more than economic, and the severity of these interests is intensified by a high level of dependency on the lands where their traditional livelihoods are practiced. The particular kinds of interests and values highlighted here justifies *why* the indigenous and local traditional livelihood practitioners should be recognised and treated as rights-holders.

Third, the process dimension of social equity as applied to rights-holders stresses the fact that the lack of attention to historical conditions by stakeholder approaches neglects existing or previously- existing customary rights (e.g. Ojha et al. 2010; FAO 2016). We emphasize the historical aspects in relation to procedure, because current state-based environmental governance arrangements do not usually indicate whether some group has legitimate rights to land, but, instead, simply reflect power relationships in modern societies. However, indigenous and local systems for self-governance have, in many cases, and existed successfully prior to state (Ostrom 1990). Therefore, to get a grasp on what is relevant for traditional livelihood practitioners it is necessary to look at previously existing systems of self-governance of the land and customary rights (see Fondahl et al. 2015; Von der Porten et al. 2015). In conclusion, a focus on historical self-governance systems further aids in answering the normative question *why* indigenous and local traditional livelihood practitioners should be considered as rights-holders.

13.2.3 Social Equity and Research Questions

This essay aims at furthering our understanding of how rights-holders can be conceptualised from a social equity perspective. In particular, it seeks to provide insight into two conceptual research questions: (1) Why should indigenous and local traditional livelihood practitioners be considered as rights-holders instead of stakeholders? and (2) What are the complexities and tensions associated with considering both indigenous and non-indigenous traditional livelihood practitioners as rights-holders? We draw on the above discussion regarding social equity to operationalize these questions. We examine the two dimensions of social equity, Distribution and Procedure, to provide justifications for why herders should be considered as rights-holders instead of stakeholders. We also consider how the third dimension, Recognition, provides an overview of how herders are considered as rights-holders with particular rights. We have designed Sect. 13.3 of this chapter to address the three shortcomings of the existing stakeholder approach: (1). Its all-inclusivity character; (2). Its prioritization of economic interests; (3). Its ahistorical view of rights. Each shortcoming is addressed by specific empirical questions to guide our case study on reindeer herding. The framework for this investigation is provided in Table 13.1.

Table 13.1 Three shortcomings in stakeholder approaches that are linked to dimensions of social equity and provide research questions tailored to the case study of reindeer herding

Shortcomings in stakeholder approaches	Dimensions of social equity	Examples of questions that can be employed in a social equity approach to rights-holders
An all-inclusive definition of stakeholder does not recognize and/or address asymmetries in rights, vulnerabilities and stakes	Recognition	How are the particular rights of reindeer herders as indigenous people and traditional livelihood practitioners recognized in policy and governance? Do they have a special position among other stakeholders?
Prioritization of economic interests over other values	Distribution	What is special about the stakes, interests and values related to reindeer herding?
Lack of attention to historical rights	Procedure	What has been the historical influence of herders on land use rights? What kind of historical self-governance arrangements and customary rights herders have existed?

13.3 Reindeer Herders as Rights-Holders? The Case of Finland

In Finland, reindeer herding is practiced both by the Sámi and by ethnic Finns. In both cases, they draw on long-standing traditions. The reindeer herding area in Finland is currently divided into 54 Reindeer Herding Cooperatives (RHC) (paliskunta), which have their own leaders and practices (Reindeer Herders' Association 2020). State-owned lands form the majority of the reindeer herding area in Finland, but reindeer also have the right to graze on privately held lands (e.g. Heikkinen 2002). The reindeer herding region covers the northernmost third of Finland. It is divided by a clear border between reindeer herding region in the north, and non-reindeer area in the south. Sápmi, the homeland of the indigenous Sámi people, encompasses the territory of northern Norway, Sweden, Finland and the Kola Peninsula in eastern Russia. In the territory of Finland, Sápmi covers the northernmost municipalities of Finland, and the northern most one third of the reindeer herding region. The municipalities of Enontekiö, Inari and Utsjoki, and part of Sodankylä in Finland are located in Sápmi.

Both Sámi and ethnic Finn reindeer herding practices have been traditionally based on natural pastures. Because of the growth of other competing land use practices, reindeer in Finland are sometimes given supplementary fodder either in corrals or in the wild during the winter or in calving time. In some cases, especially in the southern reindeer herding area, reindeer are kept within fences over the winter season primarily due to a lack of old-growth forest winter pastures. Sometimes this is also due to the threat of large carnivore predation. In 2018–2019 there were 4354 reindeer owners in Finland from which a bit less than one third live in Sápmi (1220). There are 184,934 reindeer in breeding stock from which around one third (71,109) graze in Sápmi (Annual statistics of Reindeer Herder's Association 2020). These numbers are complicated by that part of reindeer herders in Sápmi are ethnic Finns, and part of reindeer herders outside Sápmi are Sámi.

13.3.1 How Reindeer Herders Are Recognized Politically and Legally?

In Finland, both Sámi and Finn herders are recognized as groups, who are covered by affirmative laws and governance arrangements. However, Sámi herders' rights are, additionally, strengthened by international agreements and the development of indigenous rights under international law that, at least in theory, should have concrete implications on land use governance in Sápmi. For example, recent negotiations around the Nordic Sámi Convention, and the implementation of the Akwé-Kon guidelines under the Convention on Biological Diversity, are concrete examples of how Sámi herders' land rights and their rights to practice their culture are interpreted and realized in regional and local land use governance and practice. In addition, according to Finnish law, the northernmost RHCs in the reindeer herding area are defined as areas specifically intended for reindeer herding (in Finnish: "erityisesti poronhoitoa varten tarkoitettu alue"). According to the Finnish Reindeer Husbandry Act of 1990, the land in this area may not be used in a manner that significantly hinders reindeer herding practices (Reindeer Husbandry Act, 848/1990; amendments up to 54/2000 included).

In addition to the Reindeer Husbandry Act there are additional sets of laws in Finland affecting a number of dimensions of reindeer herding. Apart from the Act of the Sámi Parliament (974/1995) that sets specific prerequisites of herding in Sápmi, there is also legislation that applies to all herders and aims to enhance conditions for reindeer herding. It covers such areas as:

- Subsidies for reindeer herding and nature-based livelihoods (Act 2011/986)
- Compensation for predator damages (Game Animal Damages Act 27.2.2009/15)
- Compensation for weather-related damages (987/2011 and 655/2016)
- Obligations to consult and consolidate with herding (Act on Metsähallitus 234/2016)
- Obligations to consult and consolidate with herding with respect to mining (Mining Act 621/2011)
- Obligations to consult and consolidate with herding with respect to water use (Water Act 587/2011)

These laws suggest that all herders are already, to some extent, recognized as rights-holders by the political system in Finland. For example, the subsidies and compensations that are provided are meant to balance benefits and burdens resulting from increasing predators, weather damages and traffic. This enhances social equity in distribution for reindeer herders. Furthermore, the legislation on parks and recreation, mining and water all specifically mention reindeer herding and the need to include herders in decision making in matters that concern them. At face value, then, these can be seen as measures that enhance social equity in decision making processes that relate to reindeer herders. Yet, it is another question whether in practice, this political recognition and laws are able to ensure social equity of land use for herders as seen from their perspective.

Basically, the existence of these laws and regulations imply that both Sámi and ethnic Finn reindeer herders are, to some extent, recognized as rights-holders through their practice of a traditional livelihood. Their historical, cultural and territorial rights have, however, also led to some governance challenges. Should governance recognize and treat Sámi herders and Finn herders as two groups, with the same livelihood, but differential rights and status of recognition? This question is especially complicated in some municipalities, for example Sodankylä, which includes both Sámi and Finn herders. In addition, some national parks, like Pallas-Ylläs, which is located partly in Sápmi. This complicates land use decision-making processes, which seek to acknowledge both Sámi and ethnic Finn herders.

In conclusion, it is clear that Sámi herders within Finland are politically and legally recognized as indigenous people under international and domestic law who hold specific rights to their homelands. Ethnic Finn herders are recognized by national law as traditional livelihood practitioners and, thus, they possess rights to practice their livelihood. Whether these dual types of recognitions are actually translated into socially equitable land use practice and governance for herders in Finland is however debatable.

13.3.2 A Whole Way of Life at Stake

The Sámi culture and way of life has developed in close connection to the environment and nature-based livelihoods. Reindeer herding is an essential part of the Sámi cultural identity and an important way of life for many Sámi people. Likewise, the Sámi languages have strong connections to reindeer herding. As a consequence, basic Sámi human rights are linked to their ability to practice Sámi culture via reindeer herding (see for example United Nations, 9 August 2016).

As noted above, land use activities, policies and governance have a more severe impact on reindeer herders compared to many other actors because the former do not have a real "exit" opportunity (Komu 2020; on Sweden see Löf 2013, 2014). Sámi herders cannot leave reindeer herding without far-reaching consequences including the loss of their cultural and ancestral connections to the land as well as the potential loss of their land titles. These losses apply not only to the herders, themselves, but also for their descendants to come. Nor can herders freely choose to "enter" herding in other locations as access is largely restricted in practice. When land provides not only a livelihood, but a way of life, and is seen as the foundation of a people's rights, the consequences of growing environmental and societal changes increases the magnitude of their impact. When herding practices change as a consequence, the basis for their social relations within their communities also change (cf. Heikkinen et al. 2007).

Many northern Finns also consider reindeer herding as an essential part of their way of life and cultural heritage (Kortesalmi 2008). Ethnic Finn reindeer herding communities are also feeling rather closed in and lacking an "exit" as joining another herding community requires their local acceptance. Symbolically joining to a herding community happens thru accepting your reindeer earmark and reindeer ownership in a new community. As a response, many of these herders have adapted to loss of grazing lands by providing supplementary fodder for their reindeer. Supplementary feeding has emerged as an unwanted, but necessary, adaptation to their loss of lands, particularly in the southern reindeer herding area in Finland (See Horstkotte et al. 2020).

In conclusion, traditional livelihood practitioners have their whole ways of lives at stake when it comes to land use governance and development. Their stakes are categorically different than of those stakeholders with mainly economic interests. This implies that the issue of distribution of benefits and burdens becomes complicated, as it is difficult to put monetary value on culture, social relations and maintaining traditions. Therefore, we apply the concept of "rights-holders" to reindeer herders to acknowledge their specific kinds of dependencies of their livelihood, and the way of life that comes with it.

13.3.3 Internal Governance Arrangements

Traditional Sámi livelihoods have been nature-based, including reindeer herding, hunting and fishing. Reindeer herding has, in different forms, been practiced for many centuries by the Sámi and the cultural importance of the reindeer extend even farther back than that (see Holand et al. this volume). Historically, Sámi reindeer herders have maintained pasture circulation systems that extended from current Finnish Lapland to northern Norway. Each Sámi reindeer Siida – a flexible coalition of herder families of the region – had their own specific pasture areas (Pennanen and Näkkäläjärvi 2003). In addition, the Sámi Siidas provided the basis for customary rights of families within certain areas. Thus, in many instances, lands that may have at one time been viewed as "unoccupied" by the government of the nation-state were actually governed by a Siida system of self-governance operated by the Sámi to enhance sustainability (Cf. Tegengren 1952; Manker 1953).

It is likely that northern Finnish peasants learned the practice of reindeer husbandry from the southern Sámi as early as the eighteenth century, as taxation and inheritance record indicate (Kortesalmi 2008). Kortesalmi (2008) has proposed a theory on how Finnish semi-livelihood northern peasants developed a "Paliskunta" (Reindeer Herding Cooperative) system, from the forest Sámi (at the time called Kemi Lapps). Village and forest- based small scale reindeer herding practices were adopted by them. This included the herding related vocabulary of the Kemi Sámi language in the Kemi-river basin. It is apparent that the supposed "wilderness" of northern Finland has never been "wild" and has been under human influences. Both the Sámi and the ethnic Finn inhabitants had informally agreed on rights to certain lands in order to practice herding, hunting and fishing, which latter formed the basis for recognised customary rights. These designations still can be seen in documents found in several government archives (Tegengren 1952; Kortesalmi 2008; Mustonen 2017).

It is clear that both the Siida system and the Reindeer Herding Cooperative system functioned well before the coming of state-based governance. Due to historical circumstances and cultural amalgamations over time, many herding families and communities in contemporary Finland developed from mixed origins. A common denominator of reindeer herding among both Sámi and Finns is that both groups consider that they each hold undeniable customary communal land use rights based on generational engagement in reindeer husbandry.

In addition to having well-defined rights and responsibilities with respect to the land, it is also an important aspect of self-governance to identify who is accepted as a community member and who is not. Reindeer herding in Finland is an exclusively held occupation and in practice, family or marital relations are necessary to own reindeer and to join any herding community. In the case of Sámi, membership is based on self-identification, but this must be recognized by the community. Therefore, the community ultimately controls who can practice reindeer herding in a given area. Regarding ethnic Finns, access to a reindeer herding livelihood is open in theory, according to the law, but limited in practice due to similar customary practices (such as needed local acceptance to be part of local herding community – paliskunta – for joining communal herding efforts, and controlling accepted reindeer ear marks i.e. locally recognized reindeer ownership) (Heikkinen 2002; Heikkinen 2006).

In conclusion, exploring the concept of rights-holders, in the case of reindeer herding, highlights the importance of historical and cultural continuity in traditional livelihoods. Herders have had self-governance arrangements for defining land use rights that preceded state-based governance. Elements of this form of self-governance we can still find in current legislation. The existence of such informal and internal processes can be considered as an indication that a group can be considered as rights-holders. This relates to the process dimension of the social equity concept by acknowledging that the "rights-holders" have had their own processes to grant rights and to establish land use practises in certain geographical locations.

13.4 Discussion

Based on our case study of reindeer herding in Finland we shall move on to consider the two important research questions in the next sections of the essay: Should both Sámi and ethnic Finn herders be treated as rights-holders? Are there some tensions associated with including both indigenous and local communities in our approach to rights-holders?

13.4.1 Why Should All Herders Be Considered as Rights-Holders Instead of Stakeholders?

Our case study revealed several normative explanations for why herders should not only be recognized, but also treated, as rights-holders in land use governance. Our case study evolved around two key normative justifications. The first of these was that while stakeholder approaches prioritize economic values (Billgren and Holmén 2008), traditional livelihood practitioners have other categories of concern (c.f. Daskon and Binns 2010). Adkins et al. (2016: 351) note in relation indigenous people in Canada that *"there may be situations where no level of payment can compensate for the impact to the community's way of life"* (see also Horstkotte et al. 2020, for a similar discussion*)*. With respect to reindeer herding, indigenous Sámi herders depend upon the availability of lands on which to sustain their culture as well as earning an income. The Sámi ethnic identity and even language are linked to reindeer herding. For Sámi and ethnic Finn herders, social relations, intergenerational continuity in a traditional profession, and respect for a way of life are all connected to herding. Therefore, there are particular characteristics of the distributive interests of reindeer herders with respect to land use decisions that justify considering herders as rights-holders instead of stakeholders. It is suggested that acknowledging the reindeer herders' particular interests, and using these as a basis for considering herders as rights-holders, can help to address some of the shortcoming in stakeholder approaches to natural resource management that tend to be linked to a prioritization of economic interests. The shortcomings of a stakeholder approach to natural resources are regularly reflected in land use governance. This can be seen, for example, in cases where large and highly remunerative land uses are compared to low-profit reindeer herding. The latter tend to be placed in an inferior position to the former when only economic indicators are used to justify land use decisions.

The second of these justifications arises from the lack of consideration given to the specific histories of a people when thinking of who is a stakeholder as compared to a rights-holder. Stakeholder concept tends not to recognize indigenous and local customary rights (see Ojha et al. 2010; FAO 2016). Yet, we emphasise that a rights-holder conceptualization suggests the need to recognize the historical connections of indigenous peoples to their homelands by granting them special rights (Fondahl et al. 2015; Von der Porten et al. 2015). Reindeer herders have had self-governance arrangements that define land use rights well before the advent of state-based governance. This highlights the historical fact that the herders have had strong influence on land use rights in practice.

We connected these histories to dimension of Procedure within social equity theory. This historical view on the process was chosen because the colonial state-based practices cannot be held as a fundamental basis for land rights, especially in indigenous lands. The land claims and usage rights granted by states are not to be equated with detailed systems of customary rights that have functioned long before state intrusion into the lands in question. The reality that customary land rights preceded state-based governance is therefore important to understand when thinking about who is a rights-holder. Our definition of herders as rights-holders is based on the historical continuity of the traditional livelihood, and insists on addressing the shortcoming in stakeholder approaches that lack historical understanding of the evolvement of customary rights.

It has been observed that the allocation of benefits and burdens within natural resource management are often themselves characterised by uneven power relations in resource valuation that is linked to indigenous cultures in the Arctic (Snyder et al. 2003). This highlights the reality that two key determinants in the established stakeholder definition, interest (Distribution) and influence (Procedure), are highly interlinked. For traditional stakeholder approaches, one determinant is enough for defining someone as a stakeholder (e.g. Reed et al. 2009). When it comes to rights-holder definition we consider Distribution and Procedure as interlinked, and tied to the third dimension of social equity: Recognition (see Pascual et al. 2014). Therefore, we suggest that reindeer herding needs to be *recognized* as a traditional livelihood. Herders, as rights-holders, should have a central role in the *procedures* related to defining what are the key issues in the *distribution* of benefits and burdens resulting from the land use. This is important so as to avoid the dominance of interests by stakeholders with mainly shorter-term economic interests over those of herders with longer-term perspectives and rights. Recognizing herders as rights-holders can help to cope with the shortcoming in stakeholder approaches that equate actors that embody asymmetrical rights, vulnerabilities, histories and stakes.

We briefly outlined above how reindeer herders are recognized by current land use policies and practices. Such recognition can be based on a normative rationale that seeks to promote indigenous rights and rights of reindeer herders as traditional livelihood practitioners. However, this political recognition may be also instrumental (Reed et al. 2009), meaning that the political recognition is based on the needs of administrations to be perceived as making legitimate decisions, instead of genuinely seeking ways to empower those whose rights are recognized (Wesselink et al. 2011). This instrumental rationale seems to be reflected in the fact that reindeer herders have been included or asked to participate, in almost every land use decision making process in Northern Finland. However, they seldom have any significant impact on these decisions and may lack the resources to participate in decision-making in a way that Finnish laws would expect (See Sarkki 2011; Sarkki et al. 2016; Heikkinen et al. 2011, 2012, 2016; Landauer and Komendantova 2018; Raitio 2013). To continuously frame herders as "stakeholders" rather than "rights-holders" may become a vehicle for the continued marginalization of indigenous people, like the Sámi, and traditional livelihood practitioners, like the ethnic Finn herders in northern rural Finland. In this chapter, we have outlined some key issues regarding how the rights of herders are politically recognized, but to examine how and whether this recognition translates in concrete land use decisions, processes and practices is beyond the scope for this essay.

13.4.2 Possible Tensions Between Indigenous and Local Communities as "Rights-Holders"

We have suggested above that both Sámi and ethnic Finn herders should be considered as rights-holders. Yet, to make full sense of the rights of both groups, we need now to discuss some tensions associated with indigenous-based and traditional livelihood-based definitions of rights-holders. To start with, we strongly concur with international actions that seek to acknowledge and strengthen indigenous peoples' legitimate rights to their homelands (e.g. Ulfstein 2004; UN 2007; Wiessner 2011; Larsen et al. 2017). Indigenous land rights are, and should be, different than of those of other local groups. In the case of the Sámi, reindeer herding is connected to ethnic identity, language and to the preservation of culture via traditional way of life. Sápmi, as the Sámi homeland, creates possibilities for self-governance. It also sets responsibilities for Nordic nation states to recognize Sámi rights to their homeland and to also implement this political recognition at a practical level. The land is tied to traditional livelihoods such as reindeer herding. Herding is further connected to ethnic identity. Therefore, access to land can be considered as a basic human right for the Sámi and many other indigenous peoples.

The present essay has considered not only the indigenous rights of Sámi herders, but also the status of ethnic Finn herders as potential "rights-holders" as a result of their practice of reindeer herding as a traditional livelihood. As was discussed earlier, ethnic Finn herders also have a historical connection with reindeer herding. Like the Sámi, their way of life is also at stake as new encroachments on the reindeer-herding areas increase. However, the ethnic Finn herders do not depend on land rights or reindeer herding for their ethnic identity, language or the preservation of their cultural identity as an ethnic minority. Therefore, ethnic Finn herders do not have the same grounds as the Sámi to make claims for self-governance. Below we discuss some perspectives to make greater sense of how the status of a "rights-holder" can be better understood and applied in a nuanced way to both indigenous peoples and traditional livelihood practitioners.

Caution needs to be practiced when defining a group as a "rights-holder", since an unacceptable definition may increase tensions among local people. If everyone is considered as equal rights-holders, then no one has special position, even if that status could be justified. While recognizing legitimate divergences, the rights-holder conceptualization encounters the challenge of nurturing a peaceful co-existence at the local level between those granted a status of rights-holder and those who are not. Therefore, the rights-holder definition is not best understood in black or white, yes or no terms. Instead, it is better understood as a spectrum representing on one end, stakeholders with recently emerged economic interests (not "rights-holders") and indigenous peoples, like the Sámi, practising traditional livelihoods on their homelands (definite "rights-holders") on the other end. Those who are not indigenous peoples, like the ethnic Finns, but who also pursue traditional livelihoods on the land are closer to this second end of the spectrum. With these considerations in mind, we can offer both formal indigenous rights-based, and traditional livelihood-based definitions of a right holder. Each of these come with specific benefits and challenges that are noted in Table 13.2 below.

Table 13.2 highlights that the main features of the rights-holder concept. However, the dual definitions may be contentious. This suggests that there are various issues that need to be considered when conceptualizing and determining who is

Table 13.2 Benefits and challenges of rights holders based on indigenous and traditional livelihood-based definitions

Rights-Holder	Benefits	Challenges
Based on an indigenous-based definition	A clear recognition of uniqueness of indigenous people, their identities and their legitimate rights on the homelands.	May create undesired tensions within heterogeneous local communities.
Based on traditional livelihood-based definition	Can recognize also other marginalized groups and respect these peoples' historical and cultural links to lands, even without an indigenous identity.	May end up compromising indigenous rights by equating them with those of non-indigenous local people

a "rights-holder." We emphasise, here, that neither policy-makers nor scientists can either "invent" or "un-invent" rights that indigenous people hold on their ancestral lands *or* the rights of traditional livelihood practitioners on land where they have operated based on customary rights. The lack of political recognition of some groups' rights to land does not necessarily mean that they would not have legitimate historical claims to certain lands. In addition, self-recognition by a group having special rights to certain lands may be an indication that they should be considered as rights-holders. In certain cases, it might be necessary to develop additional means to guarantee true equity in land use decisions so as to avoid having specific group benefits being watered down by an overly inclusive definition of a "rights-holder".

13.5 Conclusion

In the present essay, we have explored the "rights-holder" concept using the three dimensions of social equity, Recognition, Distribution and Procedure, and applied it on both indigenous and traditional livelihood cases of reindeer herding in Fennoscandia. We believe that our definition of rights-holders and its application to reindeer herding can help to empower indigenous and local communities. It can also assist in highlighting possible gaps and shortcomings in current land use governance. If the concept of "rights-holders" is not used, and indigenous and local people continue to be defined primarily as "stakeholders", it is likely that they will continue to be marginalized in land use decision-making processes and in the development of natural resource practices preferred by the majority society. Therefore, we recommend that society should recognize and treat reindeer herders as rights-holders. This would help to enhance social equity within land use policy development and in management practices that affect reindeer herders. Based on considerations related to having one's way of life at stake and securing acknowledgment of historical customary rights to one's land, we can conclude that both herders, Sámi and ethnic Finns, should be recognized as rights-holders instead of stakeholders in the future development of both natural resource policy and land use governance.

While promoting the use of a "rights-holders" concept we do acknowledge that the careless use of rights-holder terminology may lead to certain unintended consequences. Similarly, applying a too inclusive definition may compromise the integrity of some indigenous rights. Therefore, indigenous peoples should be recognized as particular groups of rights-holders that depend on their homelands for their culture and ethnic identity. In certain instances, it might be better to secure rights of other local communities by other means than expanding the inclusiveness of the rights-holder concept. On the other hand, a too exclusive definition of a rights-holder may end marginalizing non-indigenous local people who practice traditional livelihoods in similar circumstances. A necessary effort to strike a balance in the term's application seems to be required. In conclusion, we recommend that we add the concept of "rights-holders" to the vocabulary used by policymakers, scientists, and indigenous and local communities in discussing their concerns regarding land use. But as always, a degree of caution and sensitivity needs to be followed in its application due to complex context specific situations involving diverse cultures, multiple histories, and divergent vulnerabilities and dependencies linked to land use and land rights. In certain cases, it might be necessary to develop other means of guaranteeing equity in land use decisions than broadening too much the definition of rights-holders.

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Chapter 14
Working Together: Reflections on a Transdisciplinary Effort of Co-producing Knowledge on Supplementary Feeding in Reindeer Husbandry Across Fennoscandia

Tim Horstkotte, Élise Lépy, and Camilla Risvoll

Abstract Combining different knowledge systems by collaborative processes is widely recognized within environmental governance. In the context of co-management of natural resources, the benefits of integrating different knowledge systems are seen as leading to both an increased empowerment of local communities, as well as a way to identify and clarify the potential impact of policies or management on local livelihoods. In reindeer husbandry all over Fennoscandia, supplementary feeding has become increasingly necessary to buffer shortages in grazing resources, or to react to other rapid and profound social, economic, and environmental changes now taking place within the region. As experiences with supplementary feeding differ widely within and between countries of the region, we endeavoured to create an arena for reindeer herders and researchers from Finland, Norway and Sweden that would allow them to share experiences, knowledge and perspectives on supplementary feeding, and to discuss the potential challenges and opportunities associated with it.

In this chapter, we present and discuss our efforts to develop a workshop that would encourage the exchange of different experiences and inspire the combination of different ways of knowing and doing. We introduce our approach to community engagement by considering its current opportunities and challenges. Based on the

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specific background of the diverse participants in the workshop and the existing relationships between them, we reflect on the particular challenges that we have encountered before, during and after the workshop. Finally, we summarize some of our lessons learned during the planning of such an effort at community engagement and the co-production of knowledge.

Keywords Knowledge co-production · Experience-based knowledge · Stakeholder engagement · Reindeer husbandry · Supplementary feeding

14.1 Introduction

14.1.1 A Social-Ecological Systems Approach

People and nature co-evolve by mutually influencing and changing each other. This complex and dynamic interaction is termed social-ecological system (SES) (Holling 2001). By making deliberate choices, people can significantly alter both the social and ecological performances of their SES (McGinnis and Ostrom 2014). Similarly, biophysical and ecological change requires people to respond to these changes. Embracing such change, rather than obstructing it, has become a paradigm in the governance of social-ecological systems (Chapin et al. 2009).

Not all members of society are exposed to change to the same degree, nor do the consequences thereof affect them all at the same magnitude. However, responding to change often requires collective action by multiple actors, bound together in a SES. Even the outcomes of these social interactions may affect participating actors differently. In particular, rural communities often depend on existing SES to sustain their livelihoods. For these communities, social-ecological change can directly affect their traditional and current forms of land use, as well as their cultural viability (Ford et al. 2015; Eira et al. 2018). Despite the urgency of addressing challenges of a rapidly changing world, a comprehensive understanding is lacking of how the dynamics of the social-ecological system may either foster adaptations that correspond to the cultural preferences of traditional livelihoods, or, alternatively, might lead to transformations with undesirable consequences (Ruiz-Mallén and Corbera 2013; Pearce et al. 2015).

To gain better insights into the external and internal forces that affect traditional livelihoods, holistic approaches are required. Such approaches embrace and integrate a broad range of different perspectives and knowledge systems. Different knowledge systems include traditional or praxis-based knowledge, accumulated over generations and handed down between them, as well as multidisciplinary research (“Western science”), involving different academic backgrounds (Mistry and Berardi 2016; Ban et al. 2018). A successful combination of different types of knowledge can contribute a variety of perspectives to solve common problems, and to clarify how policies or management decisions affect traditional livelihoods.

Therefore, there is immense potential in working together and learning from each other to facilitate social learning, i.e. a change in understanding that becomes established in broad social contexts (Reed 2008) to navigate the dynamics of social-ecological systems (Ostrom 2009; McGinnis and Ostrom 2014).

Ultimately, collaboration between different stakeholders may deliver practical recommendations, and lead to increased empowerment of local communities in the co-management of natural resources (See Chap. 6 of this volume, Guerrero et al. 2018). From an environmental justice perspective, the active involvement of stakeholders and communities is fundamental to increase the legitimacy, credibility and democratization of both science and the policies that affect their livelihoods or subsistence practices (Raymond et al. 2010). Creating opportunities and establishing arenas for stakeholder involvement is therefore an essential requirement to foster knowledge co-production in a dynamic SES.

14.1.2 Reindeer Husbandry as Social-Ecological System

Within the Nordic countries, and parts of the Russian Kola Peninsula, reindeer husbandry is a traditional livelihood for indigenous Sámi, as well as non-indigenous herders in Finland (See Chap. 11 of this volume). Revolving around the reindeer (*Rangifer t. tarandus*) as a cultural keystone species, reindeer husbandry as a true SES reflects both biophysical and socio-political dynamics that have crossed borders between nation states for centuries (Riseth et al. 2016, Risvoll and Hovelsrud 2016). The origins of reindeer husbandry date far back in history, before the Nordic states were fully developed as we know them today. Reindeer husbandry developed gradually from the hunting of wild reindeer and other subsistence uses. With high variation in space and time, reindeer husbandry became a well-established livelihood, at the latest, by the seventeenth century (Björklund 2013). During the following centuries, the national governments in all of the Nordic states pursued policies to assimilate reindeer husbandry into their national agricultural frameworks and regulations.

Today, reindeer herders generate their main income from meat production. Herding practices involve the use of snowmobiles, helicopters, GPS-collars and other technical equipment (Helle and Jaakkola 2008; Moen and Keskitalo 2010; Hausner et al. 2011). However, many herders emphasize the cultural aspect of their work as the fundamental dimension of their livelihood, i.e. a shared life between humans and reindeer with a connection to the natural environment. Herding practices differ within and between the Nordic countries, e.g. with regard to migratory patterns between summer and winter grazing grounds, as well as with respect to the predominant location of seasonal grazing grounds either in coastal or inland areas (See Chap. 12 in this volume). As a consequence of this high biogeographic and cultural diversity, certain herding practices work in some areas, but are impossible under other circumstances.

In recent years, providing reindeer with supplementary feeding has become a growing necessity for reindeer herders. This is in particular the case when the natural winter grazing resources for reindeer such as terrestrial lichens of the genera *Cladonia* and *Cetraria*, as well as arboreal lichens, mainly *Bryoria fuscescens* and *Alectoria sarmentosa*, are inaccessible or lacking. The precise nature and cause of the social-ecological changes that force herders to provide their reindeer with supplementary feeding are diverse and can be similar between and within the Nordic countries. However, pronounced local and regional differences do exist.

Accordingly, the experiences of herders with supplementary feeding differ widely within and between Finland, Norway and Sweden. Today, as herders are increasingly faced with the necessity of providing additional food for their animals, there is much to be gained by them in sharing their experiences with supplementary feeding and their views regarding how such a forced adaptation has an impact on their livelihoods and cultures. Yet, the opportunities for such an exchange of knowledge and experience involving herders from many different parts of the vast reindeer husbandry area in Fennoscandia have been somewhat limited.

14.1.3 The Initiative for a Workshop on Experiences with Supplementary Feeding

For this reason, we, the authors of this chapter, initiated a workshop as an arena for the exchange of experiences and the co-production of knowledge regarding the practices, challenges and opportunities with supplementary feeding as a response to social-ecological change. Workshop participants included reindeer herders from Finland, Norway and Sweden, as well as researchers with different academic backgrounds. Our primary focus was directed toward initiating a lively discussion and exchange of views between the reindeer herders. Researchers were to play more limited roles, such as facilitating discussions or providing input on their topic of expertise if this was specifically requested by the herders.

The workshop took place on March 22nd and 23rd of 2018 in Kiruna, northern Sweden. 23 herders and 20 researchers participated. Our aim for the workshop was to bring together reindeer herders from a wide geographical range across Finland, Norway and Sweden (Fig. 14.1).

The idea to offer such a workshop was initiated when the authors of this chapter met at the 9th International Congress of Arctic Social Science (ICASS IX), held in 2017 in Umeå, Sweden. Each of us is based in a different Nordic country and collaborates with reindeer herders. We therefore realized that there seemed to be an urgent need to address the questions related to supplementary feeding not only from national perspective, but from across borders as well, by initiating an exchange of experiences between herders from the different countries. We also decided to invite researchers from different disciplines with experience with the topic, such as anthropologists, ecologists, geographers, political scientists, sociologists and veterinarians.

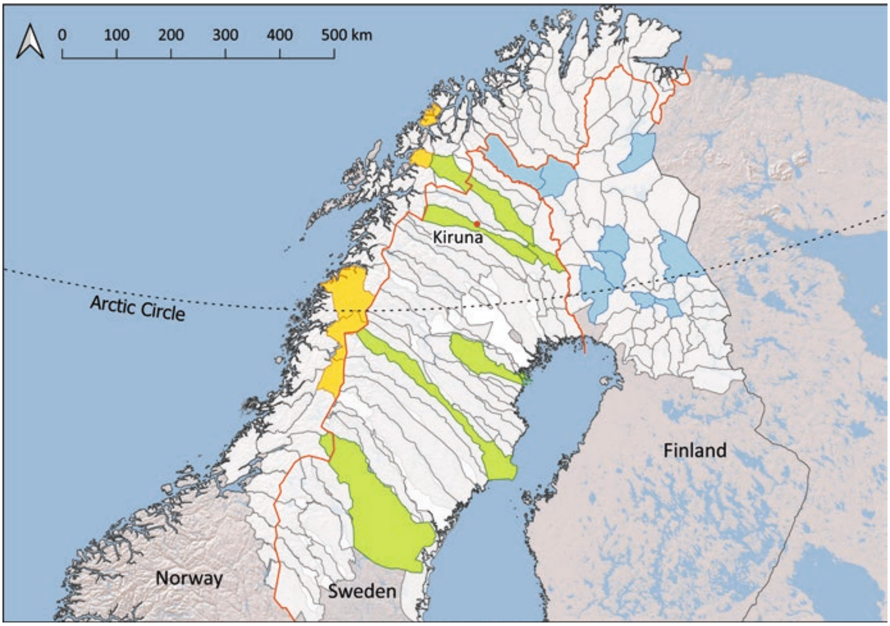

Fig. 14.1 Herding districts of workshop participants from Norway (yellow), Sweden (green) and Finland (blue). The white areas illustrate also the other herding districts per country

As a joint meeting between the Nordic Centres of Excellence (NCoEs) of NordForsk's Arctic Research Initiative were the specific reason that brought us together in Umeå, we expected that such a workshop could also provide a synergetic opportunity for some of these NCoEs to collaborate with one another. Research participants from CLINF, ReiGN and REXSAC all contributed with their different perspectives and expertise to the planning and implementation of the workshop.

The authors of this chapter, and prime organizers of the workshop, are all early-career scientists from each of the participating NCoEs. We also involved other early-career scientists in various aspects of the workshop including in the writing of the final report that would summarize and communicate the outcomes. This encouragement of participation by young scientists had been one of the guiding ideas behind the NordForsk research initiative. However, we also asked several senior scientists to assist in planning and in participation within the workshop based on their expert knowledge of co-production processes or other scientific fields relevant to the topic.

The historical and current differences between the Fennoscandian countries in terms of biogeography, management strategies and governance systems are large and continue to develop differently in these countries. There is nevertheless a need for exchange between the countries, and the respective herding communities, to respond to urgent and often multiple environmental and anthropogenic challenges. Our workshop created "Nordic added value" by an increased flow of knowledge between herders and researchers with their different backgrounds and experiences.

In this chapter, we reflect upon our goals and strategies for the workshop, and we examine some of the challenges in working together in the co-production of knowledge. We will also reflect on the lessons learned from our strategy of arranging collaborative stakeholder interaction. Before doing so, we will first consider the subject matter that directed our efforts—supplementary feeding in reindeer husbandry.

14.2 Supplementary Feeding in Reindeer Husbandry

Despite the many changes that reindeer husbandry in each of the Nordic countries has experienced over time, the practice of having free-roaming herds relying on natural grazing resources remains culturally important for reindeer husbandry even today. However, the decline in access to grazing resources, increasing land fragmentation and resource extraction practices, more frequent freeze thaw cycles and growing predator populations are all forcing herders to find alternatives to sustain their reindeer during winter (Pape and Löffler 2012; Horstkotte et al. 2014; Risvoll and Hovelsrud 2016; Lépy et al. 2018). One response to a reduction of pasture access, or the limited availability or accessibility of natural grazing resources, has been supplementary feeding. This practice can buffer shortages in grazing resources or keep reindeer within specific areas to avoid their dispersal in search of forage, increasing the herders' workload (Turunen et al. 2016).

However, the use and application of supplementary feeding of reindeer during winter periods differs considerably both between and within the Fennoscandian countries. In particular, the feeding of reindeer during winter is a far more regular practice with a longer history in the southern reindeer husbandry area of Finland as compared to traditional Sámi husbandry in the northern parts of Finland, Norway and Sweden (See Chap. 12 of this volume, Helle and Jaakkola 2008). Indeed, in Finland, supplementary feeding of reindeer has been practiced to a varying extent since the late 1960s. The main reasons for doing so has been to cope with difficult winter conditions due to ground icing, deep snow or the fragmentation of winter pastures as a result of forestry activities. In the southern part of the Finnish husbandry area, feeding in pens has become a common practice, whereas in the central and northern parts of the country, feeding without fencing is more usual (Turunen and Vuojala-Magga 2014). The practice of supplementary feeding consists of feeding reindeer with lichen, hay, grass silage or pellets. While many herders buy the feed, others grow hay on their own fields if environmental conditions allow.

Although supplementary feeding can prevent the starvation of animals when natural grazing resources are unavailable, it may also affect reindeer behaviour and their disease resistance. When the animals are close together in corrals, supplementary feeding can increase animal stress and thus induce immunosuppression and expand the risks for infectious diseases (Tryland et al. 2019). Further, gastrointestinal disorders may be caused by a rapid shift to a feed to which reindeer are not adapted (Tryland et al. 2019, Åhman et al. 2018). Additionally, freely grazing reindeer are seen as culturally important to the herders. Thus, the strategy of supplementary feeding as replacement or augmentation of natural grazing resources may turn out to have several unforeseen consequences that can affect the social-ecological system of reindeer husbandry as practiced today.

It is on these concerns and consequences of supplementary feeding that the workshop focused (Horstkotte et al. forthcoming). We intended to enable and to stimulate the co-production of knowledge as interactive and transdisciplinary processes. This would include incorporating the herders' knowledge and experiences, but also, importantly, their values and aspirations. Additional input came from the scientific knowledge of the research participants as a further source of information or inspiration.

14.3 Co-production of Knowledge as Transdisciplinary Process

Change is a ubiquitous force that shapes social-ecological systems at different spatial and temporal scales (Chapin et al. 2009). Why and how these changes may affect different members of society in different ways depends on their exposure to these changes and their options and capacities to respond (Pearce et al. 2009). Change that creates novel conditions that never have been experienced before may defy current knowledge and understanding, and thus demand the development of new knowledge (Adam and Groves 2007). Furthermore, cultural beliefs and practices contribute to knowledge in the form of holistic, often action-oriented understanding of social-ecological systems. Encoded in cultural beliefs, this knowledge is often difficult to define or to compartmentalize (Kovach 2010).

Working together with the intention to share existing knowledge, solve problems, and produce new knowledge for common solutions in times of change requires the capacity to engage with each other. Community engagement thus brings together participants as diverse as members of different communities, researchers and policy makers. The social process of 'working together' between these heterogeneous stakeholders aims to facilitate collaborative movement toward common goals and shared solutions. It also seeks to reduce conflict and to build trust by bringing together a diversity of knowledge systems (Adams et al. 2014; Reed et al. 2018). However, only when knowledge that is produced by collaboration between stakeholders is established within wider social networks, can "social learning" be accomplished (Reed et al. 2010). Diverse types of knowledge, such as local, traditional or indigenous knowledge systems and Western scientific knowledge can meet during social processes, as in our workshop. Inevitably, challenges and opportunities for community engagement and co-production of knowledge will emerge.

14.3.1 Opportunities for Knowledge Co-production

Knowledge has rarely developed in isolation. "Knowledge" is therefore best understood as a dynamic and adaptive process, where partners develop one another's capacity – the core of community engagement (Davidson-Hunt and O'Flaherty 2007). Combining different types of knowledge can result in new and creative pathways to address complex environmental and societal challenges. Such combination may help the involved stakeholders to develop a robust, holistic understanding of the challenges of managing social-ecological systems, and assist them in crafting common solutions to these challenges from both a community-based application, as well as from a researchers' perspective (Reed 2008; Tengö et al. 2014; Huntington et al. 2019). Likewise, engaging different knowledge holders conforms to environmental and social justice principles with respect to increased equality and transparency in decision-making, and the influence of research projects on local communities (Ban et al. 2013; Adams et al. 2014).

Importantly, where representatives of indigenous peoples are involved in the co-production of knowledge, it is essential to consider appropriate methodologies to overcome the historical burden of colonization, disempowerment and the marginalization of other knowledge systems. Attitudes towards experience-based or Indigenous knowledge as an evidence base can, and needs to be, strongly improved by decolonizing methodologies (Kovach 2010; Smith 2013). These methodologies consolidate cultural practices, values and worldviews inherent in indigenous or traditional societies into the frameworks and performance of knowledge production (Chilisa 2017). It further needs to be recognized that experience-based knowledge cannot be standardized. Rather it needs to be considered as place-specific and path-dependent in culture and history (Kovach 2010; Huntington et al. 2019).

14.3.2 Challenges to the Co-production of Knowledge

Challenges to the co-production of knowledge from different types and sources of knowledge include the risk of serious misunderstanding due to epistemological and institutional barriers (Nadasdy 2003; Armitage et al. 2011). Epistemology refers to the validity, scope and methods of acquiring knowledge (Moon and Blackman 2014). If different approaches to generating knowledge do not recognize the value of each other's knowledge, then the epistemological barrier hinders an effective communication between them (Ross et al. 2011). For example, indigenous knowledge often includes a spiritual dimension that may be difficult to comprehend from a Western Science perspective (Berkes et al. 2000).

Institutional barriers may arise from too narrow definitions or fragmentation of knowledge into separate compartments. For example, the reductionist approach of Western Science may be diametrically opposed to the more holistic understanding of the "human-in-nature" concept within traditional knowledge systems. Such an approach can also fail to acknowledge the complexity of other sources than scientific knowledge, resulting in in power imbalances between the involved participants (Ellis 2005; Pohl et al. 2010).

Effective communication also depends on the ability to cross language barriers. This reality is addressed in Sect. 14.5.3 below. Indigenous languages, in particular, involve accurate descriptions of complex phenomena. Their holistic terminology may combine different phenomena into a single concept. This complexity can be difficult or impossible to directly translate into other languages (Polfus et al. 2016). Therefore, respectful communication between different ways of perceiving and describing the surrounding world requires extra sensitivity and skills. Even if the same or similar languages are spoken, concepts and terminology need to be clarified between the involved participants to avoid misunderstandings between them (Reed et al. 2014).

Strategies to bridge these barriers and combine different knowledge systems in ethical and empowering ways have received much recent attention (e.g. Bohensky and Maru 2011; Ford et al. 2016; David-Chavez and Gavin 2018). Critical for the successful co-production of knowledge between different knowledge systems is mutual respect, trust, and the involvement of all participants at multiple stages of the engagement processes. This includes their participation in defining the questions to be addressed and the methodologies to be used. It may also require their active role in the design of the engagement, the data collection and analysis as well as the dissemination of results (Djenontin and Meadow 2018). Protection against an extractive approach, where knowledge is considered an exploitable resource, necessitates a respectful relationship between all participants during all stages of the co-production process. This cannot be overemphasized (Armitage et al. 2011; Kovach 2010; Reed et al. 2014; Latulippe and Klenk 2020).

Where these strategies are followed, the desired engagement is more likely to result in legitimate, transparent and constructive outcomes that create enduring relationships between participants (Reed 2008; Gratani et al. 2011; Adams et al. 2014). Neglecting participant engagement during the different stages of the co-production processes risks mis-matches in expectations or misperceptions regarding their influence on outcomes and decisions (Reed 2008; Djenontin and Meadow 2018).

Although the importance of involvement throughout the whole process is widely emphasized, David-Chavez and Gavin (2018) find that a full participatory design for community engagement is rarely applied in practice. The co-production of knowledge, therefore, does not automatically lead to the implementation of results. From an academic perspective, the congruence between different knowledge systems is acknowledged (Tengö et al. 2014). However, that congruence remains sparsely acknowledged or implemented in policy or management decisions (Sara 2011; Turi and Kesitalo 2014; Benjaminsen et al. 2015).

During our development and implementation of the supplementary feeding workshop, we encountered many of these challenges and opportunities inherent in the co-production of knowledge. In the following sections of this chapter, we consider some of these in greater detail and note what we learned from such engagement.

14.4 Working Together Across a Diversity of Knowledge Systems

In this section, we discuss how three different relationships between participants shaped the organization, development and progress of the workshop. These relationships concern the collaborative efforts that were necessary with respect to: (1) the organizing work among the separate NCoEs; (2) building bridges between herders and researchers; and (3) facilitating interaction between the herders themselves. Each endeavour is worthy of consideration.

Our workshop took place over the course of 2 days, March 22nd and 23rd, 2018. During Day One, the participating herders discussed any topic related to supplementary feeding that they desired in groups divided by language – Norwegian, Swedish and Finnish. Scientists followed these discussions, contributing their knowledge when asked by the herders. These discussions were followed by summaries of the major points of the discussions that were shared with all participants.

We used a two-part framework that asked herders for consideration of: (1) desirable and undesirable consequences of supplementary feeding and (2) the likelihood that these consequences would occur. The herders also emphasized in their discussions that their primary objective was not to need to apply supplementary feeding at all. They strongly preferred reindeer being able to sustain themselves on natural grazing resources.

Day Two of the workshop brought together all participants in one setting. The goal of this session was to fully engage herders in discussion across country borders. The results from the previous day's deliberations were considered and then compared drawing upon the different experiences and viewpoints of the herders.

14.4.1 Working Together Across NCoEs

The existence of the three NCoEs brought the authors of this chapter together in the first place. Based on our previous work with reindeer herders in each of the three countries, we identified supplementary feeding as an important topic of concern in the present and future both from the viewpoint of the herders, as well as from our own research agenda. Moreover, each of the NCoEs have their particular and unique approach in addressing responsible development in the Arctic. Each NCoE emphasizes different processes and applies different methodologies. NordForsk's aspiration to create "Nordic added value" by means of increasing research collaboration between the Nordic countries in a way that transcends national borders and interests, encouraged us in our endeavour. In particular, NordForsk's mission to involve community members more directly in research projects resonated well with our own ambitions and earlier experiences in working with various local communities, including reindeer herders.

Although the initiative that led to the workshop arose from the researchers involved, the existence of the NCoEs was as a necessary precondition and fundamental source of inspiration for necessary creative process. It provided us not only with the necessary interdisciplinary approach to address a topic as complex as supplementary feeding, but also afforded us a broad network for people to meet, exchange ideas, and set the direction for the workshop. Importantly, we were able to gather a dedicated team of researchers with different experiences – from early-career to senior scientists – who collaborated during the whole process of planning and arranging the workshop. This collaboration has continued in the aftermath of the workshop in Kiruna as we have worked together to write a report covering the workshop.

While contacts with the herding communities already existed within each of the NCoEs, the planning stage of the workshop greatly benefited from the combined efforts of all the groups and by having their collective network of contacts available to us. Importantly, we were also able to work together to secure extra funding from each of the involved NCoEs, from the NordForsk Secretariat and other funding sources including universities and local governments to realize the workshop. Additional funding was necessary to cover a number of different costs, but, most importantly, to finance the travel and accommodation expenses of the reindeer herders. Without these available resources, many might have found it difficult to participate. Funding was also necessary to compensate herders for the time they spent away from their normal work in their respective reindeer herding districts. Below, we briefly outline the particular focus of each the participating NCoEs and how their individual research agendas made an important contribution to the conception and development of the workshop.

14.4.1.1 CLINF

CLINF has aimed at gaining a better understanding of how the spread of climate sensitive infections will affect societal and individual well-being, security, and adaptive capacity in the North. Its members study the health effects of climate sensitive infections on both animals and humans. With this in mind, reindeer and their herders have been a prime interest of the CLINF researchers. They have also looked the economic and cultural impacts of such climate-induced change. (See Chap. 3 of this volume). In order to pursue such a broad task, the CLINF consortium has had a multi-disciplinary approach, along with close collaboration with societal stakeholders is necessary. The workshop on supplementary feeding with its significant interdisciplinary interests and broad collaboration with reindeer herders provided a major avenue for pursuing CLINF's tasks. Seven researchers and one PhD student from CLINF participated in the workshop. Tr roles varied between organization, facilitation, note taking and contributing to the knowledge exchange. CLINF invited one external researcher to take part in the workshop.

14.4.1.2 ReiGN

The central objective of ReiGN has been to understand the nature and consequences of both internal and external changes on the reindeer, the herders and their livelihood at several spatial and temporal levels. This required ReiGN to adopt a multidisciplinary approach involving genetics, ecology, anthropology, economics as well as socio-political views and perspectives (See Chap. 11 of this volume). Given the impact of supplementary feeding on all these dimensions found within reindeer husbandry, the workshop and its focus on the co-production of knowledge, was an important event for many of the researchers involved in ReiGN. Eight researchers from ReiGN took part in the workshop, assisting in its organisation and the facilitation of discussions. The ReiGN project also invited one external researcher to Kiruna.

14.4.1.3 REXSAC

While the primary focus of REXSAC has been on resource extraction and the sustainability of Arctic communities (See Chap. 7 of this volume), one of its additional research tasks has been to identify and analyse the impacts of multiple environmental and social pressures on Arctic landscapes and societies. Researchers from this specific research projects have looked at how new extractive industries like mining and forestry along with other infrastructures investments bring new pressures to bear on reindeer herding activities in the North. The have considered the consequences of such natural resource development on availability and access to reindeer pastures. With this in mind, the supplemental feeding workshop was also of significant importance to the work of this NCoE. REXSAC brought three researchers from geography, anthropology and ecology to Kiruna. They helped to organise and facilitate the operations of the workshop.

14.4.2 Working Together Among Herders and Researchers

An essential element in the development of participatory practices is to identify potential participants. The principal aim of our workshop was to invite herders from the different parts of the Fennoscandian reindeer husbandry area. This was to account for the different natural, social, economic and cultural aspects of the region. We sought a broad representation of the herding community. The exchange of perspectives and opinions between the herders, and the contribution of their experience-based knowledge were main objectives of the workshop.

14.4.2.1 How Was the Herding Community Approached?

Engaging the herding community in our endeavour was context-specific The way in which potential herder participants were approached has been slightly different within the three Nordic countries, reflecting already existing collaboration practices and networks. However, a common letter of invitation was drafted in English and then translated into the respective national languages. From there, different approaches were followed as detailed below.

Finland

The Finnish reindeer husbandry area is divided into 54 reindeer herding cooperatives called "*paliskunta*", where Sámi and Finnish reindeer herders practice their livelihoods. The separate parts of the Finnish husbandry area differ from one to another due to the diversity of the natural environments and the economic conditions found in each area. Three areas can be distinguished (Reindeer Herders' Association 2014):

1. The "Sámi homeland area" is covered by old-growth forests but also open fell highland areas. Industrial developments and land use competitors in general, are less present than in the southern part of the husbandry area. Areas for nature conservation and wilderness areas cover a major part of Sámi homeland. Reindeer herders have stronger position compared to the rest of the Finnish reindeer husbandry area and special consideration is given to securing the livelihood against other land uses or conflicting interests.
2. The "area specially intended for reindeer husbandry" in northern Finland is mainly covered by coniferous tree dominated forests. Though this area also has a certain level of protection to secure the livelihood, the biggest mining developments in Lapland are located in this area.
3. The "reindeer herding area" represents about half of the husbandry area. It is covered by boreal forests in its northernmost part and by expansive bog plains in its southern part of the country. Land use competition is high in this area as many industries are present in the region such as forestry, the tourism sector, as well as wind power and peat production. It is also the area where Finnish reindeer herders first started to use supplementary feeding in the late 1960s to ensure the survival of the herds over the difficult winter conditions and to maintain a stable livelihood.

In preparation for the workshop, we contacted the Reindeer Herders' Association (https://paliskunnat.fi). They advertised the workshop on their Facebook page. In a parallel effort, we sent an invitation letter to each of the 54 Chiefs of the reindeer herding cooperatives who were asked to spread the information among their members.

Ultimately, nine Finnish reindeer herders took part in our workshop. Three of them came from the "Sámi homeland area" and the six others from the "reindeer herding area". Two of the latter grouping were from reindeer herding cooperatives located at the border between "the reindeer herding area and the "area specially intended for reindeer husbandry".

Sweden

The Swedish reindeer husbandry area is comprised of 51 herding districts (*samebyar*), covering approximately 50% of the country's entire area. As in Finland, environmental conditions, history, culture and herding practices differences exist between these different Swedish herding districts. However, three major distinctions can be made.

Mountain districts (33 districts) practice seasonal migrations between the summer grazing grounds in the coastal mountains near the border with Norway and winter grazing grounds in the forest lowlands. Seasonal migrations of reindeer can be assisted by the use of trucks, where traditional migration routes have been lost due to river damming for waterpower or as a result of other infrastructure development. In the *forest herding districts* (10 districts), reindeer stay in the boreal forest year-round. Nonetheless, such districts practice rotation between seasonal grazing grounds. Thus, the habitat used by reindeer differs between the seasons. The remaining eight Swedish *concession* districts are similar in character and operation to forest herding districts. However, in these areas, reindeer may be owned by non-Sámi. However, their animals are taken care of by Sámi herders.

The natural and economic conditions found within and between these Swedish districts can vary widely. There are significant differences among them with regard to their access to seasonal grazing resources throughout the year. Similarly, they vary according to their exposure to competition with other forms of land use practices that can result in differences in herding practices and experiences, including supplementary feeding.

In order to provide a comprehensive picture of the Swedish herders' use of and experiences with supplementary feeding, it was important to have representatives of all these diverse communities represented at the workshop. We therefore started a dialogue with the Swedish Sámi Association (*Sámiid Riikkasearvi*, SSR) to identify possible participants. Rather than addressing letters to every herding district, we engaged particular herders in person, and followed up on their recommendations for possible participants. Nine Swedish herders attended the workshop. Five came from Swedish mountain districts; one from a forest district; and one represented a concession district. We also invited two participants from the Swedish Sametinget.

Norway

Reindeer husbandry is recognized as an indigenous livelihood in Norway. With a few exceptions of concession areas in southern Norway, a reindeer herder must be of Sami descent according to Norwegian legislation (Johnsen 2018). Close to 40% of the entire Norwegian land area consists of reindeer pastures. There are 82 reindeer herding districts in Norway located within 6 reindeer grazing regions. There are no land ownership rights connected to reindeer husbandry in Norway. However, since the eighteenth century, reindeer herders have maintained official user rights within the herding districts. This practice is regulated through a system of licenses referred to as 'siida shares' (siida-andeler).

Reindeer husbandry in Norway is based on seasonal migration patterns and varies across different regions due both to historical and current social, ecological, climatic conditions and regulatory frameworks. Nordland and Troms counties have a steep altitudinal gradient from sea level to the high mountains and glaciers of the North. This can result in shifting snow conditions during winter; unpredictable arrivals of spring, and fresh and nutritious pastures at different altitudes during summer (Risvoll 2015). Finnmark County is the largest reindeer husbandry region in Norway. It has both winter pastures on inland plateaus dominated by lichen, and green coastal pastures during summer (Benjaminsen et al. 2015).

Environmental and socio-economic pressures, as well as government policy, have all threatened traditional grazing patterns in Norway. These pressures include limited pasture access due to snow and ice conditions as well as predation. They also reflect increasing encroachment on grazing lands from urbanisation, cultivation, mining, and the development wind and hydroelectric power (e.g. Riseth and Tømmervik 2017; Risvoll and Hovelsrud 2016). Herders have responded to these challenges in various ways. Supplementary feeding is one such response when natural pastures are limited or inaccessible.

Norwegian reindeer herding districts apply supplementary feeding in varying degrees. We aimed at securing the participation of herders from as geographically broad areas as possible in order to obtain representation of a diverse set of herder experiences related to the supplementary feeding. The approach and point of departure for such an effort, was our previous and ongoing collaborations with the Norwegian reindeer herding communities. We utilized our existing networks and from there sought to broaden our geographical scope through a “snowball” method of recruitment. We asked key actors from the reindeer herders association about other potential herders whom we should contact.

14.4.2.2 Preparation and Dissemination of Workshop Results

All discussions during the workshop were carefully written down by several note takers during both days. This provided us with detailed material for a summary report. We aim to distribute this report to all of the participants and other potential interest groups linked to reindeer husbandry in the Nordic countries. At the time of writing this chapter, the report is almost completed (Horstkotte et al. forthcoming).

The preparation of the final report has also been an iterative effort between researchers and the participating herders. While a team of lead authors prepared the preliminary version of the report, this was subsequently exchanged with the herders for their comments, corrections, clarifications and additions of necessary details. This version of the report was made available in three national languages—Finnish, Norwegian and Swedish—for their review and comment. The final report will be published in these Nordic languages as well as in Northern Sámi and English. The importance of having both materials and discussions in indigenous languages will be addressed later in this essay.

14.4.3 Working Together Across Herding Communities Within and Between Countries

The major part of the workshop, and its primary intention, was to facilitate direct exchange of ideas and perspectives among the reindeer herders. We also sought to provide them with opportunities to discuss these among themselves. The content and character of these discussions were mainly driven by the differences that exist in practice and experience between the different herding districts within a country (Day One), and between countries (Day Two). Thus, for example, herders all from one country discussed among themselves during Day One how they used supplementary feeding during the winter, ranging from more regular use to those who have started only recently to give supplementary feeding. Discussion also revolved around differences in grazing conditions resulting from different vegetation zones and spatial flexibility. Herders also considered how to react to disturbances to their routines, including presence of carnivores or severe winter weather conditions. Furthermore, cultural aspects of reindeer husbandry were touched upon, related to Sámi and non-Sámi herding. However, these differences were not perceived as obstacles in the communication.

The discussion during Day Two of the workshop focused on the exchange of ideas and viewpoint across national borders. Here, efforts at comparative analysis and assessment took place. More than in the previous day, this discussion was dependent on bridging language and cultural barriers. Yet despite these potential barriers, herders from all countries actively engaged in the discussion, identifying how and why there are similarities and differences in practice between the three countries. Also, during Day Two, a number of questions were directed towards the Finnish herders, as they had wider experience with the practice of supplementary feeding. It became clear to all that there was significant benefit in providing such a forum for the exchange of ideas and opinion, providing a basis for future gatherings.

14.5 Reflections About Our Way of Working Together—Challenges and Opportunities

14.5.1 Invited Herders

As noted earlier, our approach of inviting reindeer herders resulted from ongoing dialogue and collaborations with herders in our respective work areas. Participants in the workshop had to travel long distances and had to take time away from their normal work. A particular limitation from the Norwegian side was that invited herders from Finnmark were not able to attend due to time constraints and other unforeseen events. Finnmark is geographically the largest reindeer husbandry area in Norway and has the largest number of reindeer in the country. Having had the views, experiences and knowledge of the herders from this region would have been a valuable addition to our workshop.

However, such cancellations, at short notice, are to be expected, as herding practices are dependent on environmental conditions that can change rapidly. Therefore, in deciding the best time for such a meeting, the input of herders is indispensable. Nonetheless, the reactions that we received from all the participants who were able attend made it clear that the workshop had inspired a willingness on the part of all to continue with further projects aimed at learning from each other and discussing the experiences of herders across the countries' borders.

In organizing our workshop, we did not invite other stakeholders whose activities or policies affect reindeer herders in their decision-making processes regarding supplementary feeding. Inclusion of a wider range of participants, however, would have necessitated another step in the development of shared knowledge related to supplementary feeding. A broader participation by diverse stakeholders who would have, potentially, brought different or contrasting perspectives. These additional herders would have required more of time and resources than we had available.

Equally important, trust between participants and a mutual understanding of circumstances needs to be developed in order to enable such collaboration (Sandström and Widmark 2007). This is particularly the case when potentially contested topics such as land use practices or rights to natural resources may form the central topics of the discussion (Larsen et al. 2017). Specific human resources are required to facilitate, mediate and communicate between stakeholders with competing interests (Cash et al. 2006; Vucetich et al. 2018). We are planning to follow up on the workshop discussed here with such a holistic approach in future projects.

14.5.2 Finding an Appropriate Meeting Place and Methodologies

Given the wide geographical spread of our workshop participants, the meeting place needed to be both as central and accessible as possible. We therefore chose Kiruna in northern Sweden, though other options were discussed. Unfortunately, it turned out not to be the optimal choice for everyone attending.

The workshop took place in a conference facility that offered sufficient spaces for large group discussions and provided the use equipment for presentations in group work. However, this environment removed the herders from the more natural setting in which they normally pursue their livelihoods. Having a more familiar and conducive setting for the herders might have sparked additional discussion on their parts or directed it in a different way. Creating a "safe operating space" for everyone involved is therefore not as straightforward a decision as we originally thought. With more time and resources available, we might have also created excursions or direct observation of feeding practices nearby in areas. This would have been a valuable addition, as it would have provided a good basis for two-way communication and additional learning in an environment closer to herders' practices. Such ambitious and resource-demanding designs for the coproduction of knowledge should be included in future efforts of this kind.

14.5.3 Multiple Languages

Language use was a challenging issue during the workshop and in the writing of the final report. Participants of the workshop – the reindeer herders as well as the researchers - did not share any common language. They normally spoke one of the Sámi languages and either Norwegian, Swedish, Finnish or English.

The workshop took great advantage of a skillful translator who was fluent in Finnish, Swedish, Norwegian and English. However, we were unable to provide translations of the workshop discussions into any of the Sámi languages. We were well aware that having at least one of the Sámi languages as a feature of the workshop would have been very beneficial and respectful. Unfortunately, such translation services were not readily available. However, overcoming language barriers should be prioritized in similar events in the future. In particular, this is the case where cultural aspects of presentations may require highly specific terminology that is not easily reflected in the other languages. A drawback with any simultaneous translation is that some of the words and thoughts of the speaker could become lost during the translation. Having such translation services, however, is efficient, and perhaps the only way, to gather many stakeholders from different linguistic and cultural backgrounds together in one place.

The challenge of handling multiple languages remained an obstacle during the writing of the final report of the workshop. As we collaborated with herders during the writing process, we asked for their feedback in their respective languages. As the core document was written in English, many translations were necessary to share its contents with the herders and the other researchers involved. It became a real challenge to keep the meanings of all the different versions the same. Despite the complexity and time-consuming nature of the translation processes, we believe that it is necessary to produce a comprehensive end report that reflected the activities of the workshop and the participants' contributions in verbal and written form. This final report will also be made available in Northern Sámi.

14.5.4 Work in Progress and the Future

Because of the success of the workshop in bringing together reindeer herders from different parts of different countries, much work remains to be done. This includes finalizing the report that documents the activities of the workshop and disseminating its results. The collaborative approach between herders and researchers this process has already been emphasized. In order for the final report to include as closely as possible to the herders' knowledge, it has been essential to maintain an ongoing dialogue around topics raised at the workshop. For instance, the Norwegian researchers and some of the herders have been able to meet after the workshop not only to discuss the final contents of the report, but also to further reflect on the issues discussed at the workshop. In this way, we ensure that the final report is not only an accurate record of the herders' voices, but a means to facilitate ongoing study and discussion between researchers and those engaged directly in reindeer husbandry.

Such an approach is true to the collaborative spirit that is central to the co-production of knowledge. It gives all participants some control over the outcome they have helped to create (Kovach 2010; Kuokkanen 2010). Using the workshop as a stepping stone for further collaborations and as a means increase our collective understanding how supplementary feeding will affect reindeer husbandry in a rapidly changing social-ecological environment is unquestionably an important accomplishment.

14.6 Lessons Learned from Our Perspective for Planning and Arranging Collaborative Stakeholder Processes

Our particular workshop with its specific goal and targeted participants taught us several lessons during all stages of its planning, development and implementation. Our one-time experience cannot offer exhaustive guidelines or clear roadmaps for all such endeavours in the future. The necessary strategies will vary from context to context, and will depend on the purpose of the collaboration and on the background of those involved. Yet, we offer our perspective on some important steps we have taken, and that might be useful as an encouragement for similar efforts.

Start Early – Time Is a Valuable Resource

Planning requires time in identifying funding sources, writing applications and in deciding whom to include and which methods to use. Importantly, potential participants need to be contacted early. True co-production of knowledge between stakeholders also involves the co-design of the process, and as such, participants should already be involved from the very start. Extra time is always necessary to ensure a satisfactory flow of information between all the partners involved.

Budget Requirements

Designing stakeholder collaboration also depends on the budget availability. When writing funding applications, it is necessary to be clear about the resources needed to carry out a project. More benefit may lie in being truly honest about the actual financial requirements of the undertaking than in being "strategic" and aiming for a more limited "reasonable" budget. Funders might still reduce the funding size of original funding package, but showing what resources are truly needed may provide a higher degree of flexibility with the final budget.

Cross and Push Boundaries

The workshop should be designed collaboratively with later participants in order to identify core topics together. Research designs need to ignite the participants' motivation and creativity. Such designs should include the cultural contexts of the participants, to overcome approaches centred on the needs of researchers. Having a multidisciplinary team provides excellent conditions for thinking out of the box.

Collaborate with the Community

Involving potential community participants in the design of collaborative projects requires effective communication skills. Asking potential participants for their help and their opinions in the planning processes should not be avoided due to shyness or sense of being inexperienced. Instead, help should be asked in a humble and respectful way. Such an approach can strongly contribute to the ultimate success of the planned event.

Follow Ethical Guidelines and Compensation Schemes

When collaborating with local or indigenous participants, it is essential to follow established ethical guidelines in a decolonizing and empowering way. This includes, but is not limited to, pursuing approaches that are in line with indigenous values and epistemology. It includes understanding and being attentive to what is useful to the participants. Financial compensation for contributed time by local participants is a common standard.

Openness to Different Opinions, Cultures, Ways of Thinking and Perceiving

A diversity of participants brings with it a variety of opinions, experiences and expectations. Though these are valued in collaborative undertakings, they can also create friction between participants. This needs to be carefully navigated. It requires regular "reality checks" and discussion of cultural differences, as well as clearly identified strategies for embracing and handling diversity.

Consider Multiple Languages

Language barriers can hinder efficient communication between participants and can be frustrating. These barriers may exist in the vocabulary of different academic disciplines, as well as the practices and approaches of different countries and cultures. Recognizing and limiting such barriers is a necessary requirement for effective collaborative inquiry. This cannot be overestimated and should be carefully addressed in the design of all activities that require interaction. Being able to use one's own words reflects the identity of participants. It often determines whether they feel represented and consider themselves able to voice their opinions (Kovach 2010).

Create a "Safe Operating Space" for Everyone Involved

Participants may differ in the level of comfort they feel depending upon the specific setting in which collaborative activities take place. What some participant might consider as a convenient meeting place, others might not. Depending on the participants involved, certain trade-offs might be required. If time and funding allow, flexibility in venue options and settings that will facilitate the co-production of knowledge and allows for joint discovery should be considered.

Communicate, Communicate, Communicate
Communication is the key to successful collaborative projects – from the initial planning and design stages until the final dissemination of results. The development of stakeholder workshops therefore is an iterative process, requiring time, patience and perseverance from all involved parties. These qualities are necessary to develop and foster both present and future contacts and to create a level of mutual trust. The reporting of workshop outcomes to participants needs to cover not only specific information, but an effort must be made to place this a broader context.

14.7 Conclusions

Connecting people by working together and sharing knowledge was the principal ambition of our workshop, where we prioritized the interactions between reindeer herders from diverse backgrounds.

We cannot extrapolate too far from our experiences in arranging workshops focused on the sharing of experience and the co-production of knowledge. However, it is evident that only long-term commitment and communication have the potential for true co-production of knowledge. A meaningful knowledge base derived from several knowledge systems can develop during an iterative process of 'working together'. Such co-produced knowledge can be harnessed in response to changes that affect both the natural and social environment. It is essential that these results enable and empower the reindeer herders to maintain their cultural preferences and identities when they make decisions and take actions.

Likewise, critical self-reflection and assessment from our side is necessary. We acknowledge the absence of the Sámi language at our workshop despite our calls for greater inclusiveness. Similarly, the selection of a more culturally sensitive venue might have better captured the realities of the livelihood of the herders and might have sparked further discussions and insights that were lost in an exclusively indoor environment. Additionally, our planning of the process could have incorporated a stronger degree of participation from the herders' side.

Our workshop, therefore, had some limitations, both from a practical perspective, as well as in its overall approach. However, we are confident that the workshop was a successful event in that it directly shared experiences and addressed knowledge gaps among herders and researchers. It is therefore only the *first step* towards an increased dialogue that will require more direct interaction between all parties in the future. From all the diversity of experiences expressed during the workshop, there emerged a unanimous conclusion that there is a great need for more collaborative investigation of supplemental feeding within reindeer husbandry in the Nordic region.

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Part V

Chapter 15
Is There Such a Thing as 'Best Practice'? Exploring the Extraction/Sustainability Dilemma in the Arctic

Sverker Sörlin

Abstract Resource extraction is an old tradition in the Arctic region and shows a variable historical pattern although with a long-term upward trend that has accelerated in recent decades. This development stands in a complicated relationship to local Arctic communities. They are rarely the prime drivers of the growth in extraction industries. Nonetheless, some of them depend on resource extraction for their very existence while others suffer from extraction, some badly. In this Chapter I will articulate some of the background thinking as we put together a very large team of 15 partner universities/institutes and some 50 scholars, scientists and practitioners in REXSAC to research sustainability and resource extraction in the context of a rapidly changing Arctic with increased vulnerability and mounting outside geopolitical interest. I will present our approaches to theorizing about resource extraction (resources as socially defined) and the formation of sustainability, and I will draw on some of our results so far. I will also present our work to critically engage with policy concepts from the recent neo-liberal past, such as sustainability, assessments, or 'best practice'.

Keywords Resource extraction · Sustainable communities · Environmental governance · Arctic futures · Arctic · Affective economies

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15.1 REXSAC – Mission and Structure

REXSAC (Resource Extraction and Sustainable Arctic Communities) is one of four Nordic Centres of Excellence (NCoE) for the period 2016–2021 under the programme *Responsible Development of the Arctic: Opportunities and Challenges – Pathways to Action* funded by the Nordic common research agency NordForsk.

REXSAC focuses on extractive resource industries in the Arctic as cultural, social, economic, and ecological phenomena. The aim of REXSAC is to contribute to practices and processes that ensure the sustainability of Arctic communities in a rapidly changing social, political, cultural, and ecological environment. To meet this aim, we started our work with three overarching research questions:

- How and why does resource extraction commence?
- What consequences does resource extraction have for communities and environments in the Arctic and beyond?
- What opportunities exist for transitions to post-extractive futures?

The perspective was from the very outset broad and integrative. Mining and resource extraction were studied in an interdisciplinary fashion, taking into account their multiple, interrelated dimensions, linking economics, ecology, and culture. Here in the original proposal for the Center in 2015:

> REXSAC will focus on *the study of extractive resource industries in the Arctic as cultural, social, economic, and ecological phenomena – from analysis of why resource extraction commences, what consequences it has for communities in the Arctic and beyond, and what opportunities exist for transitioning toward post-extractive futures*. The cultural footprint of a mine is just as real as its environmental and economic footprint, and both must be considered as related (often inseparable) parts of a single whole.

REXSAC's focus is motivated by the fact that extractive industries have had and will likely continue to have major impacts on environments and communities across the Nordic Arctic, including challenges related to mining and hydrocarbon extraction and how they interact with energy production by hydro-power and wind-power. The Arctic is in constant change, but extraction tends always to be part of the mix.

With a history dating back to the seventeenth century in northern Fennoscandia (Norway, Sweden, and Finland), mining operations are significant in a European perspective. A very large portion, at times around 90%, of all iron ore in the EU is produced in Sweden, most of it in Kiruna. Kittilä gold mine and the Kevitsa mine, both in Finland, produce significant quantities of copper, nickel, platinum and palladium. Mining has long been a central component of high Arctic communities from Qullissat and Ivittut in Greenland – which did not survive the end of mining – to Longyearbyen on Svalbard. New mining projects have relatively recently raised hopes for prosperous futures, such as rare metals deposits in Greenland or base metals in northernmost Sweden. At the same time these projects have generated concerns for environmental degradation and disruption of traditional livelihoods such as reindeer herding and fisheries. Some mines are closing down, forcing state authorities and local stakeholders to seek out ways to build new futures.

The history of fossil fuel extraction in the region is shorter but has roots to the nineteenth century in Svalbard, where several nations (Norway, Sweden, Russia) had their own mines. Some were still in operation well into the twenty-first century. While coal has taken a downturn, oil and gas exploitation has grown considerably, especially in the Barents Sea region (including Northwestern Russia), and several sites are explored in Svalbard, Greenland, and Russia. Today, fossil fuels face the combined challenges of short-term concerns from low oil prices and a longer-term need to transition into a post-petroleum future, if climate goals are to be met.

Resource extraction has been so pervasive in the north over a long period of time that it has created what has been called a "resourcescape" (Avango forthcoming). Because extractive industries have major impacts on both local economies and on other uses of land and ecosystem resources, prospects of extractive industries in the Nordic Arctic pose challenges for a wide range of actors involved because of their hard to avoid boom and bust cycles based on forces far away. Local communities usually have few alternatives to cope with the effects of fluctuations in the global market.

REXSAC's three research questions were motivated by the ambition to take the entire process of resource extraction into account. From its foundational phase, which often starts with visions, imaginaries and geopolitical strategizing (Sörlin 1988, 1989; Grace 2002), what in a Canadian mining history context has been called "northern dreams" (Keeling and Sandlos 2015: 2–4), to its operational period through to the phase when extraction winds down or closes, which is often a challenge or crisis for local communities. In setting up the Center we held as a general hypothesis that for a sustainable future for Arctic mining communities, it is essential to link all these phases together into an integrative and coherent understanding of resource extraction. Taking this three-phase scheme into consideration at the start of a mining or energy project would make it easier to make the entire cycle more sustainable.

Based on what we knew, and increasingly on our own work in the project, we felt a need to develop an alternative view to resource extraction as "a hole in the ground" in a single place, used for a while. We sought to provide an understanding of resource extraction that was built on a broader and deeper context and therefore was more true to reality. That REXSAC understanding was to see extraction as an activity, taking place in time and space – typically with market- and policy dependent ups and downs, and through its ecological, economic and social effects covering a vast space. Considered in this way, extractive industries are at the same time external and alien to local and indigenous tradition, yet also inextricably interwoven with local identities and integral to a "social-ecological-technical" system (Nilsson and Christensen 2019:117; Nilsson and Avango in progress). We developed the term for this purpose combining systems definitions from previous research (Hughes 1983; Folke 2006; Edwards 2010; Cornell et al. 2010; Avango et al. 2019).

We also started to look in some detail at the communities in question. Some of these are largely indigenous, of which our understanding has been revolutionized by research in recent years. Previous essentialisms have given way to more realistic and empathetic depictions of how Arctic citizens de facto lead diverse lives under considerable pressure, from climate change and often extractive industries (Hastrup 2012, 2015; Krupnik 2016). This research has also made it clear that policy, demography and culture all hang together and will be important for the long-term health and livability of the communities. Extractive industries affect communities profoundly, not least how they are gendered. The enduring tradition of coding the Arctic as a masculine space (Bloom 1993) not least affected the status of mining as a masculine activity. Demographic impacts – such as heavily male communities with consequent deleterious effects on social sustainability – reflect a situation that can be addressed through recoding the gendering of mining rather than deeming it an inevitable state of affairs.

Similar questions may be posed regarding knowledge and expertise, often binary coded as "Western" or "Indigenous". The Arctic was long considered an exceptional space where science, often in close alliance with national strategic and economic interests, exercised hegemony and, indirectly, also authority over nature, people and politics (Krupnik et al. 2005; Sörlin 2013; Doel et al. 2014). The sustainability of extractive industries, we concluded, needs to be examined from this wide array of perspectives.

We originally addressed our research questions through ten Research Tasks (RTs), composed of researchers from different partner institutions in REXSAC, drawn from across seven countries, and from different disciplines across the natural-, social- and human sciences. Most of the RTs also in practice involved community representatives. The RTs took on different parts and aspects of one or more of the three overarching research questions and thus operationalized them. Each RT produced specific deliverables (articles, books, contributions to PhD training), but there have also been collaborations between the different RT's, and over time some of these were merged to gain in efficacy and critical mass.

Table 15.1 below provides an overview of the REXSAC Nordic Center of Excellence (NCoE). It shows the major Research Tasks (RTs) contained within the overall project and notes the main researchers associated with each RT. In viewing this framework, the three main REXSAC research questions should be recalled:

- How and why does resource extraction commence?
- What consequences does resource extraction have for communities and environments in the Arctic and beyond?
- What opportunities exist for transitions to post-extractive futures?

15.2 Resource Extraction Has an Impact

This multi-year research effort has looked carefully at how extraction works. REXSAC has studied mining, and related extractive or other land-using activities (forestry, food production, reindeer herding) in seven Arctic countries. We have used academic expertise covering the natural sciences, social sciences, and humanities, and we have interacted with expertise in indigenous communities and among

Table 15.1 Research questions, research tasks and their lead senior participants

Research task	Main researchers (lead researcher in bold)
RT 1 & 9) Defining sustainable development: Indicators, and scenarios as tools for co-production of knowledge	**Joan Nymand Larsen**, **Annika E. Nilsson**, Jón Haukur Ingimundarson,
RT 2) Impacts of multiple pressures on Arctic landscapes and societies	**Gunhild Rosqvist**, Göran Ericsson, Hannu Heikkinen, Niila Inga, Jerker Jarsjö, Rasmus Kløcker Larsen, Rebecca Lawrence, Elisé Lépy, Mark Nuttall, Kaisa Raitio, Jarkko Saarinen, Navinder Singh PhD students: Jean-Sébastien Boutet, Sandra Fischer, Christian Fohringer, Carl Österlin, Jasmiini Pylkkänen, Camilla Winqvist
RT 3) Governance structures for extractive industries: Identifying path dependencies	**Mark Nuttall**, Dag Avango, Arn Keeling, Rasmus Kløcker-Larsen, Gunhild Rosqvist PhD students: Jean-Sébastien Boutet, Anna-Maria Fjellström
RT 4) Transnational companies, indigenous peoples – the politics of Arctic mining	**Rebecca Lawrence & Peder Roberts**, Arn Keeling, John Sandlos, Ulf Mörkenstam PhD students: Jean-Sébastien Boutet, Anna-Maria Fjellström, Jasmiini Pylkkänen
RT 5) Affective economies: How are places, communities and identities constructed?	**Kirsten Thisted**, Lill Rastad Bjørst, Frank Sejersen, Anne-Mette Jørgensen
RT 6 & 7) Extraction legacies in post-extraction communities: re-mediation, heritage processes, re-economization	**Dag Avango**, Peder Roberts, Albina Pashkevich, Arn Keeling, Jarkko Saarinen, John Sandlos, Dolly Jørgensen, Vesa-Pekka Herva, Elise Lépy, Hannu Heikkinen PhD students: Sandra Fischer, Christian Fohringer, Jasmiini Pylkkänen, Camilla Winqvist
RT 8) Co-existences: Recoding natural resources for future livelihoods	**Marianne Lien**, Gro Birgit Ween, Britt Kramvig, Thomas Hylland Eriksen
RT 10) Comparative global learning: Theorizing transitions to sustainable futures	**Sverker Sörlin**, REXSAC as a whole

Note: The table presents the situation as of the fall of 2019, a few years into the program after merging some of the RTs. The list of researcher names is not comprehensive, and the six REXSAC PhD students that were not funded by Nordforsk are not listed

stakeholders. This approach with a density and thickness of empirical work has given us a ground to stand on. We can say we know some of the past and present effects of resource extraction and, although it is a matter of valuation, how these effects are regarded, rarely as "sustainable".

REXSAC has also worked close to policy concepts. In other words, our work has been an ongoing encounter between our growing knowledge of how extraction works and our curiosity of how policy might help make extraction compatible with "sustainable Arctic futures". The most fundamental of those policy concepts is "sustainability". The literature since the 1980s, when the concept was coined in its modern version (although the idea as such dates from the eighteenth century; Warde

2018), makes it clear that it is a slippery concept (e.g. Redclift 1987; Robinson 2004). All three pillars of sustainability, the ecological, the social, and the economical stand in tension with each other. Economic and social sustainability often generate goal conflicts with ecological sustainability. Social sustainability can sometimes be achieved only at the cost of economic sustainability, and vice versa. The Arctic is no exception (Fondahl and Wilson 2017; Petrov et al. 2017).

Right before we started REXSAC, we had followed closely a comprehensive project called *The Arctic Resilience Report*, which had a mid-term report published in 2013 and a final report in 2016 (Arctic Council 2013; Carson and Peterson 2016). An impressive assembly of data on the Arctic, this project paid only limited attention to the role of technical interventions or extractive industries for the dynamics of resilience and transformation. Still, we found some of the concepts from the resilience discourse useful, for example how to safeguard adaptive and transformative capacity (Kofinas et al. 2013; Nilsson et al. 2016).

A weak point in previous knowledge was how communities were affected by changes caused by extractive industries, and we therefore decided to focus on indicators that could be used to integrate environmental, social and technological dimensions. REXSAC scholars had already engaged in shaping Arctic social indicators (Larsen et al. 2010, 2014), and we knew that we could tap into other existing environmental monitoring programs. One of the observations that we had made in our previous work was that different communities and interests used "sustainability" differently. The mining industry and other actors in the private sector tended to have their definitions, whereas environmental NGOs and some local communities used the concept in their way, and a political definition was taking shape in Agenda 2030 and the global Sustainable Development Goals, SDG.

We addressed the central paradox head on – that sustainable development is used as an argument for mining and other extractive industries in the Arctic despite being based on non-renewable resource extraction. This has been a central concern to REXSAC as a whole, although it has been approached differently in the Research Tasks. How can the broad, normative goal of "sustainable development" be understood in a context of rapid environmental, social, and technological change, with particular attention to the impact from extractive industries? What indicators are most useful at the local, national and circumpolar levels?

One approach has been to listen to different communities, as they are challenged, in scenario workshops, to gather their knowledge about drivers of change that affect the sustainability from a local or regional perspective (Nilsson et al. 2017). The theoretical foundation is the need for co-producing knowledge in order to make the analysis legitimate and salient for the intended users (Mitchell et al. 2006). It also typically allows for the engagement of local and regional actors in producing narratives about the future (Paschen and Ison 2014; Nilsson et al. 2019). REXSAC workshops have been conducted across the vast region (Sweden, Norway, Iceland, Greenland). They are hard to neatly summarize, but the local conversations point to the need for more attention to demography, indigenous rights, and the impacts of global market forces on local economic development (Nilsson and Larsen 2020). Yet the futures deemed likely are often the same as favored or disfavored futures, depending on whose voices you listen to. Local particularities come strongly to the surface, because “perceptions of sustainability are scale and place specific” (Nilsson and Larsen 2020, cf Fondahl and Wilson 2017). Workshops have been supplemented by discourse-inspired text analysis of policy and planning documents and semi-structured interviews with selected actors. A result is a better understanding of the need for assessing impacts of extractive industries and their implications for the SDG goals. To reach the goals it is mandatory to incorporate ideas and interests from indigenous communities (Sköld and Liggett 2019).

Indicators provide a tool for articulating sustainability goals in policy-relevant language and ways to monitor and assess the contribution of extractive industries to these goals. Can social indicators be linked to ecosystem indicators in new ways that would allow parallel assessment of all three pillars of sustainability, especially in the face of rapid climate change? This was a question that the Arctic Resilience Report had wrestled with (Carson and Sommerkorn 2017). There is no doubt that environmental and climate change have impacted on Arctic communities but how important are these compared to other drivers of change? There is no easy way to answer a question like this – climate change is omnipresent and irreversible, but other impacts are easier to steer and even withdraw. Time scales need to be combined. Climate change is rapid, but many social, economic factors, and technological are more rapid still. Key social indicators, such as public health, life expectancy, income, education, and career reflect changes in policy and economy more rapidly than climate change (Wormbs and Sörlin 2017; Wormbs 2018). That is why extraction is so central. Extraction brings change to bear on societies quickly and profoundly. It not only has direct impacts on the environment but also comes with changes in infrastructures, job markets, local economies and visions for the future. The fact that part of that impact is environmental and that climate and environmental change add to the challenges does not lessen the importance of extraction, on the contrary.

This is one of our most fundamental insights gained so far. Environmental and climate change must not stand in the way of comprehending that policy and economics still shape sustainability of Arctic communities on short to midterm time scales, annual, decadal, generational. This insight can sometimes be obscured when assessments from the Arctic Council and others constantly draw attention to changes in nature without balancing it with assessments of the impacts of extractive industries. Scientists tend to underrate the implications of their own critique, “erring on the side of least drama” (Brysse et al. 2013; Oppenheimer et al. 2019), and Arctic assessments themselves, it has been suggested, can be “silently normative”. They perform a policy role by their politically negotiated selection of topics (pollutants, climate, toxic substances, oil and gas, ice and snow), expertise and methods (predominantly drawn from natural science) which all affect their message. Impacts on humans and local communities tend in Arctic assessments and monitoring programs to be underestimated and threats to communities undervalued: “Arctic cultures remain vital and resilient”, “Arctic communities are resilient and will actively respond to cryospheric change” (quotes from AMAP reports 1997 and 2012) (Wormbs 2015: 297).

15.3 The Idea of 'Multiple Pressures'

Sustainable development is a normative concept, and we realized that a reflexive understanding of it was essential to several of our research questions and to reach our long-term goals. Otherwise it would be impossible to assess the consequences of resource extraction for communities and environments. Nor would we be able to evaluate opportunities for transitions to post-extractive futures unless we could say something interesting about the normative goals of such assessments. At the same time, we could not rule out the possibility that we may have reached beyond the era of sustainability as the gold standard of policy recommendations. For example, the concept of "best practice", so linked to the operational achievability, seemed very hard to discuss without a fundamental analysis of what values and interests should be prioritized. In the proposal for REXSAC we had held out the possibility that we should be able to offer a roadmap of "best practice" to reach sustainable resource extraction. As we went deeper into our research, did more and more fieldwork, and drew up comparisons across a vast region from Canada and Greenland to Svalbard and northern Fennoscandia, we started to doubt whether this was actually the right way to think about the whole issue.

One of the concepts that we developed early on was important in this problematizing effort. "Multiple pressures" was first used more or less as shorthand for the co-existence of multiple forms of use of land and resources and how they when combined increase competition and risk. Roots of the term can be found in ecology, for example in the literature on aquatic systems (e.g. Poikane et al. 2017). The term came up in our preparatory work and we found it useful enough to devote one of our Research Tasks to it. It gained currency and drew a lot of traction in its own right. We knew beforehand that such pressures were real. New extractive industries and other infrastructures, as well as a growing tourism sector, all have placed increasing pressure on existing reindeer pasturage, further aggravating land use conflicts. REXSAC researchers were already developing models that could integrate the effects of climate change and disturbance associated with land use changes and pollution, building on existing collaborations with reindeer herding communities (Rosqvist and Inga 2015).

Empirical work on the ground, much of it conducted in the Kiruna region in northern Sweden, increasingly demonstrated that for the local communities, especially the reindeer herding communities, it was hard to withstand and adapt to the constantly increasing number of pressures that appeared over the years. Our work was conducted by physical geographers, ecologists, and hydrologists together with anthropologists, political scientists, legal scholars, and members of local communities. Contributions by the local Sami communities turned out essential for the research (Rosqvist et al. 2020 in review, Rosqvist and Makers Only 2015). As evidence piled up it became increasingly clear that multiple pressures was real and we started using it consciously as a central concept of our work. It referred to changes in climate, land use, and policy – all developing concurrently and often mutually reinforcing (Rosqvist et al. 2019). Recent changes of climate in northern

Fennoscandia have seriously affected ecosystem services and human resource use patterns in the dominant traditional livelihood of reindeer husbandry (e.g. Heikkinen et al. 2012).

Although the phenomena now called multiple pressures are not new, they tend to increase stress on the reindeer as well as on the herders, for example when they aggravate already poor grazing opportunities. Access to lichen for the reindeer shrinks when forest companies cut down the trees in large scale forestry operations. Territorial expansion of mining projects has multiplied over the past few decades (Larsen et al. 2018). One particular form of stress is participation by reindeer herders in co-decision making. Just going to meetings to balance the increasing numbers of other interests is a cumbersome activity. Big companies and public agencies for mining, forestry, energy, tourism and infrastructure have people to spare for that. Reindeer herding families cannot easily leave their sites, often far away, for a one or two hour sharing of ideas (Österlin 2020). In sum, stressful moments become more frequent in time, and happen closer in space. The literature has suggested for some time that this constant over-layering of demands and pressures has been allowed to develop without considering the perspectives of indigenous and other local communities (Howitt and Lawrence 2008). Our research on multiple pressures has corroborated this notion and provided novel empirical data to support it for Arctic terrestrial and social conditions (Fig. 15.1).

Fig. 15.1 Windpower mills on the mountain Peuravaara, immediately north of the mining area in the Swedish Arctic town Kirunavaara and right in the now dormant Viscaria copper mine. (Photo credit: Dag Avango)

The evidence that has been collected to support the multiple pressures claim has also led to critical reflections about another of the main pillars of what we may call the "standard sustainability regime" since the 1970s and 1980s. Social and environmental impact assessments of extractive projects in the Arctic – where they exist – are project specific by nature and, as noted above, tend to favor topics that do not speak to communities and their interests. Even if the notion of "cumulative impacts" are mentioned in overarching policy documents about mining, impact assessments typically do not consider multiple pressures. As a consequence, their impacts tend to be invisible, under-articulated, and nobody's responsibility even when known, as assessing the total impact has not so far been a demand in current regulation or guidance for impact assessments (Koivurova et al. 2016). This adds to the shortcomings of Arctic assessments. Not only have these disregarded societal concerns and policy, they are also not reflexive about their own premises, a chief one being that resource extraction is by and large taken as a given (Wormbs and Sörlin 2017; Sörlin 2018).

An increasing number of stakeholders in Arctic extraction regions are becoming aware that these assessment processes are inadequate and think they should be developed to speak in a more realistic way to the sustainability concept (Arctic EIA project 2017). We have met this opinion in northern Fennoscandia (Kiruna and Gällivare municipalities), and it is noticeable also around the Nuuk Fjord in western Greenland where our team in RT 3 applied similar methods to conflicts between mining, tourism, and subsistence and recreation-based activities (Nuttall 2017).

The pattern is not unique to the Arctic. On the contrary, it is universal as a consequence of the ever-increasing impact of humans on ecosystems and multiple features of nature in the Anthropocene (Steffen et al. 2015). This means in turn that the empirical and theoretical insights of our research on multiple pressures have repercussions with similar work on sustainability across the world. REXSAC scholars have been able to comment critically on Environmental Impact Assessments, including supporting alternative indigenous-led knowledge-gathering processes (Larsen 2017; Lawrence and Larsen 2017; Larsen et al. 2017). This will be far from enough to deal with the oxymoronic properties of "sustainable development" but in order to be socially and politically legitimate, as well as scientifically credible, EIAs should at least represent the reality and potential impacts of multiple pressures on indigenous rights and SDGs.

15.4 Challenges of 'Best Practices'

It is implied in the notion of research-based policy, that insights from research should inform decision-making and improve practice. Scholarship should be able to suggest the 'best practice' or, at least, identify best practices and describe them in order for democratic structures to use it to improve regulation and approaches. However, that is in the ideal world (Bretschneider et al. 2005). The level of difficulty is demonstrated by our own example. In REXSAC's work on "multiple pressures" we spared no effort in engaging with community-based participatory research (including co-publishing).

Our work has been based on well-established principles of collaboration between scientists and scholars (including PhD students), indigenous/local people and representatives of government and industry. *En route* we participated in numerous workshops and conferences. We co-organized some of these with other NCoEs and/or other partners. To provide baseline data for a “vulnerability analysis” we used community-based knowledge and herding data showing animal locations and reflecting their spatial distribution and temporal usage of grazing lands. This was coupled with information about disturbances of vegetation systems, grazing patterns and impact of changing climate (Fohringer et al. 2020 in review; Rosqvist et al. 2020 in review). We have used hydrological, vegetation and climate monitoring data from national research infrastructures, including those supported by the Swedish Research Council (SITES s.a.). Finally, we envisioned effects of future impacts to become evident in scenarios showing animal use of the future landscape.

We are proud of the massive research we have done to describe and understand multiple pressures and to critique Impact Assessments and suggest improvements, for example early involvement of indigenous communities and a shift of control of the IA process from companies to public authorities, as pioneered in New Zealand (Larsen 2017; cf Allard 2006). Still, so far policy interest is modest, although it is of course hard to predict where policy will go a few years ahead. It is worth reflecting for a minute on why policy change, in the Arctic as elsewhere does not happen easily. Drafting our early working plans more than 5 years ago we argued: “The results will provide new best practices and processes for scientifically robust impact assessments, reflecting the interests and needs of affected (and often marginalized) communities and adding value to political decision-making processes and enhancing the adaptive capacity of communities to respond to change.” These words still hold out a lot of promise and we stand by them. We have learned a lot, and produced many results, still we cannot claim to provide a clear outcome, at least not yet. We may get closer to our goal in coming years. After all, the impact of environmental policy is a complex, unforeseeable process where breakthroughs of ideas may suddenly occur (Owens 2015), but we cannot take this for granted.

Clearly, the size and force of economic and political interests are considerable, in the Arctic perhaps even more than elsewhere, given the region’s geopolitical importance (McCannon 2012). Impacts from multiple pressures are allowed to continue because significant actors enjoy support from regional or national governments. These power balances shift only slowly – the systems that preserve the interests of some are indeed resilient – although such shifts sometimes occur, as we have seen in a series of court cases in recent years giving more priority to indigenous populations (Chuffart and Vinuales 2014; Sehlin MacNeil 2017). A recent example is the Girjas case in Sweden’s High Court (2020) where hunting and fishing rights were given back from the state to the Sami after almost 30 years. The reasoning in the Court indicated that Indigenous land rights could also be relevant in relation to mining.

Articulated protest has been heard about mining projects as well around the European Arctic. However, very rarely mining companies are barred from activities, even when they violate indigenous human rights. A recent study of the official Swedish stance toward Arctic mining noted that: “All three procedural safeguards in the Swedish mineral framework are not consistent with Sweden’s obligations towards Sami under the international system of human rights nor the European system of human rights” (Örnberg 2018: 87). Pressures have been noted in other Nordic countries as well (Koivurova et al. 2015).

How can these developments be interpreted? One way would be to regard it is that a larger pattern of decision-making about natural resource extraction, and indeed environmental management, has taken precedence over the last several decades; a “standard sustainability regime” where the concept of sustainability soon became central and where Environmental Impact Assessments were early adopted tools in the Arctic (Koivurova et al. 2016). Best practices were also linked to other concepts such as “benchmarking”, “governance”, and “ecosystem services” (Ernstson and Sörlin 2013) and became part of the vocabulary of goal-oriented policy in the last two decades of the twentieth century (Bogan and English 1994).

This regime has been spreading in Arctic governance, but given the geopolitical circumstances, in a less concerted way. Its practice in mining is not universal and varies widely within the Nordic region, including Greenland (Hojem 2015). It has, to a large extent, overlapped with the period of shaping a neoliberal order of public management (e.g. Pollitt and Bouckaert 2011). One of the central features of the neoliberal understanding was that there was, indeed, a possibility to reconcile multiple societal interests under a common rationality, largely economically defined. Much debated around the world, it should come as no surprise that similar arguments have appeared in Arctic governance. The question is whether the research-based quest for judging the impacts of resource extraction on Arctic communities is best served by adhering to these concepts or whether other approaches might turn out more useful?

If one regards the policy concepts that we have discussed so far – sustainable development, EIA, best practice – it is hard not to see that they operate under a weak normative articulation. With this I refer to values or properties of the future conditions that these concepts and their applications are supposed to favor are rarely spelled out. The underlying, sometimes explicit, assumption is that exploration and exploitation of resources should not be hindered, but rather adjusted or constrained if necessary. This is of course not caused by the current neoliberal resource management regime; its roots can be found in legal structures that evolved during the long period when limits and boundaries to extractive expansion were not considered significant.

Governing structures for Arctic extraction in the past were concentrated on how to make extraction grow. That was part of international law of the sea and it became a chief aim of the Svalbard Treaty. Although giving governance and sovereignty to Norway the Treaty opened up the territory for resource extraction to all signatory states, which over time exceeded 40 countries (Ulfstein 1995). It has also been the guiding principle for all states around the Arctic rim, including the US (Alaska), Russia/USSR, the Fennoscandian countries (such as Sweden's current Minerals Strategy 2013), and Denmark (Greenland).

Restrictions and a more careful guidance have largely appeared in the past half century (Avango et al. 2013). It is hard not to see that as linked to the neoliberal schemes of governance. The two have co-evolved, the former often with reference to environmental and climate concerns and the future of indigenous communities, the latter arguing economic benefits and state interests. As environmental and political restrictions have been imposed, an ever more refined ingenuity has been used to push governance towards goals and quality, in order to avoid hard restrictions or even the sealing off of certain areas for exploitation. Although the Arctic may have been a late arrival when it comes to the importance of 'the environment' (Warde et al. 2018) and to the adoption of anthropogenic climate change and the need for Arctic modeling (Wormbs et al. 2017) it is now a central region to both. There has been a considerable growth in nature reserves and national parks, called by REXSAC member Peder Roberts a "greening of the poles" (Dahl et al. 2019). Extractive industries have sought to be exempt from protection of lucrative and resource rich areas and insisted on scenarios where extraction can continue to take place, albeit subject to strict sustainability regimes and following 'best practices'. The risk otherwise is non-extraction, a bleak scenario for those who benefit economically from extraction since estimates point to the Arctic as a holder of some 30% of the world's known oil reserves and large quantities of commercial and, not least rare earth minerals of strategic importance to many states (Vikström and Högselius 2017).

A similar pattern of devolution from legality to economic efficiency can be discerned with respect to indigenous rights, in general, and for the rights of indigenous peoples to natural resources on their traditional lands, in particular. These rights are now recognized thanks to a number of international treaties and national legislation in most countries. Imbalanced power relations between indigenous and local communities and mining companies together with weak decisions making processes, however, have put up practical obstacles for the rights to be fully observed (Larsen and Ratio 2019). While the nation-state has traditionally held a central role in the governance of natural resources, multinational corporations have had an increasing influence and presence in the natural resource sector (Ballard and Banks 2003). Prospecting practices have become ever more (neo)liberalized and globalized since the end of the Cold War, not least in the Arctic which until 1989 was strictly controlled by the super powers and their allies. Under the new, liberal regime, the role of the state has become more complicated, and more self-constrained. The state is charged with overseeing responsible mining developments but has in many cases devolved responsibilities for the impacts of mining to the companies that run the mines. Corporations are expected to take on an ever-growing governance role, yet states and corporations each regard the other as responsible for the respect and protection of indigenous rights (Lawrence 2009).

As a result, an Arctic governance gap has been growing post-1989 that is perhaps most apparent in the case of the global resource industry, constituted as it is by a complexity of relationships between governments, corporations and communities that cut across local, national and global scales. Transnational companies have through these processes of liberalization and devolution emerged as actors who not only pursue extraction, as companies always did, but also have responsibilities in regards to affected communities.

15.5 Re-purposing Extraction Sites

The very core of the sustainability dilemma rests with the "boom-and-bust" character of the mining industry. In the 2000s the Arctic was part of a global mining boom, triggered by high metal prices on the world market as a consequence of a high demand in East Asia and elsewhere. In the following decade the boom turned into bust, and several high-profile mining projects such as the Kaunisvaara mine in Sweden, Sørvaranger gruve in Norway, and the Isua project at Nuuk Fiord in Greenland shut down. Even though some mining projects were restarted again, the development goes to show that all mines eventually come to an end. When they do, they leave environmental as well as social and cultural footprints behind. Detailed work by REXSAC researchers in Nautanen (Sweden) and at Josva and Ivittuut (Greenland), discussed elsewhere (Avango 2020, Avango and Rosqvist, Chap. 16 this volume), shows that there is an extensive and wide-ranging impact on water and soils from waste rock and tailings (Fischer et al. 2020).

Technical and cultural legacies on old mining sites are considerable, including ore crushers, dressing plants, transport infrastructures, housing units, and service facilities. Mineral-rich areas of the circumpolar Arctic bear these concrete reminders of more than a century of mining. They are testimony of the integration of Arctic spaces into regional and global economic systems, and to the enduring presence of indigenous and non-indigenous communities for whom mining became part of shared experiences. Considerable discussion has ensued on what to do with these legacies of extraction, spanning from environmental remediation, repurposing for new economic activities, tourism development or projects to preserve the imprints as cultural heritage (Avango and Roberts 2017; Avango forthcoming).

One key exploration in REXSAC has been how legacies from resource extraction can be dealt with when Arctic communities build new futures beyond extraction. We have identified a set of practices as particularly viable. *Environmental remediation and re-wilding* – the practice of restoring landscapes altered by extraction has been one of these. Environmental remediation is not just a matter of applied ecology, but a political, social, and cultural process involving different actors making choices. It remains to be seen how this approach can best be tailored to the expectations of Arctic communities. Ecological and environmental expertise need to be balanced against local desires. How can existing expectations for remediation – embodied in state legislation or in norms of corporate social responsibility – be specifically reconsidered in order to better serve communities (Avango et al. in progress, a, b)?

Remediation and re-wilding are still in an exploratory stage in the Arctic. Heritage processes and re-purposing projects have been tried for some time. They are essentially attempting to diversify economies and livelihoods in processes of transition to a post-mining future, for example in Greenland (Thomsen and Björst 2017) or in Svalbard, both in Russian and Norwegian mining sites (Avango and Roberts 2017). While observing several successful attempts in this vein, many of them are based on tourism, or the so-called experience industries, repurposing "ghost towns" and "zombie mines" (Keeling and Sandlos 2017). Others, based on life style projects, are directed towards down-shifting people who are tempted to try a future, or a life experience, in a northern location. But even in cases where population numbers can be reasonably upheld and people can make ends meet, fundamental questions remain. Whose narratives and understandings about the past become hegemonic and why? Can multiple and often contradicting experiences of mining histories be dealt with in heritage processes? Other related lessons to be drawn from transitions to post-extraction economies in the Arctic are attempts to turn mines into tourist attractions – historical mining sites but also ongoing mining operations. Is co-management of heritage an option (Stjernström et al. 2020)?

Whenever possible, we tried to compare cases from the European North with both other parts of the Arctic, and also with deindustrializing mining regions in other parts of the world. In this effort we established collaboration with two Canadian research network projects, MinERAL, based at Laval University in Quebec, and RESDA, working from Lakehead University, Thunder Bay, Ontario. Both maintain extensive partnerships with local communities. Working with them, we learned, above all, that challenges are universal. Transnational capital is hard to tie to post-extraction activities and multiple actor strategies are necessary.

Together with our partners, we have explored new ways of conceiving mining as a process not just of temporary extraction but *as a social process of continuous change*. In that respect "mining" could be owned by the community, or perhaps better: democratically, and indeed used to generate legacies that contribute to the sustainability of communities. This would be in contrast to such communities returning to a pre-existing state, if that was ever considered beneficial or even possible. This seems a promising way forward for a potential co-existence of resource extraction and sustainability. But it must be admitted that we have not seen much of it in practice so far. Instead we have perceived a gap between what locals may regard as ideal post-mining futures and what they expected would happen, indicating a lack of trust in how the transformation process should be conducted (Nilsson 2020). It would be interesting to start new, more applied projects and experimentation in communities where extraction companies, local government, and local residents share in taking such projects on. If good examples can be presented – or, 'good practices' – bottom up movements could help set new standards to extraction practices. At present, legislation does not require it. As a result, it seems far from evident that mining companies could be convinced of the advantage, if what they face would be more responsibility and less profitability.

Our research points to a sustainability dilemma that is hard to navigate. It demonstrates the entangled nature of the sustainability issue in the Arctic. Extraction companies by necessity often come close to indigenous communities and vice versa. Companies sometimes find local communities useful, as labor and facilitators of local services and conviviality. But tensions are also frequent and sometimes antagonistic. The cases we have looked at show that it is necessary to look at the entire cycle of resource extraction, from how mining starts, through the extraction period, to the post-extraction phase. Our research indicates that this latter phase is critical. In order for extraction to become anything like "sustainable" it is essential that governance has a focus on what is left when peak extraction is passed and activities wind down. If that is done in a hasty and irresponsible manner the risk is that not only will there be deep and lasting "landscape scars" (Storm 2014) left behind but that it will take a long time for communities to heal. It will also leave local communities that are affected by the mine in a state which may be worse than the original pre-extraction situation. Our research indicates that although rough boom-and-busts are more openly disapproved now, they certainly still happen. Sustainability, whatever the term means, is far from guaranteed and the current voluntary, devolved governance structure does not live up to its promise, at least as far as sustainability is concerned.

15.6 Recoding – With Affect, Gender, and Livelihoods

It should be kept in mind that basic logic and rationale differ. Local communities differ from transnational companies which operate under a global industrial and capitalist regime. Behind the logic, and part of the logic, is also a "structure of feeling" (Williams and Orrom 1954; Williams 1976; cf. Sharma and Tygstrup 2015) which speaks to how these, sometimes conflicting logics manifest themselves in the constantly varying contexts of national and international politics and local everyday life. The term that we adopted for this in REXSAC was "affective economies", drawing on theoretical work on the role of narratives and time in structuring economies and societies (Ahmed 2004; Schulz-Forberg 2013), and research on "multiple" or "alternative" modernities (Asad 1987; Bhabha 1992) to analyze cultural heritage and the making of identities as part of resource extraction.

Simply put, the tensions between local and transnational logics are more complex than they may seem when summarized in conventional cost-benefit analysis or assessment reports. For centuries, extractive industries were addressed, managed, encouraged, protested against and wished for. The primary paradigm fueling these discussions focused on economic development. As a result, research tended to look at the trade-offs (e.g. environmental), barriers (e.g. infrastructural) and potentials (e.g. employment) involved with particular projects. Less attention was typically given to how past, present and future extractive industries have been entangled in people's active rethinking and reimagining of histories, places, communities, political relations, aspirations and personhood.

This observation served as a reason for us to engage substantively in work on how creative cultural, social and political engagements with extractive industries came up. We studied how they interacted with the industries and how they were anticipated, planned, managed, and run. In some instances, the practice came close to what in destination management is called "branding" (Ren et al. 2019).

A key word here is "future". What is a desirable, defensible (and not just a sustainable) future? *Whose* future is at stake? That of companies with far away owners, or that of local communities? Can they be reconciled? Investments in mining are commitments to different futures for communities at all scales. Our research has addressed the cultural translations that take place in a contested field invested with emotions, memory, anticipation and expectations. To reach these cultural and societal manifestations of tension around resource extraction we have used community fieldwork, stakeholder interviews, political documents, media representations and public narratives. We have applied theoretical perspectives from discourse analysis, memory and heritage, identity/identification, narration, and post-colonial studies.

The results, mostly from Greenland and northern Scandinavia, made it possible for us to understand more about the complex and continuous *negotiated cultural space* that emerges whenever extractive industries are on the political agenda or actively pursued. We found that extractive industries often serve as a "transformative space". Greenlanders, for example, have approached extractive industries as contact zones where their self-perception has been challenged, contested, and ultimately changed (Thisted forthcoming). In the transformative space it is possible to question even fundamental colonial and post-colonial conditions ad norm, and release potentialities for revision of the relationship between Denmark and Greenland, which is always lurking in the background as the ultimate issue (Bjørst 2017; Sejersen 2019) (Fig. 15.2).

Fig. 15.2 Ilulissat harbor. The community in North Western Greenland serves as a point of departure for fisheries and nowadays also for climate change tourism in Disko Bay, full of icebergs that calved from the ice sheet front. (Photo credit: Dag Avango)

Ultimately, if tensions between sustainable, or desirable, Arctic communities and extractive industries remain yet another route to explore is that of alternative futures, where mining and other extractive industries play a more modest role. This is of course harder to research, since it is partly counterfactual, and requires elements of thought experimentation. Nonetheless, it is useful and urgent, in particular if all three pillars of sustainability are concerned. In REXSAC we talked about "co-existences" of livelihoods of different kinds, some with roots in traditional livelihoods that could be used to "recode" natural resources to fit with contemporary demands. Is a strategic balance of mining and alternative economic activities viable? Can it be a road forward?

In recent years there has been a growing interest in these kinds of approaches to long-term sustainability issues, around the world but also in the Arctic. The research conducted in REXSAC has been based partly in Finnmark in northeastern Norway, it has also drawn on recent studies of Svalbard, Alaska, Nunavut, and Australia. The base in Finnmark was motivated by new articulations of space – notably the recent establishment of the Finnmark Estate – that turned Norway's northern region into a laboratory for the (re)settling of land rights in relation to indigenous communities, but also into a rich site for exploring past and shifting livelihoods (Ween and Lien 2012; Thisted et al. forthcoming). Finnmark coastal towns have turned into hubs for oil and gas extraction and transportation in and from the Barents Sea as oil extraction have replaced mining as a cornerstone industry. On the other hand, iron mining in Kirkenes has picked up again, and planned copper mines in Kvalsund have caused considerable controversy. Although the core areas of Norwegian Sápmi are coveted by the same transnational companies that hold mining licenses across the Nordic Arctic and beyond, the population of inner Finnmark has so far been able to

Fig. 15.3 Hydroelectric power plant in the Alta River, Finnmark county, Norway. The building of the dam caused a major controversy and the building site was occupied by protesters in 1979 and 1980. (Photo credit: Dag Avango)

withstand the mining companies (Kramvig and Avango forthcoming). In Finnish Sami areas, tourism is well-established and developing from mostly male hunting and fishing tourists (Fig. 15.3).

One feature of this approach is its engagement with the gendered character of extractive industries, which creates in-built challenges to sustainability. The male dominated mining requires, literally, an unsustainable family structure as careers for women are fewer, alternatively demographically thwarted communities. Recoding gendered work has been an approach to explore these issues. While fisheries and extractive industries signaled economic prosperity, an informal economy has always contributed considerably to food security, nutrition and well-being in the Norwegian north, and indeed across the Arctic. Characterized by generalized exchange, and maintained partly through female food procuring practices and social networks, it resists the formal distinction of work/leisure and market/gift (Lien 2014). Similarly, changing technical, political and climatic conditions have opened for radically new modes of knowledge making (Geissler and Kelly 2016).

Yet another dimension of the local resource activation was its relation to time. “Recoding resource temporalities” was a research task designed to explore how various “livelihood projects” unfold in relation to each other, including both food production, tourism and science. This line of research proved useful to bring knowledge about the importance of the balance and relative positions of extractive industries and other place based resources that are non-extractive and anchored in gender and temporalities that are less interventionist than mining, based on capital and technology from the outside and more organically grown from experience but adapted to contemporary patterns of demand and desire. Speaking to the third of the main research problems of REXSAC – how Arctic communities can transition to post-extraction futures – this line of research has contributed useful insights, and a sense of non-determinism and co-existences in the quest for sustainability (Lien forthcoming; Ween 2012, forthcoming).

Ultimately, a research-based attempt to find good, or useful practices cannot remain satisfied only with local case studies. The research has to be comparative as well, and there has to be an element of theorizing in order to put the empirical results into a wider context. Long-term sustainability in Arctic communities affected by extractive industries can therefore benefit from interactive learning relations with communities elsewhere (REXSAC Brisbane 2019). All along there has been a REXSAC-wide forum for reflexive theorizing about conditions for transitions. This has happened in various formats: annual REXSAC-wide workshops, annual week-long PhD courses, with REXSAC researchers co-teaching them, several field excursions to different parts of the Arctic, again with rich opportunities for conversation, reflection, and theorizing.

15.7 Transformative Imaginaries – New Pathways to Action

Do we now know what we need to know about extracting industries and sustainable Arctic communities? Could anyone, or some ones of these be elevated to good practices, or even a best practice? Have we identified pathways to action?

However compelling, questions like these are not very useful. If posed like that, the trustworthy response is almost always 'no'. I cannot say I know pathways to action. I cannot offer a best practice with any certainty. I certainly cannot say we know what we need to know about the topic, at least not enough to know precisely what to do. In fact, I think it is futile to ask from research the answer to questions like these. These are aggregate issues and they are issues about values and the desirable, and about conflicting interests and goal for individual actors as well as for entire societies. At some level they remain essentially political. Knowledge and evidence from research are important to inform and penetrate such issues in an accessible and reasonable way, but it will not be sufficient to draw unanimous conclusions.

I would still argue our research in REXSAC provided many insights. A fundamental one was about the friction and tensions between different communities and interests engaged directly or indirectly in resource extraction. We now know that what we set out to provide, sustainable pathways, are after all more filled with values and perceptions of what is desired and ideal than research easily can make judgments about, and also than we thought at the outset.

Another, even more pervasive insight regarding sustainable Arctic communities is about the danger of locking thought and creativity into one single set of concepts or frame of mind. As much as sustainability fills a function as a common denominator of the balancing act between economic, social and environmental interests, it also tends to squeeze out alternatives, so to speak outside of the box that we may need to consider if we wish to find creative solutions for the Arctic resource entanglements.

Our work on scenarios reveals the importance of maintaining attention to a diversity of potential development paths in discussing the future, both for ensuring that different voices are heard and for fostering preparedness for external chocks and causes of change that are beyond local influence (Nilsson et al. 2019). Furthermore, forced consensus may not only hide real conflicts but also entail a risk of disregard for relevant knowledge (Larsen and Nilsson 2017). Solutions that appear to please everyone today may be no solution at all in the longer run. Goal conflicts between what certain communities wish to do and what others could not allow should be made visible which we also increasingly discovered was a necessary mission for our research.

We may posit, that the institutional function of the idea that there is an ideal, "sustainable" extraction that balances the ecological, the social, and the economic under a science-led process of optimization is, however attractive, a fiction, or perhaps a utopian thought. Therefore, we may do well to consider replacing it with something more closely linked with what we know about planetary limitations and about the long-term interests of communities, especially those that are vulnerable. What we have found in REXSAC, and what can be learned from other major social science and humanities research efforts in the Arctic in recent years, suggests that rather than continuing to tinker with already malfunctioning governance systems we should put transformations towards carbon free and ecologically sustainable societies at the forefront and probe into deeper articulations of desired states.

We have seen that data of all kinds is important, but also that there is still far too little data that is pan-Arctic, social and cultural. Natural and biological science data still dominate, partly because of the way assessments are commissioned. The old legacy of the Arctic as a “space for science” still places constraints on securing necessary data to bring out, in full, the impacts of resource extraction. Our research has revealed that there is a need for a major effort to increase the volume and quality of social data. We know more about polar bears in the Arctic, today, than we know about people. Often, what knowledge we have is too compartmentalized into states and regions. Sharing ‘good practices’ is too rare a phenomenon and, ultimately, too cheap of a pathway to action.

We have identified a range of useful *partial practices* – re-wilding, environmental remediation, re-purposing that may help shape post-extractive futures that can make communities more sustainable. We have studied several of the elements that are useful in this work: promoting cultural heritage; knowledge of place and people that builds trust and pride; affect that connect citizens with both the challenges and the solutions; and deliberative and participatory processes that mobilize citizens and institutions for the common good.

We also learned that these practices do not eliminate or solve the basic tensions. It was important to discover that legislation and governance do not require from corporations either responsibility or collaboration with communities to identify and reach common goals. Here is probably a possible pathway to action visible: government can do much more to make sure the Arctic communities have real influence on decisions that affect them also when they happen to be located nearby mineral resources coveted by industry (and consumers elsewhere). This might help redress the asymmetric power relations between extractive industries and local communities.

We found that power remains central even in issues that seemingly revolve around down to earth local conditions. In democracies, the power of small minorities is weak, unless it is supported. The conclusion is that issues about balancing extraction and sustainability are not necessarily treated best by devolving them to the lowest governance level. They are national, if not transnational. The rights and sustainable solutions for vulnerable regions merit attention outside the Arctic. It is a multi-level governance pathway that may prove cumbersome sometimes, but can balance interests.

We noted, that sustainability may well be just as well achieved by means of other livelihoods than resource extraction. Developing traditional life forms and adapting these to local needs and international markets, including tourism, is a pathway of gradual change and deep local engagement (Hastrup 2013). Extraction can bring high activity and large income in a short time span. Extraction may be more attractive for external interests (states, companies, shareholders, subcontractors) than for local communities. Recoding local communities in direction of catering to their own needs and to economies that they themselves control has a potential and can also serve as a pathway to action.

The previous point can be scaled to a structuring level. We have entered what many responsible institutions around the world regard as a necessary period of transformation, guided by the 17 United Nations Sustainable Development Goals from 2015. One pathway to action is, in the light of the decadal Agenda 2030 to begin the discussion about extraction in the Arctic as it were on a clean slate. How can resource extraction best serve the SDG goals? It may imply a more selective and deliberative approach to extraction (Nilsson and Avango forthcoming).

The extractive paradigm has grown from primitive origins in the first era of European North Atlantic whaling more than 400 years ago. It has matured over the centuries and it is now conducted in accordance with national laws and international treaties. Thus equipped it is no less eager to extract resources in the Arctic with the likely prospect of playing a hegemonic role in the region for the immediate future, but with a more uncertain long term future. The world and its economies may not continue to look the same, or even grow and develop in ways that we recognize from the recent past. Major change may be yet another pathway to sustainable communities. The role of minerals and natural resources can change, and perhaps that might not be undesirable.

One of the insights that we have gained in our research is that while imminent, local and practical pathways to action should be tried in the "space of transformation" alluded to above, we should start a conversation, just as urgently, about new imagined views, or imaginaries of specific localities and of the region as a whole. In the last 20 years these were often about something called "the new Arctic" (Emmerson 2010; Smith 2011; Evengård et al. 2015), typically with resource extraction at its midst. Governance was often looking at facilitating such imaginaries, what REXSAC member Annika Nilsson has called "creating a safe operating space for business" (Nilsson 2018).

For good or for bad, these imagined views helped guide actors on all levels, from global institutions to local communities, to a particular version of the future that through a mixture of journalism, research and lobbying also seemed likely, perhaps inevitable (Sörlin 2018). As world developments in only a few years has demonstrated, and as research in REXSAC has also found, there are other possible imaginaries of the future Arctic. They may be more compatible with sustainability. Pathways to action in the decade ahead may require new policy concepts as well.

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Chapter 16
When Mines Go Silent: Exploring the Afterlives of Extraction Sites

Dag Avango and Gunhild Rosqvist

Abstract One of the characteristics of extractive industries, in the Arctic and elsewhere, is their sensitivity to fluctuations on world markets. When demand and prices are high companies expand operations and when they fall, companies tend to close extraction sites. Moreover, no ore body lasts forever. De-industrialisation poses particular challenges to communities in the Arctic, where distances are great, alternative economies few and where the environmental and social imprints of mining often are significant. How can communities that were developed based on extraction transition to post-extraction futures? This is a key question to pose when exploring how to achieve responsible development in the Arctic. This book chapter presents research within REXSAC exploring how mining communities in the Nordic Arctic has dealt with legacies of past mining operations and under which circumstances such legacies have been ascribed new values after extraction has ended. REXSAC has dealt with this research problem in an interdisciplinary way, combining methods and approaches from humanities, social- and natural sciences. The chapter will focus on this process of research and how it has generated insights in to three main post-extraction processes: environmental remediation, heritage making and re-economization.

Keywords Arctic · Mining legacies · Heritagization · Environmental remediation · Heritage tourism · Re-purposing

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16.1 Introduction

One of the characteristics of extractive industries, in the Arctic and elsewhere, is their sensitivity to fluctuations on world markets. When demand and prices are high companies launch prospecting campaigns, start up new mines and/or expand operations in existing ones. When they fall, they tend to do the opposite – cancel prospecting and close extraction sites. In some cases, states will subsidize companies or companies will accept short term losses in order to maintain operations. In other instances, ore bodies are so rich that profitable production is possible even during times of falling demand and low prices. What is certain however is that no ore body lasts forever. Thus, in one way or another, all mines eventually come to an end. When they do, they pose problems. In the Arctic, de-industrialisation poses particular challenges to communities built around a single industry such as mining, and where distances are great and alternative economies are few. It also poses challenges in the form of environmental and social impacts from past extraction, which may be more difficult to deal with there than in industrial core areas further south. How can communities that depend on extractive industries make the best transit to post-extraction futures? How do they best deal with the legacies of past resource extraction in their transitions to post-industrial futures? These are key question to pose when exploring how to achieve responsible development in the Arctic.

This book chapter presents research within REXSAC that considers how mining communities in the Nordic Arctic have dealt with legacies of past mining operations and under which circumstances such legacies have been ascribed new values after extraction has ended. REXSAC has dealt with this research problem in an interdisciplinary way, combining methods and approaches from humanities, social- and natural sciences. The chapter focuses on this process of research and how it has generated insights into different post-extraction processes.

A general tendency in existing academic literature on mining is its focus on potential, emerging and ongoing mining industries. Far less has been written about the closure of mines and their afterlives (Hojem 2014). This is a serious weakness and a clear knowledge gap at a time when the Arctic region is going through a period of expansion of the extractive industries, particularly in mining. Often referred to as a mining boom, this surge of interest in minerals since the early 2000s has been global and has taken place both in the old heartlands of the mining industry and in regions further away from those. In the Nordic countries, the expansion has had a northern direction (SGU 2019: 34, 55). This interest is likely to continue as economies in East Asia and the global south continue to grow and demand for metals needed for green energy increase. Therefore, there is a need to build a body of knowledge on challenges pertaining to post-extraction transitions that can facilitate informed and responsible decision making in the planning and regulation of new mines.

In REXSAC, we have aimed to contribute to the building of such knowledge regarding the Arctic, based on the study of cases of post-mining transitions in the past. In the course of this work, we have identified four main processes taking place in regions dominated by extractive industries, where companies have closed down their operations. We have named these processes abandonment, remediation, heritagization and re-economization. Under which circumstances do these processes take place and why? What are their environmental and social consequences? In this chapter, we will also provide examples of these processes and discuss the interdisciplinary approach we have used to address them (Fig. 16.1).

16.2 Abandonment

In August 2019, REXSAC conducted fieldwork in south-west Greenland. The investigating group consisted of ten researchers from different Nordic countries within REXSAC and an interpreter.[1] A prime objective of the fieldwork was to gather data usable for reconstructing and explaining the afterlife of large-scale resource extraction projects in the area. Another was to determine how residents and other local stakeholders in this region viewed the future. The team visited several

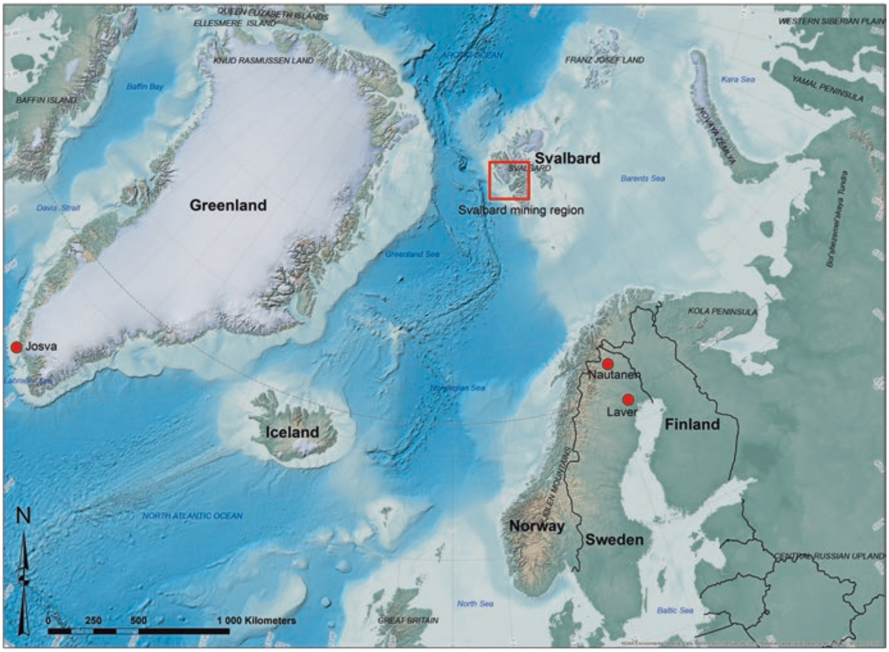

Fig. 16.1 Mining towns in transition, analyzed in this book chapter, at Greenland, in Arctic Sweden and at Svalbard

[1] In alphabetic order: Dag Avango, Lill Rastad Bjørst, Hannu Heikkinen, Jerker Jarsjö, Erik Kielsen, Lene Kielsen Holm, Annika Nilsson, Joan Nymand Larsen, Albina Pashkevich, Gunhild Gunhild Rosqvist and Carl Österlin.

communities, some inhabited, some abandoned. Two of them were former military bases. One was Narsarsuaq, a former US Air Force base from 1942 to 1958 that was later re-purposed to also serve civilian aircraft and to act as an arrival hub for visitors to the region. The other was Kangillinnguit /Grønnedal, that had operated as a US Navy base from 1941 to 1951 and then later as a Danish base from 1951 to 2014 and again starting in 2017. Two other research sites were former mining towns that had been solely built for mineral extraction – Ivittuut, where Danish companies mined and exported cryolite from 1857 to 1987 and Josva, where a Danish company mined copper ore from 1905 to 1914. Two others were settlements impacted by mining and where local residents had been involved in the mining operations – Narsaq (uranium prospect mining in nearby Kvanefjeld in the 1950s) and Arsuk near Ivittuut? All these post-mining settlements have been subject to different forms of re-use except for one – Josva. That settlement provides an illustrative example of a category of former mining towns in the Arctic – those that have primarily been subject to a process of abandonment and forgetting after mining operations stopped.

It was an industrialist from England, A. Robinson, who first started mining at Josva – or Innatsiaq, which is the original Greenlandic place name – in 1852. This was one of the earliest mines established in Greenland by actors from overseas. Greenlanders had extracted minerals long before European settlers arrived, soapstone, killiaq and cryolite. A Greenlander named Joshua discovered copper at Innatsiaq in the early 1800s, which is why the mining industry named the site Josva (Sejersen 2014: 11–13, 29–30, 40f). Soon thereafter, Robinson closed his mine in 1856 due to a combination of factors – lost ships, ineffective technology and a lack of knowledge about the ore body (Secher and Burchardt 2000: 250).

In 1904 a Danish mining company, Grønlandsk Minedrifts Aktieselskab, started a new mining operation at Josva and continued it until 1914. The investors and the company director had ambitious plans. They wanted to make it a source of copper for the Danish market, supplying it with the leading raw material for electric cables in the context of the rapid electrification taking place at the time. Their investments suggest they believed their project would last. The company established two mines on opposite sides of a bay. In order to shorten the distance between the mining sites and Qaqortoq, where the Danish colonial authority's administrative center was located, they blasted a canal through an isthmus in 1907–1908. To produce the energy needed they built a coal fired steam engine plant, which they later exchanged for a diesel-powered generator. In order to provide the copper concentrate transports to Denmark, the company acquired ships. The company also built a smelter, which enabled them to concentrate the copper on site, thereby reducing the transport costs to Denmark. The settlement housed 75 workers during the height of production in 1909–1913. The houses were equipped with electric lights – a rare occurrence on Greenland at the time. The obvious purpose for doing so was to create the comfort needed to build social stability at the site by making the work and living conditions pleasant and to attract workers. The company had even greater plans than the ones they actually realized. They intended to connect the peninsula with a sub-sea tunnel to their mine on the mainland across the bay, to build a new settlement and post-processing works there, and to establish a hydro-power station in the inland to provide the energy needed for copper mining on a much larger scale (Secher and Burchardt 2000: 251–267). In doing so, they were in the processes of building what we in REXSAC has termed a large-scale socio-technical-ecological system.

Despite their highflying plans, Grønlandsk Minedrifts Aktieselskab closed their operations at Josva in 1914, acting on the advice of a consultant who assessed that there was not enough ore there to justify continued mining (Secher and Burchardt 2000: 265–266). At this point the afterlife of the Josva mine begun. In order to gather information concerning this afterlife, REXSAC researchers assembled data from several sources. We needed historical documents describing the activities that people have conducted at the site after the company closed. We also wanted to secure interviews with people who have had reason to relate to the site over the years so as to learn their thoughts about the role of the mine in their lives and in their visions of the future. We also needed information from the site itself. First and foremost, we needed data on what remained there from the time when the mine was in operation. We also looked for traces of re-use at the site during its afterlife and the environmental footprints of the mining system in its surroundings. We also needed usable data for economic analyses of value making during and after Josva was in operation as well as information on how the region where the mine is located has been governed. Gathering this data required methods from across several disciplines. The research group conducting fieldwork in southern Greenland included social and cultural anthropologists, physical and human geographers along with scholars in history, archaeology, political science and economics. In the team there were also Greenlandic researchers and collaborators who – in addition to their competence as academic scholars – also had crucial knowledge regarding local geographical, cultural and social contexts.

The experience of our team members from Greenland and Denmark was of crucial importance for making our visit at Josva possible. The site is located on a small peninsula, some 300 × 150 meters wide, connected by a narrow isthmus to a mainland characterized by steep mountains rising directly from the sea. This is no place to anchor a boat "for long", as the Greenlandic sea pilot dryly stated, because of the high swell or waves (Geodatastyrelsen 2018: 28). The peninsula is indeed very exposed to winds from all directions except from the south. For these reasons we planned our stay at Josva to be 1 day only, a 5 h stop along our travel route between Ivittuut and Narsaq. In bad weather conditions, we would not have been able to land. We were lucky however, to arrive during a narrow window of time between low pressures systems.

The objective of our fieldwork at Josva was to conduct a thorough documentation of the abandoned mining site, the environmental impacts and indications of re-use of the site. We made an accurate map of the landscape and of all remains and imprints by collecting spatial data by drone-based photogrammetry. We also undertook photo documentations, text descriptions and measurements of said remains and imprints. We sampled soils to identify the presence of toxic waste. Making this happen within a time frame of 6 h required most of the team to work with methods they were largely unfamiliar with – e.g. economists and political scientists describing and measuring house foundations, and cultural anthropologists photo documenting derelict industrial production systems. Some tasks required special skills though, such as sampling toxic waste and operating drones. Before the six-hour window closed, we boarded our boat and left Josva very pleased with all the data we had collected.

Understanding post-extraction transitions does not only require site visits to map and collect materials. The anthropologist, political scientists and human geographers spent several days talking with inhabitants of nearby Arsuk about their perspectives on the past, present and possible futures. We also analyzed primary sources in the form of documents in archives, published written sources, statistics and policy documents, before and after the fieldwork itself.

Our work concerning Josva showed that after the Grønlandsk Minedrifts Aktieselskab had closed the mine, there were few attempts to create new values there and no attempts, whatsoever, to remediate the environment. Archival research shows that after the company closed the mine in 1914, they subjected it to a short period of re-purposing and re-economization. First, they maintained it as a base for expeditions in the area for 2 years. Thereafter, from 1915 to 1920, they took down the buildings and moved them to a graphite mine in Amitsoq some 200 km south on the south-western side of Greenland (Secher and Burchardt 2000: 266). From then on, the place contained the same remains and imprints as it does today – house foundations and rusted pieces of technological artefacts. Our chemical analyses of the soil samples at the site suggest that parts of the site are now heavily polluted. During fieldwork, we found no indications of secondary use of Josva (Fig. 16.2).

Our interviews confirmed these observations. Greenlanders living in the region have seen no value in the historical remains at the site and the same is true for the peninsula itself. Its exposure to wind, lack of freshwater along with its unfavorable harbor conditions and the wall of steep mountains blocking access to the inland

Fig. 16.2 Abandoned machinery for extraction and ore processing at Josva. (Photo: Dag Avango)

combine to make it a nasty place to anchor and put up a camp, and useless for hunting. For these reasons, the transition to a post-extraction future at Josva has been a process of slow decay, with erosion and elements of its ecosystem slowly transforming remains of a derelict production system into something that we have yet to put a name on. It is a process of abandonment that characterizes many former mining communities in the Arctic.

16.3 Environmental Remediation

Current legislation on mining and environment in the Nordic countries requires companies to remediate the environment at mining sites after closure. There is a growing literature on this topic, with university scholars as well as officials at state agencies and practitioners within mining and consultancy companies defining problems and searching for solutions. A challenge though is the fact that mineral rich areas in the North contain remains from mining centuries ago, long before the idea of environmental remediation was born. The owners of these abandoned mines are long gone.

In REXSAC, such abandoned mines have provided a window for exploring how pollution pressure from mining operations together with other environmental and social pressures accumulate and affect the long-term sustainability of human actions in the Arctic. Our hypothesis is that even small-scale operations, which took place in the past, still affect the environment significantly. Yet there are few studies of such pollution. The resulting pollution loads need to be accounted for in any assessments of total pollutant pressures on the sensitive Arctic terrestrial, aquatic and marine ecosystems and their implications for people.

All mining operations have impacts, but among the most problematic ones are the impacts from the extraction of sulfide ores. According to the Swedish Environmental Protection Agency, there are about 1000 abandoned sulfide mines just in Sweden. One of these is Nautanen, located in Gällivare municipality in Norrbotten – one of the case study areas of REXSAC in the Swedish North. The site is the subject of several studies in the NCoE and constitutes an important part of at least one PhD thesis (Fischer et al. 2020). The company, AB Nautanens Kopparfält, began operations in 1902 and mined copper for only 6 years before shutting down in 1908. The company mined 72,000 tons of ore, which resulted in around 2000 tons of copper. After closing their mines and emptying the settlement from its more than 400 inhabitants, the bankrupt company sold off their buildings and infrastructures (Ollikainen 2002). From then on, Nautanens remains consist of house foundations, roads, mines as well as waste rock piles, tailings, and metallurgical slags, all containing sulfidic material, on the ground and in the lakes across of the area.

When REXSAC scholars began their work at Nautanen in 2017, their research questions demanded a multi- and even cross-disciplinary approach. We wanted to know how the site had been used since AB Nautanens Kopparfält closed it in 1908, by whom and for what purposes? We also wanted to know how the remains from the mining had impacted the environment and local communities. We also wanted to learn what attempts had been made to remediate the environment and what the results of these efforts had been. We used a similar set of methods as were utilized in Greenland – archaeological survey, water and soil sampling, interviews as well as archival research.

Already at an early stage, we learned that even though Nautanen had ceased to exist as a settlement and mining site in 1908, it had never been completely abandoned. Over the course of the twentieth century, a variety of actors took interest in the site during different periods. Labor activists used it as a rhetorical device for political mobilization, mining companies explored and evaluated its potential economic values and state agencies branded it as cultural heritage (Winqvist et.al. forthcoming).

Little attention was paid to the environmental impacts of the waste though, until the early 1990s. In 1993, a student at Luleå University of Technology included the site in an examination essay dealing with mine waste in Norrbotten (Larborn 1993). The following year, the county administrative board of Norrbotten conducted an investigation of the water system. This was followed up by a biological inventory and assessments of the state of the natural environment in 2001 and 2002. The results, published by a consultancy on behalf of Gällivare municipality in 2002, showed that the waste rocks, concentration plant sands and smelter slags at Nautanen were releasing some 240 kilos of copper per year into the water system. It was further noted that parts of the site contained high levels of poisonous substances such as arsenic and cadmium, and that ecosystems were severely altered. The consultancy concluded that the site lived up to the Swedish Environmental Protection agency MIFO-model classification at a risk level 2 – meaning severely polluted and hazardous for human health and the environment (Bothniakonsult 2002).

The consultancy recommended neutralizing the main sources of contamination at the site, by moving concentration plant sand and the numerous waste rock piles in the area to one single location, beyond the flow of creeks, and covering it with materials that would contain the leakage of contaminants (Bothniakonsult 2002). In the years that followed, Gällivare municipality acted on this advice by starting up a project with the objective of conducting an environmental remediation of the site. Instead of following the consultant's recommendations however, the municipality made a deal with Boliden – one of the largest mining companies in Sweden with a large-scale open pit copper mine, Aitik, some 20 km from Nautanen. According to reports, Boliden removed some of the waste rock piles in the area in 2005 and 2008 and extracted copper from them in their concentration plant at Aitik (Boliden Mineral AB 2018). Bolidens commitment to the remediation did not extend to the removal of concentration plant sands however. To achieve that, Gällivare municipality launched a project with the objectives of removing the concentration plant sands, cleaning the soil from contamination, and re-direct water flowing through the most contaminated zones (Hifab 2009; Golder Associates AB 2015: 11).

During fieldwork in 2017 REXSAC scholars also sampled water from lakes, streams and soils from the concentration plant and smelter area of Nautanen. We also collected samples from the uppermost 40 cm of lake sediments. We were especially interested in the water-borne spread of copper (Cu) and its potential consequences for ecosystem functions. Thus, we sampled water from many different sites upstream, at, and downstream of the actual mining area. We compared results from our measurements campaigns in 2017 with synthesized historical measurement data from 1993 to 2014 (Boliden Mineral AB 2018; Larborn 1993).

We found that the concentrations of copper (Cu), zinc (Zn), and cadmium (Cd) on-site as well as downstream from the mining area, still are much higher than the local background values and that the Cu concentrations had been relatively constant during the 25-year period during which monitoring had taken place. Interestingly, the average Cu loads in surface waters 4 km downstream of the main mining area, relative to the number of tailings and slag produced i.e., the stream load-to-tailings ratio, was relatively high in comparison with other larger mining sites (Fischer et al. 2020). So, despite the small scale of the Nautanen mining site, the short duration of its operation, and the long time since closure the impact on the environment is still significant. The results also show that the effort so far to remediate the environment at Nautanen has yet to deliver significant reduction of contaminants in the water system that runs through the area. Based on our results we also suggest that there is an urgent need to pay more attention to the potential release of metals from other abandoned mining sites in the North. We fear that disproportionately large amounts of metals may still be added to surface water systems at sites similar to Nautanen and that the total pollution pressures from mining in Norrbotten therefore has been underestimated.

In 2017, the County Administrative Board of Norrbotten ranked Nautanen as number five on a list of prioritized industrial sites in need of environmental remediation for the period 2018–2020 (Norrbotten 2017: 1717). However, the actual work to undertake it still remains to be done. Today the situation is further complicated by the fact that Boliden holds a prospecting license for Nautanen, first issued by the Mining Inspectorate of Sweden in 2009. In 2016, after 75 drilling operations in the area, the company, nonetheless, concluded that the site held previously unknown bodies of ores that are rich in copper, gold, silver and molybdenum (Boliden Mineral AB 2016). The company has mentioned that there is a possibility to remove the contaminants at Nautanen if they apply for, and receive, a concession to mine. But they have made no promises (Boliden Minereral AB et al. 2018).

Adding to the complexity of planning future large-scale interventions in the contaminated parts of the old mining site, is the fact that it is listed as a cultural heritage site, used for recreational purposes by local people in Gällivare and considered as a potential resource for heritage tourism by the municipality and tourism entrepreneurs. Is it possible to harmonize the ambitions to protect heritage values with the need for environmental remediation – and if so – how? An even more burning issue is the fact that Nautanen is located on the lands of a local indigenous Sámi community. The Baste čearru reindeer herding community uses the land as winter-spring grazing pastures for their reindeers. Their position on the future of Nautanen could very well have a strong influence on what happens in the future, in the aftermath of the Girjas court case.[2]

The case of Nautanen shows just how important it is to pay careful attention to planning for the post-extraction phase of mining projects. It also highlights the need to develop a program for dealing with toxic waste from former mining sites – in the North and elsewhere. Given the multitude of actors who are using these former mining sites for various purposes, it is imperative to allow for strong local scrutiny of the afterlives of former mining sites.

16.4 Re-economization

Nautanen has not just been an instructive case about the challenges of remediating environments transformed by mining that took place long ago, before there were laws requiring environmental remediation. It also showcases the difficulties of making sustainable visitor sites for heritage tourism out of polluted places. Nautanen hardly qualifies as a success story of tourism related to heritage making in the Arctic. There are, however, other more successful examples. Over the course of our research in REXSAC, we have studied several cases of post-extraction transitions in which the legacies of former mining operations have played a role in the creation of new values; thereby contributing to sustaining communities once built for the sake of mining beyond the lifetime of the original activity. In the Arctic, the archipelago of Svalbard provides several examples.

Svalbard carries remains and imprints of more than 400 years of natural resource exploitation. Natural resources was the reason why people came there in the first place. Svalbard was uninhabited when Dutch explorer Willem Barents discovered it in 1596. Reports on abundant whale populations encouraged whaling companies to go there in the early 1600s. They established whaling stations along the coastlines and soon emptied the seas of Greenlandic whales. From the late seventeenth century onwards whaling moved off shore. Hunters from north-west Russia (Pomors) established new stations to support their terrestrial hunting activities for furs and walrus ivory. From mid-nineteenth century, Norwegian hunters also arrived on the scene, adding new hunting stations to the area. During this same period, scientists built stations there, and so did a new wave of whaling companies. Resource exploitation up until this time resulted in massive pressures on the ecosystem of the archipelago, but the built environments that they left behind were comparatively modest compared with what was to come (Avango et al. 2014; Hacquebord 2001).

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[2] The Girjas court case, between the Swedish state and the Girjas Sámi Village, was settled by the supreme court of Sweden on January 23, 2020. The court awarded the Girjas Sami Village exclusive rights to issue licenses for hunting and fishing in its management area, instead of the state, based on legal and inherited rights. The court ruling may set precedent for future rulings also on other land use conflicts which involves the Sámi indigenous people in Sweden.

From the opening years of the twentieth century until the early 1920s, a growing demand for energy resources, along with a resource scarcity during the First World War and geopolitical maneuvering by Sweden, Norway and Russia, resulted in a coal mining boom at Svalbard. Mining companies from northern Europe and the USA established several mining towns there. These were for year-round use and together with their extensive infrastructures, they transformed vast areas of land into an industrial setting. In addition, the companies built prospecting camps all over the archipelago (Hacquebord and Avango 2009; Avango 2018). Although the companies abandoned most of these mining installations over the course of the twentieth century, the mining industry still persists in Svalbard up until the present time. In recent years however, mining companies and their state backers have started to phase out mining as a consequence of falling coal prices and the coming of new environmental policies (Avango and Roberts 2017a, b). Therefore, in 2020, Svalbard seems to be at the end of a 400 years era of extractive industries and at the doorstep of a new post-extraction future.

In this process, state and corporate actors on Svalbard are trying to find new ways to remain in business and maintain settlements and infrastructures that were once built for the purpose of mining. The research we have conducted in REXSAC at Svalbard shows that the material remains of these 400 years of extraction – stations for whaling, hunting, science and prospecting, and entire mining towns and their infrastructures – form an important part of an effort to build a tourism-based economy on the archipelago.

A multidisciplinary team of REXSAC scholars have studied this transformation process since 2016. The work included two fieldwork campaigns in the summers of 2016 and 2017. In the first, a team of ten researchers collected data for understanding whether the remains of extractive industries at Svalbard could become a resource for a sustainable post-industrial future, and if so, how and why this could be done. The team consisted of scholars in human geography, the history of science, technology and environment, archaeology, ethnology, and social anthropology. We worked in four different mining settlements – Longyearbyen (provincial capital and seat of the Norwegian administration of Svalbard), Sveagruvan (Norwegian mining settlement), Barentsburg and Pyramiden (Russian mining settlements). Each participant had unique methodological skills to bring to the effort, but working as a team with a large body of data to collect, in four different locations, required us to leave our "comfort zones" and to help each other out. In this manner, we conducted interviews with representatives of mining and logistics companies, engineering consultancies, workers' organizations, tourism firms, state and municipal authorities, museums and representatives of scientific communities in Svalbard. We also documented built environments pertaining to the socio-technical system of mining in the four settlements. Systematic photographic documentation and text descriptions were undertaken. At several sites we combined these methods in the form of "walk and talk" interviews.

The actors we talked to had different visions and ambitions about the future of Svalbard, but a shared common understanding that coal mining belonged to the past and the future was associated with the tourism industry, education and scientific research. Almost all actors we talked to considered the legacies of past extraction as something valuable and useful when building this future. Tourism entrepreneurs argued that housing and service buildings from mining could be reused as hostels, shops and storage facilities. Our documentation of the built environments from mining era showed that this is already happening. Tourism has grown into a substantial business in the former mining town of Longyearbyen, profiting from the proximity of an airport with daily connections to Norway. Several actors argued that the same is possible in addressing de-industrializing elsewhere at Svalbard. Framed as industrial heritage in remote locations with more direct access to the Arctic wilderness, settlements like Barentsburg and Pyramiden are already attracting a growing number of tourists – the latter as a "frozen moment of time" from the former Soviet Union. This narrative seems to work. The owner, Trust Arktikugol, has claimed they are making almost as much money from tourists as they do from coal (Fig. 16.3).

Our surveys also showed that there are many examples of built environments originally designed for resource exploitation, that today are used to house scientists and laboratories. The same is true also for education. Since the Norwegian state established The University Centre in Svalbard (UNIS) in Longyearbyen in 1993, education has changed the balance of its outputs from coal to academic scholars and professionals. It has also changed the social composition of Longyearbyens population and the usage of its built environment. Former mine workers barracks nowadays house students. The Norwegian government is promoting this change. Opinions

Fig. 16.3 The former mining town Pyramiden – a coal mining settlements from (1910) 1946–1998, today the subject of heritagization and re-economization as a visitor site for tourists. (Photo: Dag Avango)

diverge, however, as to whether science and education is enough to sustain permanent settlements that contain costly infrastructures for energy production, heating, water management and transport. The former mining community of Ny Ålesund, today a platform for research in the natural sciences, is often mentioned as a successful example (Paglia 2019). The idea of doing something similar focused on geo-science at the closed mining settlement of Sveagruvan has not resulted in the same enthusiasm (Avango et al. forthcoming). Critical voices ask how many Ny Ålesunds there can be on Svalbard? Two? Three?

Despite these examples of enthusiastic re-economization of built environments of the mining settlements at Svalbard, our research also showed that not all legacies of mining are reused. The landscapes surrounding the former mining settlements are dotted with remains of transport infrastructures, waste rock piles, and industrial buildings, which no one is using for anything. It could seem awkward to ascribe values to such remains in an archipelago that the Norwegian government describes as a "well-preserved wilderness". Nevertheless, many of these remains are protected by Norwegian heritage laws and most actors we talked to hope that they will be preserved because they value them as representations of what they believe makes Svalbard unique as an industrial outpost in the high Arctic. A common argument heard was that Longyearbyen and Svalbard should not become just like any other place in Norway. Svalbard should be a different place, because that's why we like to live and work here and that's why tourists come here.

The results from the REXSAC fieldwork campaigns in Svalbard both adds to and confirms results from previous research we have conducted within the polar regions. It indicates that successful re-economization of abandoned built environments rests on two related conditions. One is the presence of actors who see benefits in repurposing them for new economic activities. The other one is the will and possibility to ascribe heritage values to them. At Svalbard, the Norwegian environmental laws, which stipulates that any material remains older than 1946 are protected as cultural heritage, creates favorable conditions for ascribing heritage values to mining legacies. Thus, with committed actors and an amenable institutional framework, mining legacies can generate new incomes, both directly through re-purposing and more indirectly through heritagization that both contributes to place- and destination making conditions for tourism.

At Svalbard, heritage making has also other important dimensions. Since the signing and ratification of the Treaty concerning Spitsbergen (often called the Svalbard Treaty) in 1920 and 1925, Norway has developed a policy of exercising sovereignty by maintaining Norwegian settlements on the archipelago. For most of the twentieth century, the Norwegian used the coal mining industry as the economic base for this policy. From the 1980s, Norway gradually opened up its main settlement on Svalbard, Longyearbyen, also for other economic activities such as tourism and from the 1990s education. With the de-industrialization that started in earnest in 2015, Norwegian governments have stepped up its efforts to promote tourism, education and science development in order to create a new economic basis for maintaining the settlements and exercising sovereignty. The re-economization and heritagization of former coal mining settlements works in favor of this policy.

16.5 Heritage Making

REXSAC scholars have drawn important insights about post-industrial processes of change in former mining settlements from our research at Nautanen and at the former coal mining settlements in Svalbard. In both cases – with very different results – actors have attempted to ascribe new values to mining legacies by defining them as cultural heritage. In public debates about sustainable development in the Arctic, cultural heritage is often connected with positive values – preservation as opposed to destruction, remembrance and recognition as opposed to amnesia and ignorance. Cultural heritage sites were, and often still are, considered as places representing universal human values rather than individual interests. For REXSAC, working towards the objective of contributing to Arctic sustainability, it has been imperative to approach the concept of heritage in a critical way. This necessitates exploring not only how but also why historical remains are transformed into cultural heritage. Therefore, from the outset, we took inspiration from the field of critical heritage studies (Harrison 2013; Walsh 1992; Lowenthal 2015). We considered cultural heritage as something constructed and fluid, in constant transformation due to socio-cultural as well as natural processes. These made and re-made our cultural heritage through a wide range of interacting human and non-human agents. To answer the question of why some remains from past extractive industries have been constructed as cultural heritage, we used concepts developed by heritage scholar Rodney Harrison (2013). He drew a distinction between "official" and "un-official" heritagization. The former are processes in which state authorities designate remains as heritage, guided by expert advice, and then act to protect them under law. The latter involve processes where non-state actors, for example local historical societies, ascribe heritage values to sites and maintain them by other means. To these two categories, we added the concept of corporate heritagization, where commercial companies play a leading role in the heritagization process. Our rationale for doing so grows out of the fact that companies often play a leading role in designating and preserving cultural heritage in the Arctic. This is particularly the case for tourism firms but also companies in the extractive industries. Through their social networks, financial resources and often influential positions locally as job providers, such actors have the means of making heritage and defining history that local historical societies seldom have.

In the Nordic Arctic, official heritagization of mining legacies has, first and foremost, occurred in northernmost Sweden and Norway, and in Svalbard. In the latter case, many of the systems and built environments formerly used for mining are now protected as heritage based on their age. There are also noteworthy cases where the Governor of Svalbard has designated mining remains that are younger than 1946 as heritage sites. In northernmost Sweden, the Swedish National Heritage Board has designated parts of the large systems of mining there as national interests of cultural heritage – including components that are still in active use. Just like in Svalbard, this official heritage making has been part of Swedish national policies to diversify the economy, with cultural heritage serving as a resource for place making and heritage tourism. However, the state and municipalities have also seen heritage making as a way to build a sense of belonging and thereby a new quality of life for local communities (Avango and Roberts 2017b).

We have also investigated examples of unofficial heritage making pertaining to extraction sites in the Arctic. An example from Sweden is the Porjus hydro-power station. Here, the state hydropower company, Vattenfall, saved the facility because of an initiative by a local historical society for whom the old power station was, at least partly, a monument to Swedish working-class history. As Anna Elmén Berg has shown, it was also about preserving local identity and pride in a settlement where most jobs in hydropower sector has disappeared (Elmén Berg 2007). There are more examples of this type of effort, but it is noteworthy that unofficial heritage making at industrial sites in the North is far less common than in the southern parts of Fennoscandia. The reason remains to be explained, but there is no doubt that such mega-projects are challenging to transform into working life museums, because of their sheer size or their locations far from main roads and population centers. Another reason for their difficulty in establishment pertains to the contested nature of their histories and their impacts on the land uses and lifestyles of local and indigenous people.

REXSACs research has also provided new insights regarding the role of industrial companies as drivers of heritagization in the Nordic Arctic. In some cases, they have played an important role, benefiting local communities in transition. One example is Svalbard, where the Norwegian mining company Store Norske Spitsbergen Kull Co (SNSK), has invested heavily in preserving parts of its former production systems and buildings as heritage sites, offering visitors experiences of mine work and narrating their history in guided tours. Other cases contain more tensions. The mining company LKAB, which operates the iron ore mines at Kiruna, Svappavaara and Malmberget in northernmost Sweden, has made considerable efforts to protect its own historic buildings in Kiruna and Malmberget for posterity. This has been done as a part of their project to relocate these settlements because of their ongoing mining operations. The company has also invested in the writing of its history, producing books and pamphlets, often in connection with anniversaries. In addition, LKAB has produced museum exhibitions for its own museum in Malmberget and their immensely popular visitor centre inside of their mine in Kiruna. Not surprisingly, these heritage sites, publications and exhibitions tend to celebrate the histories of the company and the built environments it created. However, the perspective is solely that of the storyteller, the company. Other voices and possible narratives are largely absent.

The field-based learning we developed for the REXSAC PhD student school and the field-based workshops for current researchers, has enabled us to discover more dimensions of corporate heritage making than we anticipated when we started our research. From Kittilä and Kolari in Finland, to western Greenland, to Finnmarken in Norway, to Svalbard and Norrbotten in Sweden, we became increasingly aware of the ways in which mining companies enroll and mobilize legacies of the former mines in an effort to influence public opinion and decision-makers in governing bodies of states with regard to new mining projects.

Companies use mining legacies in three types of narratives in which they connect the past and the present in ways meant to work in their favor. The first of these are narratives about local identity, where companies make remains of former mines into anchor points for the argument that the settlements where they want to start new mines are, in fact, are old mining communities. Against this background, new mining projects are made to represent continuity, a re-vitalization of old traditions, new building blocks placed on foundations constructed by generations before. The second type of narrative is one that suggests that the proposed site is no longer pristine. It has already been transformed by mining in the past and therefore should not be assessed in the same way as a location where no mining has taken place in the past. In this type of narrative, companies use historic mines to advance an argument that re-opening a former mine is better than impacting un-impacted environment elsewhere. In some cases, mining companies will connect this line of argument to a third type of narrative, in which new mining projects may be seen to undo harm to the environment that took place in the past. A recent case example of this use of narrative can be seen that of a new proposed mine at Nautanen described above.

There are cases where actors with diametrically different opinions about new extraction projects in the Arctic are using the same historic mining sites to advance widely differing narratives of what these sites represents in the present and future. An example of this, that REXSAC scholars are now researching, is the abandoned mining town of Laver in Norrbotten, northern Sweden. In 1936, the Boliden mining company built a mine there to extract copper. This mining settlement had some 350 inhabitants. Boliden was designed it to have comparably generous living conditions for its inhabitants – spacious houses and flats, electrified kitchens, hot and cold running water, water closets and central heating. The community had its own school, grocery shops, communal hall and a cinema.

Despite these investments, Boliden decided to close Laver 10 years later and empty it of its inhabitants. The company proceeded to pull down or move the existing houses to new locations. In the forest, the company left house foundations, the imprints of streets, the mine and its above ground production system and waste management facilities, including a substantial tailing pond encompassing the toxic wastes from a decade of copper ore concentration (Alerby 1994; Lundqvist and Boliden mineral 2016: 63–69).

Today Boliden wants to open a new mine at Laver. It would be an open pit copper mine which together with its tailing dam and waste rock piles is meant to cover some 46 km^2. The inhabitants of Älsbyn municipality, where Laver is located, have divergent opinions about the project. The mining company, together with politicians and locals in favor of the new mine, argue that it will bring employment and economic spin-offs. Those who are opposed to it argue that it will have massive impacts on the environment, pose serious environmental risks for centuries to come and will destroy indigenous reindeer herding.

To support their vision of the future, Boliden and its supporters offer a narrative history where the new mining project is simply a continuation of the old one. The new mine will re-awaken the mining identity of Laver and provide recognition of the efforts of those who started it all back in the 1930s and 1940s. The opponents provide an alternative historical narrative of Laver. They highlight the collapse of its tailing dam in 1952 and the subsequent pollution of land and water downstream. Both sides anchor their narratives in the site of old Laver. Both bringing visitors there for guided tours. For those in favor of the new mine, the site provides the remains of a celebrated settlement. For those opposed, the site offers a view of a toxified landscape impacted by the old tailing pond.

The cases mentioned above demonstrate how the material legacies of the Arctic can mean different things to different actors. They also suggest that actors frame and use their histories in relation to their experiences, their visions of the future, and their interests. This multiplicity of perceptions of the past is seldom represented at mining heritage sites, however, and only rarely in popular publications. This will be a challenge for those who believe that heritage making can contribute to responsible and sustainable post-extraction futures in the Arctic. How can we make mining legacies as heritage interesting and useful to a wider range of actors?

16.6 Conclusions

Through our multi- and transdisciplinary approach, REXSAC took important steps towards an understanding of if, how and under what circumstances legacies from past extractive industries can contribute to sustainable and responsible futures in the Arctic. To begin with, it is clear that the majority of former mines in the Arctic are, and will most likely continue to be, abandoned places where no new detectable values are created, but where significant amounts of toxic wastes are deposited in the environment. These are what environmental history scholars like Arn Keeling and John Sandlos have called "zombie mines" – abandoned mines that are dead but who continue to haunt the living through heavy metals and, in some cases, also by memories of colonial abuse (Keeling and Sandlos 2017). Cases like Nautanen, Josva and Laver also show that historic mines need to be taken into account in all environmental impact assessments of new mining projects – not as an argument in favor of carte blanche approvals of new environmental impacts, but as an important reminder of the multiple pressure arising from resource extraction undertakings that affect the environments and communities in Arctic regions today.

REXSACs research into post-extraction transitions also show that the legacies of mining have the potential to contribute to local livelihoods and well-being through re-economization. Some contexts seem to work in favor of this, such as when institutional frameworks provide different possibilities to deal with remains of mining after closure, encourage local influence over such processes, allow for manageable environmental legacies and the contributions of committed actors who envision and ascribe values to remains from the past – economic values and / or heritage values.

Some context does not work in concert with such approaches. These are locations which are extremely costly to get to and that few people even know exist. There are mining sites where all buildings have been removed or destroyed. Sometimes existing legislation offers few opportunities for post-extraction efforts.

There are also sites where toxic waste, unwanted physical barriers and difficult histories discourage actors from ascribing values to them.

Heritage making may provide an avenue for responsible post-extraction futures in the Arctic, but it is clear that it requires a careful balancing of needs and desires to heal real and perceived existing wounds to the environment and to people. This is not only an issue of environmental remediation, but equally important, an issue of how heritage makers choose to narrate historical remains and places. There is a need to include a greater multiplicity of perspectives and historical experiences of mining, including from those who never benefited from it and only received its problematic impacts. And there are all those in between these extremes, who both suffered and gained something. In this way, extraction legacies made heritage could become an arena for public debate about both the past and the future of resource extraction in the Arctic and what it takes to make it sustainable in the decades to come.

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Chapter 17
Mining Emotions: Affective Approaches to Resource Extraction

Frank Sejersen and Kirsten Thisted

Abstract Within the field of resource extraction there is consensus that emotions should be avoided. We are constantly reminded that mining discussions should be based on facts and rational arguments rather than let the emotions prevail. In this chapter we argue that this is a false dichotomy. Without hope, potentiality and engagement the minerals will stay in the ground. Thus, mining not only relies upon the mobilization of emotions but also fosters emotions, which support certain discourses and narratives while silencing other. The concept of 'mining emotion' is thus double. It allows us to point at the emotional work and practices associated with mining, as well as the negotiations and translations that take place in a highly contested setting with different and possibly contrasting emotions. The chapter presents research within REXSAC, which contributes a focus on mining activities as deeply entangled in human affects. Drawing on the so-called "emotional turn" in the social sciences, we investigate how affects and emotions as cultural practices empower discourses that connect (or disconnect) resource extraction with community making and nation building. Our analyzes are based on studies and field work in Greenland and Sápmi in Northern Scandinavia.

Keywords Mining · Arctic · Emotions · Indigenous peoples · Community-making

17.1 Introduction

> We are of course both sad and surprised that the majority of the Municipality Council did not listen to our arguments that this would be a good project. We think it is stupid that we were not given the permission to start an environmental impact assessment, so facts could be laid on the table. As it stands now, people are voting with their heart (Vuolab and Gaup 2013, translated by the authors).

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This comment was made by a frustrated director of the Swedish mining company Arctic Gold in 2012 when the Municipal Council in Guovdageaidnu (Kautokeino, Norway) dismissed the company's plan for reopening the mining area in Biedjovaggi, 40 km northwest of the town. The comment reflects an established contradiction between reason and emotion in discourses on mining and extraction. The very emotionally involved director can – without having to argue the case – attribute emotion to the other party while associating himself and his company with reason. In the hegemonic discourse on mining and extraction, financial gain equals 'hard' facts, while taking into account 'softer' values such as well-being and ecology equates 'emotion'. Since there is a consensus that reason ranks above emotion, inherited from a centuries-long European discourse on enlightenment, there is a vast discursive power associated with the right to judge what can count as reason and what must be dismissed as emotion. A power that, in this case, allows the speaker to dismiss the opponent's decision as 'stupid'.

An obvious topic for a humanities-based approach to mining and extraction is to take a closer look at such speaking positions. Instead of accepting the prevailing discourse that emotions are irrelevant to the issue of extraction, we must analyze how emotions are included in the debate and with what effect. It requires us to consider whether some emotions are more legitimate than others, and who has the power to define the borders between emotion and reason.

Mining and extraction can be said to constitute a special social domain based on a variety of discourses and genres (cf. Fairclough 1992). The scientific report is a central genre within this domain. Scientific reports are by definition considered 'objective' and based on facts. Yet scientific reports on extraction often carry titles that include words such as 'potential', as for instance a report published by GEUS (Geological Survey of Denmark and Greenland), on behalf of the Government of Greenland, Ministry of Minerals and Resources: *Uranium Potential in Greenland* (Thrane and Steenfelt 2018). According to Cambridge English Dictionary 'potential' means: "Someone's or something's ability to develop, achieve or succeed." Collins English Dictionary states: "If you say that someone or something has potential, you mean that they have the necessary abilities or qualities to become successful or useful in the future." (Collins English Dictionary online) The noun 'potential' thus carries unambiguous positive connotations. By creating the link between the words 'potential' and the word 'uranium', the positive connotations that attach to the former rub off on the latter. Supporting the process of achieving someone's or something's full potential is considered a good thing. Therefore, initiating a process where Greenlandic uranium can fulfill its full potential must also be a good thing. In this way the report's framework naturalizes one argument in an ongoing debate. Combining the object uranium with the noun 'potential' silences other combinations, where uranium could, for instance, be potentially dangerous and thus unwanted.

Despite its scientific authors and its strictly 'scientific' appearance, the abovementioned report on 'uranium potential' mobilizes emotions. In this case, positive feelings about uranium, which by virtue of the word 'potential' become linked to a promise of something positive that will happen in the future. Thus, in mining one not only mine minerals but also emotions. It extracts powerful, emotional narratives about place and connections to place, which link in with temporal visions of the past and the future.

Strong interests are involved in mining and extraction, and there are usually many stakeholders with conflicting interests. The concept of 'community' is central in the study of the work that emotions do in debates about mining. Some stakeholders will argue that a given project is of benefit to the community, while some will take the opposite position. However, 'community' could be many things: the local community, or a certain community within the broader local community, the national community, or maybe even the company community or the community of shareholders. Therefore, an important focus of a humanities-based analysis of mining and extraction is to study the work that emotions do in creating different visions of future happiness, based on different definitions of 'community' and different ideas of 'the good life'. In both cases, emotions productively engage in community-making no matter the scale of the imagined community (cf. Benedict Anderson's seminal book *Imagined Communities*, Anderson 1991 [1983]).

The analytical approach we describe below is linked to the so-called 'emotional turn' in cultural and social sciences (cf. Greco and Stenner 2008; Clough 2008). Rather than regarding emotions as individual psychological states, social sciences view emotion as cultural practices: something that is located in the interaction between people rather than within an individual itself, underscoring the sociality of emotion. Within a wide range of disciplines, emotions that have otherwise had their place primarily in psychology and the study of fiction have thus in recent years been included as a factor that must be subjected to analysis. New scientific disciplines have emerged, such as the history of emotions, the sociology of emotions, the anthropology of emotions, or emotional geography, the latter focusing on the emotional intersections of people and places (Davidson et al. 2005).

It is difficult to establish fixed boundaries between these disciplines, since much of the research is interdisciplinary in character, crossing the fields of humanities and the social sciences. It is also difficult to talk about emotional or affective theory as a single discipline, even within cultural and social sciences, as different researchers use different analytical methods and define the same concepts differently. This applies, for example, to the concepts of affect, emotion and feeling.

Often, the words 'affect' and 'emotion' are used as synonyms. There is, however, some consensus that affect precede social organization, but that it is through socialization that human beings learn what should trigger affect and how it should be dealt with (Ahmed 2014). Thus, affect is commonly defined as being biological in nature and origin, while emotions spring from the cultural context and hence vary depending on time and place (Griffiths 1997). Feelings are generally seen as the latest and most personal, so that while affects are prepersonal, and emotions are social, feelings are personal and biographical (Shouse 2005). The discussion does not, however, play a major role in the kind of analysis that will be developed in this essay.

With its biological focus, affect theory has brought the body back into the political arena. In analyzing this arena, scientists usually focus on meaning making: opinions, ideas, ideologies and in recent decades not least discourses. All of which has to do with interpretation, rather than sensation and immediate experience of being in the world (Thrift 2007; Wetherell 2012). While some scholars, including the geographer Nigel Thrift, use the emotional turn to break with the tradition of discursive studies in social sciences, other researchers, including the social psychologist Margaret Wetherell, see discourses and affect as inextricably linked. Borrowing Barbara Rosenwein's concept of emotional communities (Rosenwein 2006) Wetherell argues that communities are held together by shared repertoires of emotion, intertwined with shared repertoires of interpretation. Thus, the sense of community comes from the recognizability and cohesion produced by the shared affective practices. These, through routine and repetition, become internalized in the individual and work as a sort of "affective habitus" (c.f. Bourdieu's habitus concept, see Wetherell 2012: 106f., 139).

Where many researchers see discourse as having a taming effect on affect, Wetherell sees it the other way round, so that it is the discourse that makes affect powerful and provides the means for affect to travel and spread from one person to another (Wetherell, 2012: 19). It is national discourse that produces and circulates love for the nation and hatred for those who threaten it. Likewise, discourses about mining and extraction circulate emotions such as hope, anxiety and anger, which fuel opposing positions in the debates.

Also, Sara Ahmed, who has gained a great deal of influence in critical cultural studies, sees a close correlation between discourse and emotions. Ahmed introduces the concept of *affective economies*: a circulation and accumulation of emotions, not unlike the way money circulates and accumulates. In order to accumulate, emotions must be put into circulation, and this is done through discourse, where certain emotions 'stick' to certain objects. Like when the color 'white' in twentieth century racialized discourse equaled 'clean', 'highly developed', 'superior', while the color black equaled 'dirty', 'under-developed' and 'inferior'. Thus, emotions do not reside in the object itself, it is through metonymic slide that certain objects become readable in a certain way: "[E]motions work to shape the 'surfaces' of individual and collective bodies. Bodies take the shape of the very contact they have with objects and others" (Ahmed 2014: 1).

Human bodies are transformed into objects of emotion, which then circulate, like any other object. Through processes of discourse and stereotyping, shame seems to stick to certain bodies, while pride sticks to other bodies; as in the racialized discourses or discourses on the 'fat' versus the 'slim' body. Thus, 'sticking' is dependent on "past histories of association" that often "work through concealment" (Ahmed 2014: 13). Power then, as both Wetherell and Ahmed demonstrate, is crucial to the agenda of affect studies. Who is emotionally privileged and thus powerful in the discourse, who ends up emotionally disadvantaged?

The research presented in this chapter is embedded within the framework of The Nordic Centre of Excellence for Resources, Extractive Industries and Sustainable Arctic Communities (REXSAC). The main purpose of REXSAC is to contribute to practices and processes that ensure the sustainability of Arctic communities in a rapidly changing social, political, cultural, and ecological environment. The REXSAC research group focusing on emotions argues that naturalisation of activities, and the overall framework of sustainability, conceals the emotional involvement of all agents and how emotions drive dynamics in extractivism. Hence, responsible development requires analytical attention to how emotions are played out and work.

Mining not only relies upon the active and productive mobilization of emotions but also fosters the mobilization of active and productive emotions. The concept of ‘mining emotion’ is thus double. It allows us to point at the emotional work and practices associated with mining, as well as the negotiations and translations that take place in a highly contested setting with different and possibly contrasting emotions.

Drawing on the work of a number of REXSAC researchers, we will in this essay provide examples of how affect theory can be productively applied in mining and extraction studies. We have organized our presentation around three keywords related to mining and extraction: place, future and past.

Mining and extraction take place somewhere, and that place definitely will not remain the same once a huge industrial project is initiated. Thus, mining and extraction can be seen as placemaking activities. Likewise, mining and extraction have to do with the creation of the future, because they introduce new horizons of potentiality. What may seem more surprising, however, is that mining and extraction also have a creative influence on how people envision and interpret the past. People can engage themselves in the kind of stories that can create a connection between past, present and future. Or they can imagine a future where there is no room for the past or certain elements of it. Decisions are made in order to lock the unwanted away in the past, never to return to the present or the future. Thus, place, past and future are tightly linked in political imagination. Affect and emotion play a central part in the way this imagination is presented and made worth fighting for.

17.2 Creating Places

Mining has many phases: it can be anticipated; it can be planned; it can be ongoing or it can be abandoned. In all phases people are forced to start a process of reevaluating their understanding of their relation to place. This reflection on place requires that people have to rethink who they are and whom they wish to become. These processes of reflection are often difficult and deeply linked to emotions. For many Arctic communities, ideas of place-based community, the good life and social and economic stability/dynamics take center stage when mining becomes the dominant frame of reference. Hence, important place-based cultural activities have to be (re) evaluated and (re)organised. Places that are thought of as places for the good life are also highly emotional sites. In some instances, these places constitute sites of previously lived experience which tie the body and the social together with the emotional. In other cases, the created places are sites of potentiality and positive emotions are linked to the expected to come but not yet there.

A mine will, even in its initial planning phase, trigger reflection and mobilise a variety of emotions that start to circulate. A central point of reference in mining is the extractive site itself. However, other sites that are tied together by the mine's infrastructural requirements emerge as analytically important too (roads, harbours, factories, communities, stock exchange, administrative offices, cities, universities etc.). All involved parties start to invest and circulate emotions toward particular places and networks of places. This process both involves the demarcation of objects that are given emotional value and the scaled framework within which these objects are to be understood and valued. The continuous and often conflicting circulation of emotions as an inherent aspect of place-making also points our analytical attention towards place consciousness as a socialized conception of space which implies that the "[...]identities of places are always unfixed, contested and multiple…Places viewed in this way are open and porous" (Massey 1994: 5).

Place consciousness and place imagination are emotionally challenged, reconfigured, reimagined and stabilized. These processes of place-making have something to offer in relation to how people conceptualise ideas of development, social life and politics. They also have a relation to people's continuing ambition of (re)producing neighbourhoods, communities, companies, regions and nations. Thus, emotions are pivotal in the construction and promotion of such processes. In some cases, places are evoked as important for particular intimate social relations, interests, values, practices and boundaries. Nuttall (1992) for example points out how Arctic communities emphasize their intimate and emotional relationships with particular areas and locations. Indeed, in the place-making projects of the communities studied by Nuttall the idea of 'homeland' becomes immanent and underpinned by narratives of history, identity, sociality, community, interdependence and local knowledge. These place-making projects create and scale space and time in ways that invest the social with particular meaning and emotions.

Place-making projects may converge, diversify and conflict with other activities. In case of mining, place-making projects can often conflict to such an extent that mining-projects become zones of emotional clashes where different emotions are stuck to certain objects that emerge as central for the movement towards better futures. As will be demonstrated later, mining of uranium in Greenland is closely linked to the mobilization of emotions of good as well as bad futures. A mining company's spokesperson may evoke positive emotions through a particular place-making project using, for example, geological data which indicates the possibility to produce profit from that place. A governmental official may produce positive emotions by showing economic data that indicate how mining jobs will boost community development and state taxes underpinning the population's welfare.

In another instance, a caribou hunter may evoke positive emotions to the use of the particular place demarcated for mining by producing historic evidence of the life-giving man-nature relationship that has been maintained through generations. When people decide to link certain emotions to particular objects, they also circulate emotions about the good (and right) life and what is important in the reproduction of the social. Emotional work is important in the production of locality (Appadurai 1996).

These objects, geological substances, mines, caribou, fish caught in a certain way, that are enmeshed with emotion are installed in different place-making projects that play with time-space relations in quite different ways as well as in different social configurations. In the following discussion we will first look further into the interrelatedness of place and community through emotion. From there, we will consider how epistemic difference is silenced in the case of administrative hearing processes which are based entirely on Western, 'scientific' ontology.

17.2.1 Communitification

While the term 'community' appears as a descriptive term in her research, Anne Mette Jørgensen introduces the alternative term *communitification* in order to describe this creative process in which people come together as a community in order to claim the ownership of a certain place and negotiate its desired future (Jørgensen 2019). Comparing the towns of Sakajärvi in Norbotten County, Sweden and Qullissat in the Disco Bay, West Greenland, Jørgensen investigates in her REXSAC research how emotions linked to place become cultural capital in both a case where a mine is expanding (Sakajärvi) and in one where the mine is closing (Qullissat).

Even if the inhabitants of Sakajärvi had long been good neighbours, it was the expropriation of their land (in 2017) that turned them into a community. The expropriation united them in their frustration, anger and grief over the loss of land where they had created their livelihood and upon which they had based their vision of the future. Likewise, they were turned into a community by other inhabitants of the municipality who saw them as "traditionalists" that lacked an understanding of the common interest in promoting development and jobs. Nevertheless, Jørgensen argues that by circulating their emotions of grief and distress through the media, this group of Sakajärvi inhabitants managed to make the mining company admit to the emotional value of the properties. Thus, affective capital might in this case potentially influence the monetary compensations.

In West Greenland the former inhabitants of Qullissat (*Qullissarmiut*) became associated with negative feelings when the mine closed down in 1972 and the inhabitants were relocated to other Greenlandic towns. Not being able to decide one's own destiny means being turned into a passive object, which is always associated with shame. Integration into the new towns was also not always easy. The Qullissarmiut became known as '*Annangiat*' meaning 'those in need to be saved'. Thus 'Qullissarmiut' took on a derogatory meaning, associated with emotions of shame and inferiority. To the Qullissarmiut themselves, the old life in Qullissat became associated with nostalgic emotions, but in some families, the loss and longing was so traumatic that it became a taboo even to mention the name Qullissat.

While it has been contested to what extent Greenlandic politicians were complicit in the decision to close down the Qullissat mine, Qullissat soon became a symbol in the anti-colonial upheaval. Advocating Home Rule in Greenland and in the diaspora in Copenhagen the movement borrowed and adapted a narrative of Qullissat as an emotional community to their political campaign. The case has continually contributed to a wider postcolonial discourse of Danish guilt on the one hand and Greenlandic pain and suffering on the other. Interestingly, the Qullissarmiut, themselves, rarely took an active part in this political movement. Only later did former Qullissarmiut and their descendants begin to promote narratives about the abandoned town in which they themselves were active agents, according to Jørgensen's interviews and investigations. Thus, the legacy of the town was increasingly liberated from the 'sticky' negative affects.

The two cases of Qullissat and Sakajärvi demonstrate how place and community are productively made into interrelated entities. Furthermore, the cases point at how boundaries dynamically appear, change, and disintegrate, depending on the discourses and emotions associated with them at a given point in time.

17.2.2 The Power of the **Seidi**

The REXSAC research initiative pursued by Marianne Lien in Northern Norway further points our attention to some of the complex interplay between place-making and emotions, in particular shame (Lien forthcoming).

In the mountain in Varanger visible traces of the 40-year-old infrastructure of the quartzite quarry still exist. The open pit in its environment is a significant signature of the extractive activities that once took place there. However, recently, the license to extract has been purchased by Chinese investors, and the plan is to initiate a massive expansion of the quarry, which will affect and interrupt a wide range of practices and life projects of humans and animals. As in all other mining projects, stakeholders started to air concern or satisfaction. At a certain point, the different perspectives and interests were organised and translated into official assessment reports. Here, the voices are conceptualised and compartmentalised into demarcated areas of attention: 'culture', 'environment', 'economy' etc. (see also Sejersen 2019a). In Lien's research the attention is not only focused on how the proposed expansion is a concern for Sámi reindeer herders, for whom this place is part of seasonal migration routes across the Tana/*Deatnu* river, but, also, on how the expansion will interrupt the movement and handling of the animals. She is also trying to navigate and explore the more ontological aspects of the conflict, including the emotions that are linked to objects in particular ontologies.

The mountain is, also, possibly the site of other powers known as the Giemaš that manifest themselves, for instance, in unexpected accidents. She explores how the planned expansion evokes this contested site as more than a singular mountain, and how divergent knowledge encounters serve to interrupt the extraction of resources in unexpected ways. In particular, she seeks to convey how practical ontologies and emotions conflict with the undertaking of consultancy and planning. Conflicts emerge because administrative hearing processes are deeply based in a Western ontology which ignores and silences other manifestations and configurations of reality. This means that hearing processes not only function as political arenas saturated with different interests and perspectives. In fact, they operate as intensive sites of place-making projects in which only certain voices and emotions are made possible.

In the Sámi understandings of the mountains and the powerful stones termed *Siedi,* the non-human world emerges as (inter)active and intentional, to such an extent that the powers of the non-human in some cases guide, intervene and interrupt the human activities. The *Siedi* have to be respected and honored. Lien's analysis of these epistemic differences opens up an understanding of different ways of perceiving the world and the tension and uneasiness that these can create. Moreover, an analytical framework focusing on emotions makes it apparent how certain understandings, arguments, perspectives, worldviews and ontologies are 'shamed out', making people cautious about evoking what might be thought of as superstition by others. In the discourse of the majority society, Sámi ways of conceptualizing and practicing their world have for centuries been disdained as superstitious and 'primitive'. Thus, current processes of shaming have historical roots in the colonial oppression of Sámi as indigenous.

However, shame is not the only reason why Lien's interlocutors were reluctant to discuss certain topics. There are certain entities in the landscape (like the *Siedi*) that people find uncomfortable and inappropriate talking about directly, due to the power of these entities. Therefore, in cases like these, fairness, politeness, respect and fear are also some of the emotions that are circulating and intimately linked to place-making activities taking place in relation to mining.

17.2.3 Green Colonialism

On a similar note, REXSAC researchers Britt Kramvig and Dag Avango have investigated how a range of localized and specific practices and concepts which bring forth Sámi landscapes become untranslated and silenced in the discourses over mining futures (Kramvig and Avango forthcoming). Documents do more than establish control; they define what the issue is all about. In the ongoing mining debates, the focus tends to be on documents such as acts, scientific reports and environmental assessment plans. In such circumstances, the Sámi herders are forced into navigating through a 'contact zone' (cf. Pratt 1992), where two different ontologies clash with one another in a context of highly asymmetrical relations of power (Ibid., p. 7). Clarifying the conflict, as an opposition between ontologies, not identities, is important, since it creates openness to the fact that not all Sámi – or for that matter all non-Sámi – share the same ontology. Conflicts based on different lifestyles and different ontologies divide communities across ethnic affiliation. In today's post-colonial and complex societies, there is no one-to-one connection between ethnic identity and ontology. Research must take this into account and avoid essentializing (naturalizing) identity, in the same way that researchers are warned against "methodological nationalism' (Wimmer and Schiller 2002). Even though a particular ontology may be pointed out as emerging out of a cultural past (e.g. the Sámi past), ethnic identities should not be used as an organizing principle in the analysis of this sort of ontological conflicts.

One would think that the so-called 'green shift' in environmental discourse would promote the kind of ontology represented by the Sámi inheritance and cultural practices, in which humans are situated in nature, not outside it or above it (see e.g. Østmo and Law 2018). This, however, is only partly true. Just about any business nowadays brands themselves with words like 'sustainable', 'climate-friendly' and 'green' as in 'green energy'. Likewise, companies are using a new strategy to convince Europeans that mines should also be situated in Europe" in order to secure minerals for the European Union that are mined under orderly working conditions and under strict supervision of environmental impact. This resonates with national pride in being a nation that takes on responsibility. Thus, mining infrastructures participate in the production of a new nationalism which is not necessarily responsive to Sami ontology. Some Sámi are now talking about "green colonialism", in order to make it clear that these so-called "green industries" are still rooted in Western imperial ontology with associated practices of place-making (Kramvig and Avango forthcoming).

The concept of 'green colonialism' is provocative and powerful because it disconnects the word 'green' from the context of positive emotions and orientation towards a desired future in which it is usually inscribed. Further, it associates the word 'green' with the word 'colonialism', which predominantly carries negative emotions linked to a past that, as Europeans, we like to think of as a closed and shameful chapter in history.

17.3 Creating Futures

Often, mining results in job-opportunities, pollution, environmental transformations, infrastructural requirements, community change, and profits. However, it also sets in motion a complex process of reinterpretation of place and people in a future yet to come. These processes of reinterpretation are tied to imagined social life in which emotions play an important part. The issue of creating 'better futures for all" is also a matter of addressing the question of who is basically understood as "us." In the reproduction and transformation of society, places and the images of social life are continuously revisited, recreated, and bent in unexpected ways and are interwoven with ever changing ideas of the future good life (Sejersen 2015).

Hope becomes an important component of mining discussions no matter the specific character of views. Even though hope can be mobilised and scaled in a variety of ways and configurations, emotions are always an inherent aspect of this mobilisation. Weszkalnys (2016) argues that in global debates about natural resource extraction, emotions have played an increasingly prominent, if somewhat nameless, role. Thus, she suggests that one should approach resource affect both as an intrinsic element of capitalist dynamics and as an object problematized by corporate, government, and third-sector thought and action including institutionalisation. She shows how affective horizons are generated by different stakeholders and argues that what we see emerging is a new resource politics that revolves around not simply the democratic and technical aspects of resource exploitation but increasingly their associated affective dissonances and inconsistencies.

The future of mining cannot be established without hope and hence emotions become central in extractivism. Often, the emotions of hope are circulated in society by means of objects that are evoked as 'happy objects': Sara Ahmed's term for objects which function as a promise of future happiness and thus circulate as social goods, accumulating "positive affective value as they are passed around" (Ahmed 2010: 29). As earlier described, affect 'sticks' to objects. Thus, hope, potentiality and the promise of happiness can be glued to bodies and objects.

17.3.1 Uranium as a 'Happy Object'

We find an excellent example of this link between hope, futuremaking and the promise of happiness in the Greenlandic uranium debate. Greenland got home rule in 1979 and self-government in 2009. However, the international interest in the Arctic has fuelled the Greenlandic dream of full independence. Analyzing a number of significant communicative events in the Greenlandic debate about whether to allow mining of uranium or not, REXSAC researcher Kirsten Thisted argues that this debate is not first and foremost about secession, but rather what is expected to be the result of secession: the termination of the emotional economy that has characterized the relationship between Denmark and Greenland since colonial times (Thisted 2019).

Generally, the Scandinavian countries are perceived as a family (of closely related languages and cultures with roughly the same social structure known as 'the Scandinavian model", Erikson et al. 1987). Greenland, however, is perceived as belonging to the family only by virtue of adoption (Thisted and Gremaud 2020). Back in the eighteenth century, Greenland was 'adopted' into the Kingdom of Denmark by virtue of being colonized by the then Danish/Norwegian Kingdom. Thus, the Greenlanders were embedded in the emotional community of the Kingdom. However, due to their partly different origin and kinship with the other Inuit in Canada, Alaska and Siberia and their related narratives of 'their nature' versus 'our culture', the emotional attachment is divided and conditional.

In family discourse, words such as subjugation, oppression and exploitation, which are usually associated with the domain of colonialism, are replaced by words such as love, care and protection, which are associated with the family domain. On the collective level, the words signal community and communality. This emotional community was closely associated with a financial economy where products and goods circulated between Greenland and Denmark. Denmark zealously maintained its monopoly on trade in Greenland, which was governed by the Royal Greenland Trade Department. Raw materials such as blubber, fur and fish were exported from

Greenland, while groceries, potatoes, coffee, rifles, ammunition and building materials were imported from Denmark to Greenland. The idea was that the trade should generate a profit. However, throughout the centuries, a narrative of Danish benevolence developed. According to this narrative, Denmark was not primarily in Greenland for the sake of trade and earnings, but to help the Greenlanders. This narrative was reinforced in the twentieth century, first as Denmark's supremacy over Greenland was challenged by Norway (Beukel et al. 2010), and then later during and after World War II, when Denmark wanted to retain Greenland even in a new era in which colonialism was abolished globally (Ibid.).

Thus, emotions and money/goods circulated in a self-optimizing circuit: Although the Greenlanders paid for the goods they received, the Danes established themselves as the 'giving' party, while the Greenlanders were assigned the role as the 'receiving' party. Through myriad affective practices, the Greenlanders were expected to show their gratitude and thus demonstrate acceptance of their subordinate position. The act of giving, places the giver in a superior position. The recipient is consigned to an inferior and shameful position (cf. Mauss 2016 [1925]). Borrowing Ahmed's terminology, we would say that the narrative of Danish benevolence and charity towards the Greenlanders made pride and abundance stick to the Danish body, while shame and inferiority stuck to the Greenlandic body.

Today, the annual block grant (financial support from Denmark amounts to roughly 50% of Greenland's GDP) which Greenland receives as a part of the Kingdom of Denmark, plays the role of a gift. As long as Greenland receives the block grant from Denmark, Greenland can maintain a welfare society, with or without mining. Because Greenland was never integrated as a full and equal part of the Danish Kingdom, the block grant that Greenland receives has a completely different character than the same type subsidy given to other, integrated parts of Denmark. The Danish block grant may even be withheld if the Greenlanders make decisions that run counter to the Danish interpretation of the Danish constitution – in which case the membership of the Kingdom will be terminated. Thus, in the Greenland – Kingdom of Denmark relations, the entanglement of affective economy and pecuniary economy prolong colonial relations, long after its historical origins.

It is within this scenario that uranium could suddenly be transformed into a 'happy object' in Greenland – even though uranium is otherwise regarded as a 'toxic object' associated with negative emotions in a Danish – Greenlandic context. There was, and is, a morally motivated distaste for nuclear energy both in Denmark and Greenland. However, in the new discourse led by Greenlandic politicians advocating secession, uranium was now equated with positive words like 'freedom' and 'independence'. Conceived as the antithesis to the unhappy condition of present postcolonialism, independence is staged as the perfect end in the Greenlandic vision of future secession from Denmark. The argument is that history has made the Greenlanders residents in a foreign state. This is perceived as something bad, something that one would want to move away from. In order to attain happiness, the Greenlanders must achieve independence from Denmark, financially as well as emotionally. Becoming a significant exporter of minerals, including uranium, promotes this goal, and therefore uranium becomes a 'happy object' in this version of the secession discourse.

Thus, uranium is not inherently associated with happiness. Instead, for some Greenlanders uranium promotes a *promise* of happiness in the form of a brand-new Greenlandic people who are free from the bond to Denmark and thus free of the emotional inferiority that the economic dependency so long has caused.

Although the decision to lift the ban on uranium was undertaken by Greenland's parliament in 2013, the growing link between uranium and independence has continued to underscore the question: Independence at what cost? To an outside world, including Denmark, it has been difficult to understand why Greenland would bet its reputation as an unpolluted environment and as a home of an indigenous people who are supposed to have a close relation to nature, instead of continuing to receive an annual block grant from Denmark. The Danish public generally respond with incomprehension – and hurt feelings – to the Greenlandic desire to leave the Kingdom. The situation echoes the British reactions to the loss of the empire – a condition that the cultural scientist Paul Gilroy has called *postcolonial melancholia* (Gilroy 2005). He argues that England has neglected to mourn the loss of the colonies and clings to the fantasies of ancient grandeur. In the same manner, it will be tough for Denmark to lose its status as an important Arctic nation – which would be the result if Denmark lost its sovereignty over Greenland.

Thus, finding a solution to the future relations between Denmark and Greenland is very much about dismantling outdated emotional economies. In this regard, the question is not so much whether mines are to be opened or not. Rather, the discussions on mining and extraction are part of the negotiations and reorientation taking place within the community of the realm in a turbulent time when a melting Arctic provides new partnerships and a brand-new form of connectography (cf. Khanna 2016) in the North, that challenges old relationships and power relations.

17.3.2 Emotional Futures of Happiness

When mining is on the agenda or is being undertaken, ideas of the future become an inherent aspect of all discussions. According to the REXSAC research of Frank Sejersen (2019b) the complex processes of creating futures of happiness require the mediation of skillful brokers. One of the difficult tasks of such brokers is to make the extraction of minerals stand for more than just the relocation of stone. When minerals have come to represent national welfare, new positive beginnings and emancipatory futures, it requires complex acts of cultural translation as well as the creation of narratives of positive futures. In these narratives extractive activities are not the goal, but, instead, are turned into the means for positive development. This entrepreneurial activity is working with imagined futures that are used to (in)form the present. This means that when successful brokers evoke narratives of desirable futures, they are able to shape people's decisions, attitudes and behavior in the present.

On the basis of this, Sejersen argues that the processes of mining involve more than just geological expertise and technology. Successful mining also requires hope. Therefore, the "brokers of hope" take up a pivotal position in the extraction of resources because they do the difficult work of linking mining with positive societal futures. The infusion of hope is thus a special skill and a social technology that mobilizes positive emotions that can circulate widely. All hope narratives are also working with ideas of the social organisation itself; the future is linked to particular social configurations like the 'family', 'community' or the 'nation' to mention but three examples. When brokers combine hope and promise with particular social configurations, they also work with social inclusion and exclusion and thus engage in processes of social demarcation and people-making. In this process "brokers of hope" also promote new understandings of social configurations and their importance for the dynamics of society. Mining in Greenland may for example be promoted as favorable for particular social groups in Greenland if they organise, think and perform in certain ways. Mining may also be promoted as good not only for the persons and communities that engage in extractivism but to the Greenlandic people as a whole. Thus, positive mining futures and nation-building can go hand-in-hand in these hope narratives.

Once brokers of hope mobilize an idea of a future-to-come they also mobilize a future social imaginary, which has a complex relationship to ideas of collective identities. One can say that by producing a 'future us', brokers of hope also produce a 'contemporary us' and an idea about who 'we' can become. Hence, in the creation of positive futures, brokers of hope additionally have to work with the politics of the social. Not only do they have to navigate existing political images of the social, but they have to sketch out emotionally convincing and desirable social horizons.

Sejersen's study of the political activities of two Greenlandic Premiers (Kuupik Kleist and Aleqa Hammond) clearly demonstrates that political brokers can work with the concept of a 'resource' in quite different ways and thus promote different translations of the word. One of the Premiers, Aleqa Hammond, evoked 'resource' as minerals to be extracted whereas the other, Kuupik Kleist, mobilized 'resource' as human engagement and productivity. Those two different uses of the term provide understandings that result in two quite different future-making activities and the circulation of different objects of happiness. Furthermore, Sejersen argues that the dissimilar evocations of positive emotions also result in different understandings of how things and people should be organised, approached and regulated. Thus, the government rationalities not only (re)form the expectations of citizens, companies and stakeholders but produce these subjects in the process of governance. For Premier Kleist, the government's goal was to boost the educational level of Greenlanders in order to encourage and facilitate citizens' direct participation in extractive industries. Jobs were seen as being linked to happiness. In contrast to this, Premier Hammond saw as the objective of her government to install a complex bureaucratic system of royalties related to the amount of minerals taken out of the ground by companies. Here the size of the mineral deposits, and the associated royalties, were linked to societal happiness.

This research on stakeholders in mining takes on a different form in the REXSAC work of Lill Bjørst. She investigates the creation of cooperation between the large number of stakeholders that are required in the extraction of uranium in Greenland (Bjørst forthcoming). In particular, she describes how the idea of 'partnership' emerges as a conceptualisation of supposedly productive cooperation. Bjørst shows how the creation of the concept of 'partnership' is based on the mobilization of emotions linked to trust and even love. Such emotions promote ideas of 'trust', 'equality', 'responsibility', 'stability', 'generalized reciprocity' and 'long-term commitment'. Her analysis points at the ways that 'partners' approach each other through strategic moves that are highly grounded in rhetoric of positive emotion. In the case of uranium, the implication is – among other things – that people arguing against mining projects often find themselves in a position where they have to 'break up' a happy 'partnership'. Due to the emotional investments in the potential cooperation between community and mining company, they are – as concerned citizens – always in danger of being singled out as "kill-joys." This is Sara Ahmed's term for people who do not buy into the common promise of happiness and thus end up spoiling the mood (see also Thisted 2019).

The case of uranium in Greenland also illustrates that all parties involved in the extraction of resources, including governments and companies, are working with emotions in order to create and promote happy futures. An important finding of this type of research is that emotions are not to be seen as inappropriate in extractivism because all parties involved, in fact, work with emotions. The dismissal of emotions as irrational, as compared to fact, becomes quite difficult when one acknowledges that emotional work is inherent and pivotal in extractivism.

Mining in all its stages may also be related to emotional futures of disaster and dispair. Though centering on Arctic communities, REXSAC has also involved researchers working elsewhere outside the region. An article written by Hedda Askland (2020) shows how the small Australian village of Wollar is caught in a temporal bind where past futures have become uncertain and ontological anxieties have been unleashed. This kind of anxiety undercuts people's sense of stability in the world; it undermines the basic elements that people think the world is made of and how these elements are related. Over the past few decades, multinational open-cut mining operations have gradually seized the area, reducing Wollar from a close-knit rural community of 300–400 people to a ghost town with less than 30 residents. This transformation has been generally slow and silent. For the people who live there, it has been a disaster. It has ruptured their community and unsettled their future. Mining voids – both present and future – have become significant markers for physical and social landscapes; painful scars you not only have to live with but which intervenes in social life. As a metaphor, the mining voids embody the contradiction between utopian narratives of a coal-sponsored future and dystopian imaginings at the coalface. Because voids – physical as well as metaphorical – are perceived as destructive, they challenge local dwelling, bodies, places of remembrance and future-making. The Wollar case is interesting in comparative terms because many Arctic communities who are neighbors to mines also express similar temporal concerns. They fear both losing the past and losing sight of a future.

17.4 Creating Pasts

In our investigations of resources, extractive industries, and Arctic communities, the REXSAC cluster of researchers working with emotions has been inspired by historian Hagen Schulz-Forberg's concept of *uchronotopia* (Schulz-Forberg 2013). To Schulz-Forberg, history consists of narratives defined by the way time and place are connected, as described by the semiotician Mikhail Bakhtin. He coined the term *chronotopos* (from Greek *chrónos*, time, and *tópos*, place). According to Bakhtin, the way time and place are connected within the different literary genres lays out the possibilities for the narrative to unfold. The *uchronotopia* concept advanced by Schulz-Forberg combines *chronotopos* with *utopia*: the ideal society, which was earlier imagined as a different place but since modernity imagined as located in a different time: the future (Schulz-Forberg 2013: 20). Thus, the term uchronotopia signifies a vision of the perfect future for this particular place.

Inspired by the philosopher Martin Heidegger, Schulz-Forberg investigates how the idea of the perfect future inspires the notion of the past. In general, people like to feel a continuity with what went before them. However, societal crises can trigger the desire to create a kind of 'zero hour', as in Europe after World War II (Schulz-Forberg 2013). A zero hour calls for a completely new perspective and for certain things to be locked away in the past and not allowed to have any influence on the future. The Greenlandic wish for secession from Denmark is an example of a yearning for such a zero hour, when colonialism and its emotional economies will be locked away in the past. However, a Greenlandic uchronotopia based on the idea of detachment from Denmark also provides a specific framework for the interpretation of colonial times. It invites a narrative about Danish colonialism as an unequivocally malignant structure of brutality, violence, objectification, racism and exclusion (cf. Scott 2004, see also Thisted and Gremaud 2020). Thus, envisioning a certain kind of future can set the framework for the perception of the past.

Analysing the case of the reopening of the Biedjovággi mine in Guovdageainnu /Kautokeino, Norway, Kramvig and Avango (forthcoming) document how the past and present of this particular place differ within separate documents written by environmental organizations and those composed by consultancy companies hired to do the assessment plans for the project. While the former sees the past as a source of significant experience that is still important in the present, and with value for the future, the latter sees the past as completely irrelevant – a mixture of outdated tradition and superstition that cannot be incorporated into the making of an industrial future or in integrating the place and community into the modern Norwegian society.

These conflicting perspectives were also expressed in the public debate sparked by the announcement in 2012 of new plans for the mine, as studied by Kramvig and Avango. In a local newspaper of that time, two opponents of the reopening of the mine wrote a feature where they referred to a public meeting in Guovdageaidnu (Joks and Bergstrøm 2012). According to the authors, the reindeer herders did not get to speak about how the mining would influence the future of their land and animals, because the discussion centered on deposit, density of refuse, and environmental effects. The critical authors pointed out how easy it was for the mining companies to set the agenda, and how easy "we that are not directly affected are guided to ignore those of our fellow citizens who through generations have learned to use Arctic renewable resources by developing knowledge on how to live in and off marginalized and exposed areas" (translated by the authors). In a comment in response to their article, entitled "Unfactual Debate", Lars-Åke Claesson, the CEO of the mining company, Arctic Gold, argued that the arguments that these two authors had brought forth, were disrespectful claims, pretentious in character and with no value for the discussion of future business development in the region. He ended by suggesting that:

> It is of the utmost importance that the participants in the debate are able to maintain a certain standard of objectivity and fact-based arguments when the question regarding a potential environmental impact assessment is discussed […] This debate is way too important to Kautokeino and the citizens of the municipality to be conducted in such unworthy ways (Claesson 2012, translated by the authors).

In shaming the opposing parties with the characterization of their words as being "unworthy", the CEO wanted to lock the argument of the past, and its validity, firmly away *in* the past.

Likewise, the envisioning of the future plays an important role for the perception of the past in the case of Greenland. The pre-colonial past has been dominant in the Greenlandic assertion of an identity difference from the Danes. It has figured prominently in demands for home rule and self-government. Today, however, there is a growing interest in research projects such as Anne Mette Jørgensen's efforts. In her work she emphasizes the long-term experience of Greenlanders as paid workers in industry and mining. In this way, the vision of an industrial future is framed as a natural extension of Greenlandic history – contrary to an earlier discourse that situated industrialization as part of Danish exploitation. Incorporating industrialization within Greenlandic cultural heritage could be an important argument in the promotion of a future based on mining and industrialization.

17.4.1 Challenging the Imperial Other

The creation of future social imaginaries can be seen as an interesting and powerful process of escaping the colonial "othering" (cf. Spivak 1985). In post-colonial theory, processes of othering often focus on hegemonic discourses that marginalise colonial subjects by means of stereotyping and stigmatization. Through these activities the (re)production of social relations of power takes place. This has a huge imprint on culture and society as well as on individuals (Said 1978).

For indigenous peoples the contemporary dynamics of subtle as well as blatant oppression, discrimination, and marginalization are often understood as a continuation of a long historic process of colonialism. By rooting the current societal asymmetrical relations in the past, the past, itself, can be evoked as an important point of reference when mobilising emotions in relation to the extraction of natural resources. Some indigenous voices make it clear that such extractive activities will foster a continuation of the cultural destruction that indigenous communities have experienced during colonialism. Other indigenous voices turn the argument the other way round, and claim that the extraction of natural resources can be organised in such ways that the activities may in fact underpin and promote indigenous communities.

In any case, those trying to escape a marginalized and stigmatized position, especially indigenous peoples, need to invest much effort in breaking processes of "othering" (see for example Smith 1999). In such undertakings, they are not only trying to escape the colonial gaze of the imperial Other, but are also creatively trying to establish a potential new position for themselves in the future to come. The research by REXSAC investigator Sejersen (2019b) shows how the "brokers of hope" in Greenland have diligently used the colonial past to challenge the agenda and trustworthiness of Denmark and its offer to 'help'. Thus, the past is made relevant for the planning of the future, but also made useful to carve out expectations to new 'partners': in no way should partners position Greenlanders in a subordinate position again.

Chinese interests in Greenland have increased, since the beginning of the twenty-first century. Greenland has welcomed Chinese investments and political cooperation because Greenland did not see Chinese engagement as reproducing colonial power relations; the Chinese were perceived as totally detached from colonial agendas and the colonial past. The "brokers" employed the potential for Chinese partnership as a means to break Greenland's historical dependency on Denmark. Hence, the Chinese interests were evoked as a way to make new beginnings where Greenlanders could emerge as proper, equal and respected stakeholders that can form their own futures without the benevolence of Denmark (Sejersen 2015).

The colonial relations between Denmark and Greenland were maintained in a variety of ways. Among other things, Danes produced an image of the Inuit as closer to nature than Western people. Consequently, Inuit did not have the 'rationality', 'self-control' and 'intelligence' of Danes. Today, these images and stereotypes are still circulating. When Greenlanders are portrayed as being 'children of nature' and 'children of the moment' they are seen as incapable of rational planning and negotiation. In this dominant discourse Greenlanders are expected to face problems when they meet the giants of modernization in the shape of the transnational mining company or Chinese investors, unless they get help from the Danes. When the 'brokers of hope' mobilize narratives of the future based on Chinese commitment and partnership it is not only welcomed in Greenland as a hope for better futures, but as a better and more dignified future for Greenlanders. Thus, indigenous peoples' creative articulations of an emancipated 'nation' are, often, closely related to direct articulations of a colonial oppressive past. Worldwide, extractivism takes many forms, but when it affects indigenous territories, indigenous articulations are in one way or another linked to the negative emotions and experiences of colonial relations. Some indigenous voices frame the extraction of natural resources as a continuation of colonial practices, while other indigenous voices use such extraction as a means of emancipation and nation-building.

17.5 Conclusion

Mining has been scrutinized, criticised, celebrated, orchestrated and assessed by a multitude of academic approaches. Each approach works creatively with the mining activities by evoking objects, scales, temporalities, causalities and protagonists. In doing so, these approaches offer enormous discursive potential. However, we argue in this essay that it is analytically productive to engage scientifically with the emotional work linked to mining because it points our attention in an important direction. Such analytical work engages with some of the important drivers of, for example, communities' concerns and hopes, investors' creation of profit potentiality, as well as the supremacy of technical solutions and governments' development schemes. In fact, we argue that emotions are pivotal in mining. Without hope, potentiality and engagement the minerals will stay in the ground. If one approaches emotions as a means to govern the conduct of populations or people, emotions can be seen as a government technology (cf. Dean 1996). The theoretical perspective of Sarah Ahmed (2010, 2014) clarifies how the emotional work can take place and how emotions may circulate in powerful ways in society. When emotions are glued to objects that are set in motion and circulate, then places, pasts and futures as well as people and communities are not only given value but emerge as part of that emotional work.

One of the findings of the REXSAC project is that emotions in the forms of hope, trust, love, shame, and happiness are diligently evoked by all the involved parties in mining; emotions work with the social. Emotions work to create certain relations between past, present and future. This productive temporal link produces anticipated social spaces of potentiality. Furthermore, participating in the emotional work emerges as a pivotal act of power because emotions install and mobilize certain rationalities in the present with direct consequences for community-making.

Analytical attention to, and interest in, emotions does not have to stand alone. It can be combined with other research fields as noted above. However, it requires that we acknowledge the important and fundamental role that emotions play and the emotional work that people are regularly engaged in. For a long time, the emotional engagement of people in mining activities has been ignored, downplayed or ridiculed. The 'facts of science' have always been demarcated as the proper arena for attention and those 'facts' are frequently portrayed as being threatened by emotions. Yet, hope, shame, anger, concern and despair are just a few examples of emotions that can be seen to be at play when mining is on the agenda.

The goal of mining activities is to produce resources of value, and these resources are to enter into the economic system's larger network of circulating value. The production of value rests on creative acts of making places, pasts and futures. In these processes, emotions are pivotal. Emotional work takes place in the maps of a geologist, the contractual support from the neighbouring communities, the consultants' elaborate impact assessments, and in the financier's market analyses. They are all part of the creation of value. Our REXSAC research clearly shows how emotions are not only entangled in resource extraction but are, in fact, a driving force.

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Part VI

Chapter 18
The Challenge of Synthesis: Lessons from Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies (ARCPATH)

Leslie A. King and Astrid E. J. Ogilvie

Abstract Large-scale, long-term, international, interdisciplinary, transdisciplinary, multi–topic research projects with many different country, university and non-academic partners are increasingly the norm, particularly in areas of global significance such as climate change and biodiversity loss. Such complex projects present new challenges, such as the need to integrate different methods, languages, knowledge-systems, time frames and, most of all, to synthesize research findings. This chapter identifies these problems in the context of the *Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies* (ARCPATH) project and offers solutions based on the ARCPATH experience. We identify processes, structures and actions required to synthesize emerging findings throughout the lifetime of the project. These include initiating synthesis by developing appropriate processes and structures from the outset, regular communication with, and interrogation of, researchers from different parts of the project, joint authorship, and project meetings on topics that require input across the project. They also include means of harvesting and integrating findings, wresting meaning from them, identifying policy-relevance, co-creating and mobilizing findings to ensure their applicability to the problem addressed by the research and addressing the on-going policy, practice, and scholarly legacy.

Keywords Research synthesis · Transdisciplinary research · Synergy · Knowledge mobilization · ARCPATH

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18.1 Introduction

Large-scale, long-term, international, interdisciplinary, trans-disciplinary, multi–topic research projects with many different country, university and non-academic partners are increasingly the norm, particularly in areas of global significance such as climate change and biodiversity loss. Such complex projects present new challenges including the need to integrate different methods, languages, knowledge-systems, time frames and, most of all, to synthesize research findings. This chapter identifies such issues in the context of the *Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies (ARCPATH),* a NordForsk-funded Nordic Centre of Excellence project and offers solutions based on the ARCPATH experience. ARCPATH research elements include: climate and sea-ice modelling; historical climatology; marine biology; environmental science; anthropology and economics, as well as sub-disciplines of these. In seeking to synthesize results from such separate disciplines encompassing very different research methods, ARCPATH places great emphasis on the need to go beyond the multidisciplinary approach in which different aspects of a project are conducted separately. Instead, the objective becomes interdisciplinarity where different research elements are integrated in order to provide greater insight into research questions and results where the whole is greater than the sum of the parts. Transdisciplinarity is a further goal, where research is undertaken in collaboration with members of a community, stakeholders and other knowledge holders.

The processes, structures and actions required to synthesize emerging findings throughout the lifetime of the project are identified. These include initiating synthesis by developing appropriate processes and structures from the design phase of the project, regular communication with, and interrogation of researchers from different parts of the project, joint authorship, and project meetings on topics that require input across the project. They also include means of harvesting and integrating findings, wresting meaning from them, identifying policy-relevance, co-creating and mobilizing findings to ensure their applicability to the problem addressed by the research and considering the on-going policy, practice, and scholarly legacy especially with respect to Arctic research.

18.2 Research Synthesis in the Literature

Definitions of research synthesis are scarce in the scholarly literature (Nature 2010). Other than its chemical meaning (the production of a substance by combining simpler substances through a chemical process) synthesis is broadly defined as the “composition or combination of parts or elements so as to form a whole” or “the combining of often diverse conceptions into a coherent whole”. (Cambridge English Dictionary, Merrriam-Webster) The word “synthesis” is from the Greek, *syntithenai* meaning “put together, combine”. In rhetoric, synthesis refers to the dialectic combination of thesis and antithesis into "a higher stage of truth" and in philosophy, the "combination of ideas to form a theory or system" (Merriam-Webster, Cambridge English Dictionary). Meta-analysis is a particular form of synthesis used most frequently in the health field. Kastner et al. (2012) attempted to create a taxonomy of knowledge synthesis methods and define synthesis as: "A knowledge synthesis summarizes all pertinent studies on a specific question, can improve the understanding of inconsistencies in diverse evidence, and can define future research agendas". This activity differs somewhat from our use of synthesis in that it attempts to synthesize a broad range of different research projects and synthesis methods, whereas the type of synthesis to which we refer here in the context of ARCPATH, attempts to synthesize the findings of different parts of the same interdisciplinary research project (Young et al. 2009).

The definition from the literature that comes closest to the meaning of synthesis that interdisciplinary social science researchers and we in ARCPATH adopt is the one put forward by Wyborn and colleagues: "Research synthesis is the integration of existing knowledge and research findings pertinent to an issue. The aim of synthesis is to increase the generality and applicability of those findings and to develop new knowledge through the process of integration" (Wyborn et al. 2018). We would add that research synthesis should link research findings within a project to each other. It should also communicate the overall meaning of those integrated research findings and identify and ensure the usefulness of research findings to the research communities and to broader society as a whole (Hall et al. 1993).

The scholarly literature contains few references to studies of research synthesis relevant to the kind of synthesis that is being undertaken in ARCPATH. In the past, research synthesis has taken the form of reviews of literature or meta-analysis of existing research findings on a specific topic (especially in the health sciences field, e.g., Haidich 2010, Barnett-Page and Thomas 2009) as a basis/evidence for practice and decision making (Denyer et al. 2008) or to assess research impact (Wyborn et al. 2018). However, this retrospective form of research synthesis has little relevance to the active form of knowledge creation based on synthesis of emerging findings within a large-scale interdisciplinary research project such as ARCPATH.

One area of inquiry that has useful implications for research synthesis is research evaluation. It looks at impacts and outcomes particularly in transdisciplinary and sustainability research (Belcher et al. 2016). Belcher and colleagues offer criteria for research quality. In addition to traditional measures of research rigour, legitimacy and efficacy, they include relevance, social significance and applicability, integration and reflexivity, inclusion and fair representation of stakeholder interests, and actual or potential contributions to problem solving and social change (Belcher et al. 2016, 2019). While Belcher's criteria could provide principles for research design, his work focuses primarily on retrospective analysis with little information on how to "do" effective research synthesis. In terms of guidance for achieving research synthesis, experience from other large-scale international knowledge creation projects such as the *International Dimensions of Global Environmental Change (IDGEC)*, see Young et al. (2009) or *Protected Areas and Poverty Reduction (PAPR)*, see Murray and King (2012) seem more useful. They offer some suggestions for ARCPATH synthesis, such as identifying the goals of synthesis, and suggesting synthesis outcomes, such as providing a synthesis conference and publications at the end of a project. However, these projects focused on the initial stages of pursuing meaningful research synthesis and often left synthesis to the end of the research project rather than designing it into the project from the beginning. Other forms of research synthesis such as meta-analysis for quantitative studies (Bergman 2008) or narrative synthesis (Campbell et al. 2019) or a narrative (as opposed to statistical) summary of study findings (Rodgers et al. 2009) or meta-ethnography (France et al. 2019) or qualitative evidence synthesis (Cronin et al. 2008; Suri 2011), have been useful for more narrow topics, for example, in the health and social work fields. However, they provide little guidance for inter and transdisciplinary projects such as ARCPATH, which include natural, physical, social sciences and humanities in interdisciplinary research.

Yet another area of scholarly research relevant to synthesis comprises studies that identify the problems faced in interdisciplinary research (e.g., problem complexity, problems of research leadership) and aim to assist interdisciplinary research teams (Palmer et al. 2016; Cornell and Parker 2014). These broad forms of synthesis, although helpful in identifying the challenges of interdisciplinary research provide little specific direction for advance synthesis planning for a single inter and trans-disciplinary project such as ARCPATH or across projects such as the other three Nordic Centres of Excellence discussed in this volume. Overall, the existing literature provides little guidance to-date on the kind of synthesis structures, processes and outputs that are needed to integrate and derive meaning from research findings across different disciplines, geographical areas or specific research topics. Nor does it identify knowledge gaps that might help guide policy from large scale, complex, interdisciplinary, international projects such as ARCPATH. Due to a lack of guidance from the literature, the ARCPATH team were therefore faced with blazing our own trail and developing unique mechanisms for synthesis. These include syntheses structures, processes and products which had not been attempted in earlier large-scale complex inter and transdisciplinary research projects. (See below for a description of these innovations.)

18.3 The Role of Synthesis in ARCPATH

ARCPATH is a ground-breaking project designed specifically to synthesize results deriving from a variety of traditionally very different and separate academic disciplines. The project's overarching goal is identified in its original proposal sent to Nordforsk. There it is noted that: "ARCPATH seeks to address the complex and interlinked issues of climate and socio-economic and social-ecological change occurring in the Arctic by focusing on near-term changes, with the overarching objective of fostering responsible and sustainable development" (ARCPATH 2015). Such efforts would require the reconciliation of environmental, social, and economic demands as well as the application of the different disciplinary perspectives needed to understand them. The project's three specific goals were: (1) To predict regional changes in Arctic climate over the coming decades using innovative methods to capture both anthropogenic and natural factors in global and high-resolution regional models; (2) To increase understanding and reduce uncertainties regarding how changes in climate interact with multiple societal factors, including the development of local and regional planning and adaptation measures; and (3) **To combine improved regional climate predictions with enhanced understanding of environmental, societal, and economic interactions in order to supply new knowledge on potential "pathways to action".** Goal three succinctly summarizes the synthesis challenge of the ARCPATH project.

As noted in Chap. 7 of this volume, ARCPATH has consisted of seven discrete but interlinked work packages. Of these, one has focused entirely on project synthesis (Work Package 6). This work package was designed to: (1) Harvest the principal scientific findings of ARCPATH, and to generate new cross-cutting insights and concepts; (2) Explore the policy and action relevance of these findings; (3) Mobilize the generated knowledge for the academic community, policy-makers, practitioners, NGOs, the media and the general public; and (4) Identify lessons learned as well as remaining gaps in knowledge and directions for future research. It should be pointed out that synthesis was identified in the design phase of the project as both a necessary and desirable outcome of the research effort. At the inaugural "sail-off" project meeting, and in all subsequent meetings, much emphasis has been placed on how to achieve synthesis. As was noted in the project application: "Unlike other international collaborative projects, we shall not wait until the end of the project to synthesise and identify the significant joint findings, meanings and significance of those findings. Rather, synthesis will be built into data collection" (ARCPATH 2015).

This focus on synthesis led to the identification and development of a number of synthesis mechanisms such as structures, processes and outcomes of synthesis for the project as a whole. (See Table 18.1 below). The structures included the creation of a "Synthesis Committee" consisting of the members of the Executive Committee along with representatives from each of the work package teams. This was led by the researchers primarily responsible for Work Package 6.

The global advent of "big science" and the identification of research priorities and the funding of research to fulfill those priorities by central, national and multinational research agencies has led to unprecedented large-scale multidisciplinary research projects that involve many different countries, universities, and partners seeking to advance understanding of complex issues such as climate change, biodiversity loss, and their social impacts. Examples of these types of undertakings are: the US National Science Foundation programmes, "Arctic System Science" and "Navigating the New Arctic", Canada's Social Science and Humanities Research Council's Knowledge Synthesis Grant: "Living Within the Earth's Carrying Capacity", Nordforsk's call for proposals for Nordic Centres of Excellence, "Responsible Development of the Arctic, Opportunities and Challenges: Pathways to Action", and the Belmont Forum's request for proposals on "Resilience in Rapidly Changing Arctic Systems" (NSF 2012, 2018; SSHRC 2019; Nordforsk 2017; Belmont Forum 2019). With the proliferation of such complex inter- and

Table 18.1 Suggested synthesis tasks and actions

Action	Who?	When?
Engage communities, policy-makers in research design	PIs, researchers, communities, policy makers in selected countries	Proposal writing stage; pre-funding
Meeting of all researchers to develop terms of reference and parameters for data collection. Establish means of communication across all researchers. Web site, meetings, virtual meetings	Convened by PIs	Immediately post-funding announcement
Establish a synthesis committee; develop criteria for synthesis, synthesis tasks Build synthesis into data collection and analysis	PIs, executive committee, leaders of all work packages. All researchers	Immediately post-funding announcement Ongoing during research process
Identify gaps in records and other knowledge gaps Explore inconsistencies and contradictions	All researchers, executive committee	During all project meetings – And check-in virtual meetings across work packages
Identify significant joint findings (at meetings, conferences)	Work package leaders, PIs, all researchers, interaction with communities, policy makers	Throughout research process
Plan synthesis products e.g., joint publications, conference presentations, summer schools, courses, involvement and outreach to communities etc.	PIs, all researchers Synthesis committee, work package leaders	Year one and two
Begin integration, identifying significance, meaning of findings. Policy implications	PIs, synthesis committee, work package leaders, all researchers	Year two project meeting
Design data management, archive	PIs, executive committee, all researchers	Beginning of project
Identify continuing knowledge gaps, recommendations for future research Iidentify policy implications of findings	All researchers	Throughout research process
Prospecting, scanning research environment and real-world environment to identify new problems, new programs	PIs, all researchers, funding body	Throughout research process
Initiate collaboration with other research agencies programs (NSF, Belmont, SHHRC)	PIs, all researchers, funding body	Throughout research process

(continued)

Table 18.1 (continued)

Action	Who?	When?
Assess consistency with goals, (for ARCPATH for example, identify transformative pathways, pathways to sustainability) Plan and initiate knowledge mobilization strategies-engage policy makers, communities, industry	PIs, executive committee, project meeting participants	Mid point assessment and throughout the process
Convene a synthesis conference: Invite researchers, community members, policy-makers, civil society representatives, media. Task and train knowledge brokers at the conference to mediate among scientists, policy makers, knowledge users and creators the purpose of the conference is the co-creation of new knowledge through the process of synthesis	PIs, synthesis committee, all researchers	Nearing end of research process, but planning to begin earlier
Plan and initiate synthesis publications, co-authored across research topics, book, special journal issue	PIs, executive committee, synthesis committee, all researchers	Throughout research process. Planning should take place early in the research process

transdisciplinary international projects focussing on climate change, ARCPATH designers and researchers immediately recognized the importance of synthesis of research findings in order to facilitate knowledge mobilization and an effective project legacy. As previously noted, many such international projects attempt to conduct synthesis only at the very end of the research. ARCPATH is unique in that it is developing methods of building synthesis into the research process at all phases of research from design to application and legacy. Thus, ARCPATH research efforts include identification, analysis, and evaluation of synthesis methods as well as the application of synthesis and connections among findings as they emerge in the research process. This has been and will continue to be an iterative process with early synthesis efforts communicated to all researchers who then adapt data collection and analysis to meet those synthesis challenges and goals. It also seeks to address reactions and feedback from the research communities to those emerging findings.

ARCPATH research involves extensive cross-disciplinary collaboration including the use of approaches and methods from climatology; environmental science and humanities; economics; oceanography and cryosphere research; marine and fisheries biology; fisheries management; anthropology; governance systems; and human eco-dynamics. It has also sought to explore and apply traditional ecological and local knowledge. Drawing on these separate but interlinking disciplines ARCPATH is able to form a truly synergistic Centre of Excellence.

As discussed in Chap. 7 of this volume, ARCPATH has been collecting, assembling, and analysing a wide variety of different data sets and other sources of information with a focus on local communities in Iceland, Greenland and northern Norway. ARCPATH methods include the use of: (1) Earth System Models such as the Norwegian Climate Prediction Model (NorCPM) and the European ESM (EC-Earth) Model in order to perform global climate predictions; (2) Regional Arctic Climate Models to perform Arctic climate predictions; (3) Quantitative economic modelling, supported by qualitative interviews as discussed in Chap. 8 of this volume. ARCPATH uses proven ethnographic research methods to solicit community insights concerning Arctic change, and to document how people are adapting to its impacts. The main research methods here involve: participant observation, semi-structured and specialist interviews, official documents and surveys and engaging community members and other stakeholders as discussed in Chap. 9 of this volume. The evaluation of historical data follows established methods of analysis.

Reconciling these different research methods with one another and harmonizing the resulting data to form a comprehensive picture of change, responses, and adaptation in the region is a significant synthesis challenge. Similarly, differences in time frames can also require new collaborative thinking. ARCPATH research time periods include information from the distant past (concerning sea ice and weather records) to the present and from the near-term future to longer-term futures. In summary, reconciling the different disciplinary languages, perspectives, time frames and understanding, has proven to be a daunting synthesis challenge.

The early identification of gaps in the climate and historical records and a consistency of approach ensures better analysis and mobilization of knowledge produced by the project. However, ensuring effective communication among participants is also necessary. Although the authors of this paper are comfortable in both social and natural science spheres, from the first project meeting it became clear that many of the climate modellers and the social scientists had difficulty in understanding each other and making sense of early findings from the separate disciplines. It was clear that we needed ways of enhancing communication and connections among the researchers in the different work packages and identifying the relationships across our different disciplines and findings. To this end, frequent project discussions on the practice of synthesis involving the sharing of emerging findings, joint publication and presentations and the identification of gaps and challenges of research methods have been held. These have been ongoing efforts among all project researchers and participants.

At the 2017 annual meeting all researchers were asked to bring examples of research synthesis or questions emerging from the data for other team members. Subsequently, the annual project meeting for 2018 which was held in Bergen in Norway, adopted the theme of "Back to Basics". There ARCPATH members sought to educate each other in terms of the basic elements of historical research, social, ecological and anthropological research along with climate research and modelling applicable to the Arctic. At all subsequent meetings, in addition to presenting emerging findings from the work packages, researchers were asked to identify key linkages and connections across their work packages as well as suggesting synthesis questions for each other. These undertakings ensure that researchers from the different work packages and disciplines are engaged with one another on an ongoing basis. The tasks of synthesis clearly include learning the language and methods of the different disciplines represented in the project and developing new ways of discerning important connections so as to create truly interdisciplinary findings. This has been an ongoing challenge in ARCPATH and in other major research projects in which ARCPATH researchers have been participating.

Overall project synthesis tasks for ARCPATH include the following: (1) Harvesting findings of ARCPATH (emerging and final findings) by identifying the most significant findings in terms of contributions to existing knowledge, to the research community, to policy and practice, to our research communities and to Arctic communities in general. This is being done mainly through consultations with the team members and partners and with the communities mentioned above, both academic and practical, through a series of meetings, (including the ARCPATH annual meetings, work package meetings, teleconferences with the synthesis committee, focus groups, and academic conferences) to harvest significant findings; (2) Identifying opportunities for impact and engagement in the application of findings for Arctic communities as the research team does significant field work in the ARCPATH case-study communities; (3) Consulting with partners, research communities and Arctic policy makers to identify policy implications and pathways for application of the findings; (4) Engaging with policy makers and community and regional leaders and identifying opportunities to influence Arctic policy and practice, for example, by presenting and engaging participants at influential and high-level conferences such as the Arctic Circle Assembly (Arctic Circle Assembly 2019) and other venues including the University of the Arctic and the Arctic Council; (5) Expanding the research networks with whom ARCPATH researchers interact; (6) Identifying new and transformative development paths that can contribute to the future social and economic sustainability of Arctic communities such as ARCPATH researchers providing key information and data concerning climate impacts on sea level, loss of sea ice, changing ocean currents and marine-species distribution for Arctic communities in the research areas; (7) Identifying pathways to Arctic sustainability so that such Arctic communities can not only survive, but thrive, by taking advantage of new opportunities and development options identified by ARCPATH researchers conducting fisheries and marine-mammal studies; (8) Communicating syntheses products to research, policy and political communities including presentations at the Arctic Circle Assembly, (Arctic Circle Assembly 2019) the INSTAAR Arctic Workshop, and other high-level policy conferences; and (9) Identifying continuing knowledge gaps, and recommending future research efforts to fill these gaps, either by reaching out to other Centres of Excellence or research projects and networks in which ARCPATH team members participate. All of these examples have been the synthesis activities of ARCPATH during the past 3 years. Additional information on the synthesis process is also presented in Table 18.1 above.

18.4 Specific Examples of ARCPATH Synthesis

One specific example of project synthesis is the use of historical climate data (Ogilvie 2017) in combination with systematic observational data. In this case, accounts of sea ice from East Greenland reaching the coasts of Iceland, together with early and contemporary instrumental climate data are used to cast greater light on current climatic processes. The sea-ice index is based on an historical reconstruction of the amount of ice sighted from Iceland, measuring the amount of ice in the Greenland Sea. The index covers the period 1600–2000 and is an important and independent source of information for past climate in Europe and the North Atlantic region. The index shows variability on all time-scales with large values around 1800 and 1900 and small values in the first 200 years. The index decreased in the first half of the twentieth century and has stabilized thereafter. Comparing it with other indices from the instrumental era (last 100–150 years) ARCPATH analysis has shown a significant and robust negative correlation between the ice index and the summer northern hemisphere mean-surface temperature (HadCRUT4). Significant and robust negative correlations for summer are also found between the ice index and the Hurrell station-based NAO index. The connection to summer temperatures and the NAO is further confirmed by studying correlations between gridded temperature (HadCRUT4) and sea-level pressure fields (Jones et al. 2014). In particular for temperature, significant negative correlations are found for large areas in the Atlantic and Arctic regions. Positive correlations between the ice index and the Fram strait ice transport calculated from historical records of *storis* from southwestern Greenland (Schmith and Hansen 2003) were also found. Such analysis of the sea-ice record for Iceland (Ogilvie 2010) provides an excellent example of cross-disciplinary synthetic research.

Another example of progress in project synthesis comes from the social, economic and marine biological research and fieldwork taking place in Iceland, Greenland, and the seas around Svalbard and northern Norway. This includes anthropological fieldwork in Húsavík documenting present and historical multiple marine resource use, including fishing and whale-watching activities, as well as collaboration with local authorities in terms of developing a Marine Protected Area to better manage the multiple and growing uses of the seaspace of Skjálfandi Bay. Blue whales have increasingly been moving north and currently come into Skjálfandi Bay every summer in June. ARCPATH now has a photo-identification catalogue of 148 different individuals (Madsen 2018; Madsen et al. 2019) as well as matches of the same blue whales sighted off Svalbard and from Húsavík. This possible shift might be due to warming Arctic waters and climate change. It has been suggested earlier that blue whales are moving even further north for this reason (Iversen et al. 2009). Ethnographic fieldwork has focused on the seasonal use of marine mammals by vocational and recreational hunters in Ittoqqortoormiit in East Greenland. This involved mapping the annual hunting cycle, including the hunting of narwhal and polar bear. For northern Norway, the focus has been on the shifting relationships between migrating whales, fisheries, and tourism in Andøya and Skervøy and how research can contribute to new knowledge dialogues to develop responsible whale-watching practices.

In the following section of this chapter we identify the ARCPATH synthesis structures, processes, and outputs. An illustrative table, Table 18.1 above summarizes specific synthesis tasks, methods, and timing, along with an indication of who should be involved (see Table 18.1 above). We then move on to explore the relationships of knowledge synthesis to knowledge mobilization, to the practice of transdisciplinary research, to case study methods and to research synergy.

18.5 Structures, Processes and Products for Synthesis

For any large-scale research project, synthesis structures, processes and products are needed to achieve true research synthesis of the project's findings. For ARCPATH, the original structures were designed to include a Synthesis Committee that has been described above. Its purpose was to facilitate the sharing of ideas and encourage cross-fertilization across all the work packages. Examples of ARCPATH synthesis processes include annual meetings with synthesis as a permanent agenda item, such as the 2018 "back to basics" focus, along with ad hoc synthesis meetings by teleconference as well as opportunities for researchers from different work packages to consult with each other. Annual NordForsk meetings with the other NCoEs in attendance have also provided excellent opportunities for synthesis and synergy with other projects. Synthesis products will include a synthesis conference, publications, developed web sites, special journal issues and books involving ARCPATH project researchers and participants. Ensuring a variety of means for knowledge mobilization, dissemination, and on-going application of significant findings in conjunction with communities and stakeholders are also means of achieving research synthesis.

18.6 Synthesis Tasks and Recommended Actions

In Table 18.1 above, examples are given of the specific synthesis tasks and actions to be accomplished throughout the life of a research project like ARCPATH. While the listings are specific to this one research effort, we suggest that many of these are reflective of common synthesis tasks and actions to be found in most scientific undertakings involving a large number of researchers who are engaged in inter- and transdisiciplinary inquiry.

This table, while not comprehensive, gives an idea of the wide range of synthesis tasks and mechanisms, who should be performing those tasks, and at what times during the research process they should occur. Some of these tasks should occur at the design phase, (e.g., engaging communities, policy-makers and other stakeholders) others throughout the research process or at mid-term, (e.g., assessment of consistency with research goals) and some only at or near the end of the research (e.g., the synthesis conference). The following section of the chapter explores other aspects of synthesis: the relationship between research synergy and synthesis, the nature of synthesis in transdisciplinary research, the role of synthesis in the mobilization of knowledge and finally ways to synthesize findings through comparative case study methods and achieve synergy across different research projects.

18.7 Research Synergy and Synthesis

Research synergy (building on the research findings of others) and synthesis (integrating research findings to create a holistic understanding) are related and mutually reinforcing (Fielding and Fielding 2008; West et al. 2014). Synthesis of research findings often enhances possibilities for synergy within and between research projects. Synergy refers to "working together" where results are "greater than the sum of the parts". In the case of ARCPATH the parts are the separate project work packages and the other Nordforsk Centre of Excellence projects, as well as Arctic climate research as a whole. Achieving synergy should accelerate knowledge production and sharing by building on disparate findings to achieve a holistic, comprehensive view of an issue, a geographical area, a problem or a research question. The creation of research networks, information and data sharing, archives and historical collections are all ways to promote research synergy and ARCPATH has been active in promoting them all. Communication, collaboration, application of findings to problems, communities and geographical areas are all ways to achieve synergy, as are identifying policy implications and relevance and the rapid identification and filling of knowledge gaps. These ways of building synergy can also result in new research proposals and accelerated feedback. The Nordforsk annual meetings which focus on sharing knowledge and emerging findings have the potential to influence the course of each of the current projects and to identify cross-cutting themes such as gender, traditional ecological knowledge, knowledge systems, adaptation, governance, drivers of change, development pathways, historical perspectives, participation, outreach and engagement. They also have the potential to increase the reach and impact of the combined four Centres of Excellence to a wide variety of geographical regions.

18.8 Synthesis and Transdisciplinary Research

Transdisciplinary research and synthesis often go hand-in-hand and can be mutually reinforcing. Transdisciplinary research is distinguished by a number of characteristics and principles, including, *inter-alia,* co production of knowledge, incorporation of different knowledge systems, partnerships with non-academic partners (across academic and non-academic stakeholders) and a focus on real-world solutions and capacity building in research (Patterson et al. 2013; Lang et al. 2012). ARCPATH researchers aim to incorporate all these elements into project research. Co-design of the research project and co-production have been important elements of ARCPATH. As above, many different communities, scholarly and geographic, were involved in the design of the research. This included explicit provision for synthesis from the beginning of the project. Furthermore, the knowledge that is emerging from ARCPATH is co-produced by research participants, communities, stakeholders and knowledge users such as policy and decision-makers at all levels of governance. (See Chap. 10 of this volume.) Many different arenas have been used for this co-production including international conference presentations. A primary example of this is the Arctic Circle Assembly conference at which feedback has been solicited from audiences and other community fora and discussion groups as part of ARCPATH outreach activities. Chap. 10 of this volume also focuses on the topic of outreach.

ARCPATH has also placed much emphasis on incorporating local, scientific and Indigenous knowledge systems in the research, in particular by including traditional ecological knowledge (TEK) held by knowledge keepers in Indigenous communities in our case-study regions (King 2004, 2018). From the outset of this research ARCPATH researchers have been united in seeking to address the impacts of climate change in our research communities and regions and in helping those communities to adapt and develop livelihood options to ensure resilience to the rapid social, ecological and environmental changes they are experiencing. The research is thus solutions-oriented and aims to build a holistic understanding of the impacts and approaches to climate change in our communities.

The following section discusses the important relationship between synthesis and knowledge mobilization with synthesis as a necessary pre-requisite for effective mobilization of knowledge.

18.9 Synthesis and Knowledge Mobilization

For ARCPATH, synthesis, dissemination of research and knowledge mobilization are inextricably connected to one another. Ground breaking research by Kastner et al. (2012) and Wyborn et al. (2018) identifies research dissemination and knowledge mobilization as critical goals of research synthesis. Kastner et al., state that knowledge synthesis is also an important part of the knowledge translation process and, ideally, should form the "base unit" of strategies for providers and policy makers.

Wyborn and his colleagues investigated the impact of research synthesis on policy and practice in the field of conservation (Wyborn et al. 2018). According to the Social Science and Humanities Research Council (SSHRC) of Canada the definition of knowledge mobilization also incorporates research synthesis as a way of improving knowledge mobilization: "Knowledge mobilization is an umbrella term encompassing a wide range of activities relating to the production and use of research results, including knowledge synthesis, dissemination, transfer, exchange, and co-creation or co-production by researchers and knowledge users" (SSHRC 2019). One of the synthesis responsibilities of all ARCPATH partners has been to identify synthetic outputs and to provide jointly authored journal articles, web postings, and other contributions to social and popular media. All of these mechanisms integrate findings across the project and communicate synthesis outputs of the project.

This practice will continue throughout the remaining time of the project. An international synthesis conference is planned for the final stage of the project. It will bring together researchers, policy makers, and representatives of civil society, as well as the knowledge brokers that mediate across the groups and link them at a forum where synthesized research findings can be presented and discussed. In the process, an attempt will be made to wrest meaning from these research inquiries and to clarify the policy and planning implications of their findings. An effort will also be made to identify remaining knowledge gaps and needs for future research. We hope that this conference will address the synthesis goals noted above and coordinate and communicate the synthesis outputs of the entire project. This conference and the meetings leading up to it, will be the culmination of the synthesis process and will demonstrate the co-production of research findings and applications.

Examples of specific synthesis findings already emerging from the work packages, as of this date, include identifying the implications of finer-scaled regional climate models for community and economic planning in the case-study countries of Iceland, Greenland and Norway. Synthesis findings from WP4 (focusing on climate, social-ecological systems, cetaceans and tourism) are suggesting ways in which changing migratory patterns of cetaceans might determine livelihood and economic opportunities in coastal communities. WP5 (focusing primarily on fisheries, governance systems and climate change) has explored these linkages by investigating institutions and administrative practices with regard to fisheries and ocean governance and their role in planning the future of Arctic communities in Iceland, Norway and Greenland.

At the most recent annual ARCPATH project meeting in Reykjavík in October of 2019, renewed emphasis was given to the ongoing synthesis needs of the project. It was agreed that synthesis challenges remain, in particular, in terms of connecting the climate models to the community response and livelihood options aspects of the undertaking. These and other ongoing synthesis challenges will be addressed in the remaining months of the project with a specific focus on the scientific, policy and planning legacies of the ARCPATH in order to ensure the effective dissemination, mobilization and application of the findings to partners and communities.

ARCPATH research includes identification, analysis, and evaluation of synthesis methods as well as encouraging synthesis and connection among findings as they emerge from the research process. To this end, discussions and the practice of synthesis are ongoing efforts among project researchers and participants. At project meetings, in addition to presenting emerging findings from the work packages, researchers are asked to identify linkages and connections across all of the work packages. ARCPATH members seek to educate each other in terms of the basic elements of historical research, sociocultural, ecological research and climate research and modelling. This ensures that researchers from the different work packages and disciplines are required to engage with one another on an ongoing basis.

The tasks of synthesis include learning the language and methods of the different disciplines represented in the project and developing ways of discerning the connections and linking those connections to create truly interdisciplinary findings. Synthesized research findings are already apparent in co-authored journal articles and conference presentations as well as different forms of feedback to communities. This body of synthesized research findings and identification of policy, community and scholarly significance will continue to grow and will provide evidence of the success of our synthesis efforts. Nevertheless, interdisciplinary research synthesis remains a formidable challenge. In the next section, some of the lessons learned from ARCPATH synthesis efforts are presented in the hope that these will be useful to others engaged in complex research projects.

18.10 Case Study Synthesis and Approaches

> *"Using individual case studies, to evaluate what factors best promote community resilience and sustainable economic practice"* ARCPATH Work Package 5 (Marine governance, security and rapid social and environmental change).

Case-study methods present particular synthesis challenges. A well-known limitation of case-study methods is the inability to generalize from one case to any others. This problem can be mitigated to a certain extent by a synthesis approach and by archiving consistent case studies so that researchers can use the qualitative data from them to make comparisons across all cases as well as in conducting post-hoc comparisons across countries, regions, places, times and cultures. This can be achieved, for example, by encouraging and maintaining consistency in the use of terms, units of analysis, variables and commensurability. The rewards of understanding provided by in-depth case studies often more than make up for some of their limitations. However, care should be taken to ensure comparisons are valid by incorporating contextual variables to the greatest extent possible.

As discussed in Chap. 10 of this volume, ARCPATH researchers are actively engaging with local case-study communities in Iceland, Greenland, and Norway. The issues on which they are collaborating are those identified by the communities themselves, and are relevant to the research teams. Communities are participants and partners in such research. It is at the local level that the impacts of climate change are most profoundly felt and it is at the local level that the disparate results of the processes that are studied are felt in an integrated way – on lives, livelihoods, social- ecological systems and human futures. From the outset, the importance of engaging with local communities has been recognized in all phases of ARCPATH research including the mobilization of knowledge resulting from the project as well as ensuring its enduring legacy in those local communities. An example of this type of engagement can be seen in the project's study of youth participation in fisheries in Iceland and Greenland.

As well as engaging communities in research, relevant partnerships such as the whale-watching industry in Iceland and Norway have been sought, with the goals of enhancing alternative livelihoods and contributing to economic development of the communities in the face of climate and other environmental changes. Such collaboration has resulted in the possible establishment of a Marine Protected Area in Húsavík, Iceland. It should be noted here that synthesis and collaboration have different meanings in the context of research. Synthesis cannot occur without collaboration but collaboration can possibly occur without it leading to synthesis. For example, if collaboration in one part or work package of the project is not linked to other work packages or areas of the research, collaboration may not lead to synthesis. In ARCPATH, we use collaboration in our case-study communities as a basis for and contribution to, synthesis of all research findings.

18.11 The Challenge of Synthesis: Lessons Learned from ARCPATH

Two overarching questions are crucial to the project's overall concern with synthesis. The first of these is: How can the use, impacts, outcomes and legacy of a large, complex, interdisciplinary and multi-partner, research project be guaranteed? The second is: How can we ensure that ARCPATH and by generalization, other major research projects, deliver the scientific results and societal benefits promised at their inception? Such considerations lead to a third question: Is it possible that the use of research findings can ever be ensured or indeed, dictated? With this in mind, we need to consider what practical steps need to be taken to ensure that projects like ARCPATH can deliver, as far as possible, on the promises they have made.

One way to facilitate this is for researchers to take responsibility for synthesizing and mobilizing research findings. Researchers are very wary of being policy prescriptive. However, one of the only ways for research to be policy relevant is to present findings in an integrated rather than a fragmented discipline-bound way. This will ensure the presentation of a clear and comprehensive picture of the interrelated societal and planetary phenomena that form the focus of a project such as ARCPATH. This is the primary task and challenge of synthesis. Based on our experience in attempting new ways of achieving research synthesis in ARCPATH, the main conclusion to be drawn is that synthesis is difficult, time consuming, intellectually and organizationally challenging and poorly funded. To be effective, synthesis must begin at the beginning – at the research design phase. In order to ask the most relevant research questions, research projects should be co-designed with the producers and users of the knowledge sought. In ARCPATH this involved the engagement of communities and policy-makers in the design of the project from the earliest stages of the proposal's development. Only in this manner can knowledge be truly co-produced (see Chap. 10 in this volume). Synthesis should take place throughout the research process in order to harvest and integrate findings as they emerge and extract meaning from them for scholarly, policy and public communities. Outcomes need to be clarified for the different audiences and users of the knowledge. Researchers will be called upon to identify the governance, policy and action implications of the findings, to mobilize knowledge with diverse participants and stakeholders and identify knowledge gaps for future research. These are the tasks of synthesis that are often neglected or resisted by researchers and not to be pursued by the faint of heart. The discussion above explains how many of these tasks were accomplished in ARCPATH, but we do not pretend to have accomplished all of the goals we identified for research synthesis at the outset. Effective research synthesis is still in its infancy; nevertheless, we hope that this description of ARCPATH synthesis efforts will provide both guidance and inspiration to others to engage in scientifically important and societally relevant research in the Arctic.

18.12 Summary

One of the main goals of ARCPATH summarizes the synthesis challenge faced by its core research. This is to supply new knowledge of ARCTIC pathways to action by ***combining*** improved regional climate predictions with enhanced understanding of environmental, societal, and economic interactions. The synthesis challenge is the need to synthesize the findings of large-scale inter- and transdisciplinary multi-faceted research related to the complex and interlinked issues of climate and social, economic and ecological changes and apply those findings and understanding to urgent problems of adaptation, livelihood, resilience and integrated planning and policy. The synthesized results are intended to help Arctic communities respond and adapt to the rapid social and ecological changes they are facing now and will face in the near future. To achieve research synthesis requires reconciling different research approaches, disciplines, cultures, geographical areas, problems, languages, methods and time scales. The solutions derived from such efforts will be transformative changes to development paths and the pursuit of new pathways to sustainability. ARCPATH is responding to these challenges by synthesizing and integrating the findings from the seven inter-connected work packages, answering the inter-connected research questions, linking and integrating the work packages (*e.g.,* improved regional-scale models useful to communities and regions in planning future economic and livelihood strategies to be tested in northern communities), creating new knowledge, mobilizing that knowledge to communities, policy-makers and planners and identifying continuing knowledge gaps with recommendations to fill those gaps with new research. ARCPATH is thus engaged in a process of creation and co-creation of new knowledge. The implications of findings are being identified: for governance, policy, northern people, northern communities, and for addressing issues of livelihoods, poverty reduction, gender, women, youth, equality, resources, education, and local to global governance regimes that manage them.

As we approach the end of the ARCPATH research project, we need to provide answers to the following questions in order to articulate our findings related to synthesis: What do we know now that we did not know at the beginning of the project? What answers do we have to the questions posed in each Work Package and how do they relate to one another? How have we interrogated each other's work packages to enhance the inter-connections among them and derive meaning from those relationships? How have we ensured that that new knowledge is used positively by partners, communities, practitioners, policy makers? What are the continuing knowledge gaps and recommendations for future research? What is the legacy of the project, the enduring legacy and learning from our findings and mobilization of the knowledge products of the research? Have those findings fostered responsible and sustainable development in northern communities and identified new pathways to sustainable resilient Arctic societies? If we can answer those questions to the satisfaction of the researchers and the research communities and stakeholders, we shall have achieved our synthesis goals.

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Chapter 19
The Assessment and Evaluation of Arctic Research – Where Have We Come From and Where Do We Need to Go in the Future?

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Abstract This essay represents the penultimate chapter of a volume that focuses on change in the Arctic and the challenges and opportunities for conducting research within the context of NordForsk's Responsible Development of the Arctic initiative. It provides both a backward glance at the needs that inspired this undertaking and seeks to offer some forward-looking ideas and suggestions as to the direction for future similarly-directed research efforts within the North. It gives attention to the important roles which assessment and evaluation have played in the evolution of the NordForsk project and focuses attention on the specific work of the Scientific Advisory Board (SAB) within this context. It discusses some of the challenges the SAB has encountered in conducting its work. Comparisons are also made with similar efforts at assessment and evaluation conducted by other funders of Arctic research. Views are also presented in this essay on the nature of integrated assessment within large and complex undertakings like the Responsible Development of the Arctic. Finally, a discussion is offered concerning where the future of interdisciplinary and cross-disciplinary scientific research in the Arctic may be headed and the requirements it must embrace in order to be successful.

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19.1 Introduction

The extent of the present rapid change in the Arctic has never been witnessed before. (IPCC Assessments 2014). Winter and summer temperatures are soaring and sea ice and permafrost are melting quickly especially since the start of the new Millennium. The sea ice is all but gone each year in the summertime which opens up the waters for new activities and shipping routes. The Greenland ice cap is melting and losing much water each year as it contributes to the sea level rise. The consequences are profound not only for local communities but also for the world as a whole. Sea levels are rising faster than anticipated. As the permafrost thaws, enormous amounts of greenhouse gases are being released into the global ecosystem.

A new geopolitical arena is also unfolding in the Arctic. Many heads of government have come and visited in the region and seen the dramatic changes taking place with their own eyes. They are also voicing their opinions of how future economic developments in the North should be stimulated. The situation is also changing since circumpolar countries, including the Nordic states, are becoming more interested in the exploration and exploitation of minerals and fossil fuels in their northern regions. As noted in Chap. 2 of this volume, the Nordic Council of Ministers and NordForsk took the initiative to issue a call for proposals in 2014 to study the effects of warming on local northern peoples and their ecosystems and to come up with meaningful pathways to action. These scientific investigations were to look into regional problems and opportunities in an integrated fashion that would allow scientists to work with local communities to co-produce ways to improve the situation.

19.2 The Arctic Initiative by NordForsk and the Nordic Council of Ministers

The research initiative was designed to produce new knowledge that would highlight opportunities and challenges for the responsible development of the Arctic region. The growing pressure on the Arctic arises from major socio-economic and environmental change, both regionally and globally, that necessitates that we enhance our understanding of this fragile region. The main drivers of change are currently considered to be climate change and industrial expansion, the latter including increased demand for natural resources like uranium, coal, natural gas and oil. In addition, security issues are deemed highly relevant in the Arctic.

The initiative was meant to stimulate cross-disciplinary work and to build on integrated research efforts in public health and medicine, the humanities and social sciences, and the natural sciences and technology. It focused on areas where joint Nordic research adds value to national initiatives (Nordic added value). It addressed existing and emerging knowledge gaps and facilitated international research cooperation at the highest level between Arctic as well as non-Arctic countries. This initiative explored the full range of possibilities to explain Arctic change, allowing for innovative approaches that would combine the legacy from previous International Polar Years (IPYs) with new knowledge on the rapidly changing realities within the Arctic. Furthermore, synergies were sought with certain other key Nordic and international research and innovation initiatives (See Chap. 2 of this volume.)

The initiative stimulated integrated research with monitoring and data collection on, for instance, climate and the environment, social and economic trends, education, and public health. It also supported the joint use of existing archives, scientific collections and other research infrastructure. Furthermore, it supported research on new technologies to strengthen the Arctic region and its communities, in such areas as telemedicine, distance education, and environmental technologies. Funded research was to increase the region's adaptive capacities and to realize a responsible development of the Arctic. Its overarching purpose was to produce integrative new knowledge on past and current change in the North as well as projections for future change that can inform societal discourse on probable or desirable directions for response to theses.

The initiative was to create pathways to action by strengthening the knowledge base for political decision making, education, industrial and human development. This was done by inviting the full range of stakeholder communities, including politicians, industrial actors, public sector officials, educators, NGOs and local communities, to take active part in the creation of new integrative knowledge within this initiative.

19.3 A Nordic Emphasis on Assessment and Evaluation

It has been noted in several studies that the Nordic countries have a penchant for assessment and evaluation within many areas of their societies (Aarrevaara et al. 2019). This is particularly the case with regard to the search for knowledge. The Nordic region is known globally for the extensive manner in which it both tests and critiques new inquiries and research. Similarly, the Nordic countries are renowned for their preparatory work and their deployment of cost-analysis in both scientific inquiries and the formulation of public policy (Arnold 2004; Benner and Sandström 2000). They are high on the list of societies that operate from the principles of "value for money" and perceived societal benefit. They are frequently in the forefront of making major investments in innovative areas of science and technology based upon such ideas.

Within all these undertakings there is an overarching concern that resources should be deployed strategically and in a rational manner. Key to providing such assurance is the establishment of regular assessment and evaluation procedures for all funded projects. In the minds of most Nordics, good business, science and public policy all come with a healthy dose of regular review and accountability (Jacobsson et al. 2015; Furubo 2011) Such requirements have been integral parts of NordForsk's Arctic initiative. At regular intervals, from even before the launch of the project through its complete implementation, specific efforts have been made to ensure that important and meaningful inquiries have been conducted and that research resources have been well deployed. Chapter 2 of this volume has already considered the careful steps that were taken prior to the announcement of the Responsible Development of the Arctic call for proposals. In the following sections of this essay the specific undertakings that came after thus announcement of the call for proposals are briefly considered.

19.4 Assessment of Proposals

As earlier discussed in Chap. 2 of this volume, this intiiative took the form of a research call that was designed to stimulate new efforts at pan-Nordic cooperation in Arctic research The NordForsk call resulted in the eventual submission of 34 proposals from different Nordic research consortia each representing scholars interested in bringing forth new knowledge and insights regarding the challenges and opportunities of the Arctic and increasing the Nordic added value. Soon thereafter, a team of Nordic and international scholars were asked to review each of the proposals.

The initial assessment process took place on an individual basis involving more than two dozen reviewers from around the world utilizing a common set of criteria and scoring directions supplied by NordForsk. In a subsequent workshop held in Copenhagen an actual comparative evaluation of all of the proposals was conducted by a smaller panel representing the broader group. This resulted in an intial joint rating of all the proposals. As a final step in the process, the cross-disciplinary research potential of each proposal was also scored because this was considered of special concern. Based on these specific steps, agreement was reached that of the 34 proposals submitted, six would be recommended to NordForsk's for possible funding. Subsequently, in December of 2015 the Board of NordForsk decided to fund four of these proposals for a total of 112 million Norske Krone.

19.4.1 Areas of Special Emphasis Given Consideration

Reading through the criteria for proposal selection, the reviewers sought to incoporate a variety of its dimensions in their recommendations. In addition to acknowledging traditional requirements for a clear project design and specific deliverables, they also wanted to acknowledge efforts that would make innovative contributions to Arctic inquiry. They wanted to stimulate integrated research with data collection in data poor regions of the North. Model development and calibration was considered very significant for the Nordic region since earlier global climate change models had done a poor job predicting temperature change in the European North. Stakeholder consultation to produce promising solutions with the input from local communities was also seen as very important. The reviewers also felt it important to encourage a global One Health approach for the North. Climate sensitive infectious diseases could become a health threat to the local and indigenous peoples and their reindeer herds. More knowledge was also needed on the prevalence of some of these diseases. If was felt important, as well, to stimulate tourism in the North such as trekking and watching the Aurora as well as whale watching instead of whale hunting.

As noted above, an important selection criterion became the ability of each proposal to demonstrate a commitment to interdisciplinary or cross-disciplinary work. The reviewers all recognized that this type of research is not easy and would would require considerable extra effort. However, it was felt that this was exactly the type of research most necessary for the broad needs of the Arctic today. The ability to think in holistic ways and to work across disciplinary boundaries with new partners, methods and approaches was considered to be vital for the success of such research efforts.

Reviewers also were interested in seeing an indication of gender awareness within each of the proposals that they considered. This meant not only having a desirable number of both women and men involved in the proposed projects, but that there be a recognizable sharing of design, implementation and management responsibilities among all the participants. It also was deemed important that specific gender perspectives be addressed in any funded research. This would include a consideration of both gender roles as well as the differing impacts of change in the North upon both men and women.

Also, in the minds of many of the reviewers was the key importance of creating a new generation of Nordic Arctic researchers. They also wanted to reward collaborative interaction among established scholars in the various fields of inquiry and newcomers. In this regard, special attention was given to how each project would contribute to the education of graduate students and new scholars with regard to the Arctic. Due consideration was also given to the opportunities that might exist for such individuals to provide leadership within the various work packages of each proposed NCoE and for them to have opportunities to publish the results of their work.

The four Nordic Centers of Excellence that were ultimately funded started their work in 2016 for an anticipated period of four years until the end of 2020. The present volume endeavors to take stock of their efforts as of mid-2020. Hopes are high, however, that these four Nordic Centers of Excellence will continue their excellent work for a number of years.

19.5 The Scientific Advisory Board

It is the usual practice for a NordForsk funded research initiative like the Responsible Development of the Arctic to have both a Program Committee and a Scientific Advisory Board to help assess and evaluate its endeavors (See Chap. 2 of this volume). The Program Committee (PC) has the responsibility to set the terms and direction of the overall effort. It also provides an opportunity for the funders of the initiative to receive information and regular updates on the progress of the constituent Nordic Centers of Excellence (NCoEs) The Scientific Advisory Board (SAB) is a body composed of external research peers with special expertise in the areas of investigation. The SAB has the responsibility to review the research being conducted by each of the NCoEs and to assess annually the progress of its work and to identify any deviations from the funded workplan. This annual evaluation along with recommendations for the enhancement of research efforts is shared with each of the NCoEs as well as the Program Committee.

The SAB for the Responsible Development of the Arctic initiative has consisted of a five-member group of nominated scientists from Canada, the USA, Sweden, the Netherlands and Finland. They assemble each year to collectively review the annual reports of the NCoEs and to interview representatives from each regarding their efforts. Thus far, the SAB has met in Umeå Sweden, Helsinki Finland and Reykjavik Iceland. The meeting provides an opportunity for the members of the SAB to learn more about the operation and accomplishments of each NCoE and to offer ideas, advice and recommendations regarding how its future efforts could be enhanced. The work of the SAB is ably assisted by officials and staff from NordForsk.

Usually at each of these gatherings an effort is made to provide a variety of opportunities for interaction between not only the SAB and the four NCoEs, but also to offer time as well for the exchange of information and collaborative ideas among the NCoEs themselves. The view from the outset has been to encourage and facilitate collaborative research among the several sponsored projects. A result of such efforts is detailed in Chap. 14 of this volume. Annual meetings between the SAB and the NCoEs have also sought to highlight common opportunities and challenges faced by Arctic researchers. At the Umeå gathering, a concerted effort was made to underscore the contributions of early-career scientists and to link the session to the Ninth International Arctic Social Science Association's conference. In Helsinki, an emphasis was given to opportunities for collaboration across project lines and was convened in conjunction with a stakeholder's conference on "knowledge gaps" in Arctic research that was sponsored by the Swedish Presidency of the Nordic Council of Ministers, the Swedish Polar Research Secretariat and NordForsk. (NordForsk 2018). In Reykjavik, attention was directed towards the challenges of research collaboration and synergy with a one-day workshop devoted to these topics. The gathering in Iceland also served as the inspiration for this volume which seeks to pull together the separate strands of the NordForsk Arctic research initiative and highlight some of its prime accomplishments.

19.6 Challenges in Assessment Faced by the SAB

Throughout the period of the NordForsk Arctic initiative, there has been a distinct mutual learning process in evidence on the part of both the scientists involved and those, like the SAB, who have been tasked with the responsibility of evaluating and assessing their efforts. The former has made substantial progress in securing their research objectives and in explaining the nature and significance of their findings. The latter has been generally pleased with these reported results and sought to encourage the scientists onwards to further accomplishments through their focused advice and counsel. The interplay between the parties has been challenging at times but good spirited. Any tensions that have arisen between the two groups stem from the inherent differences between those who are up close to and involved in the day-to-day operation of the research effort and those who must assess the work from some distance and from a larger context. What may seem at times clear and obvious to one group may appear cloudier and less evident to the other. Sometimes, as discussed in Chaps. 2 and 18, disciplinary barriers can also get in the way. There may be the need to learn one another's academic language and perspectives. Occasionally, however, real limitations and deficiencies have surfaced in the annual reports of the NCoEs and the SAB has been responsible for singling them out and seeking additional clarification from the authors. These include a variety of types of concerns.

The first of these relates to limitations in the reporting of information regarding the activities of some of the NCoEs. In living with these projects on a day-to-day basis, most principal investigators are well aware of the several undertakings of their researchers but may not be adept in capturing these in sufficient detail in their annual reports. The SAB has regularly reminded each of the research projects to share with it as much information as possible so that a fair assessment can be made of the work that has been undertaken. It has encouraged each of the NCOEs to place such information not only within their annual reports but on the web pages that each maintains. Those who have employed a project manager for their research effort have done a consistently better job in gathering and reporting such information.

A second area of concern by the SAB has been the sometimes-limited discussion of reallocation of project resources. Again, the rationale for doing so may be readily apparent to those close to the project, but it may be not as evident to those charged with assessing the effective use of grant resources. Changes in availability of personnel or swings in the value of differing currencies involved in the project may account for the majority of these resource reallocations, but these frequently need to be more thoroughly discussed along with their implications for ongoing research priorities. Having a dedicated program manager to keep track of reallocations and to capture the reasons for making them has placed some of the NCoEs in a much better position than others.

The next several limitations which the SAB identified in the work of some of the NCoEs all relate to discrepancies between the plans made by some of the projects in their initial proposals and their actual delivery of effort. One of these was with regard to interdisciplinary or cross-disciplinary work. While all of the projects promised to advance innovative efforts in these areas, not all have been successful in doing so consistently, across the board, throughout the duration of their project. Some of this discrepancy has stemmed from the reluctance of a few individual researchers to ultimately "buy in" to the cross-disciplinary enterprise. Some researchers have clung tenaciously to a single discipline's perspective and methods without exploring the potential contributions offered through collaboration with others. In a few instances, the problem has arisen from the reluctance of a project leader to strongly encourage interdisciplinary orientations and practices. When such hesitancy is observed, it can be seen as a neglect of one of the key criteria on which the project was originally selected.

Another observed limitation within some of the projects has been their lack of adequate attention to gender perspectives. At the outset, most of the NCoEs made a conscious effort to make sure that equal numbers of both male and female scientists were taking part in the various work packages of their projects. It should be noted that a relative parity of participation has been regularly reported in most of the subsequent annual reports. However, what became increasingly evident to the SAB over the years, was that a broader gender perspective was not often being discussed in some of these same annual reports. All of these should have included consideration of the differing impacts of change on gender in the North and, in particular, how their NCoE was considering these changing life experiences of women and men in the region. Unfortunately, some individual researchers responded to such concerns with the time-worn refrain that "science does not involve itself in matters of gender." While this was a distinct minority response, it was still unsettling to hear it voiced since attention to "gender perspectives" was one of the prime areas of concern during the selection process. Appreciatively, there are several chapters contained within this volume that have given the gender perspective due attention (See Chaps. 3, 4, 6, 7, 9, 10, 15, 16, and 17).

Still another limitation among some of the projects were their sometimes lack of attention to the involvement of local and Indigenous communities in their research. While all of the NCoEs included some aspect of this selection priority within their reported efforts, in some instances, it was confined to only one or two of their work packages rather than being thematically woven through their full endeavor. Although mention was made of the importance of local and indigenous contributions and involvement in the various research endeavors, few details of such participation were offered in some of the first annual reports from someof the NCoEs. The difficulties of facilitating the co-production of knowledge and the incorporation of Traditional Knowledge (TK) were discussed at the outset, but the actual demonstration of their benefits to research of such efforts was more limited until the latter stages of the project. Fortunately, within this volume there are a number of chapters which speak directly to NCoE experiences in these areas. (See Chaps. 4, 6, 9, 10, 14, 16, and 17).

In a similar manner it would have been useful for each of the NCoEs to have more regularly presented in their annual reports a discussion of how their research findings were being received and used by specific stakeholders and knowledge users. Admittedly, in the early stages of reporting there were limited research results to share. However, as time went on there still was only a limited consideration by some of the NCoEs regarding how reported research results might have implications or consequences for local residents, practitioners or policymakers. Perhaps this is reflective of the normal hesitancy of some scientists to promote the utility of their inquiries over the more general advancement of knowledge in an academic field. For some of the NCoEs there was more sharing of results within academic settings and publications than there were in public forums or through interaction with policymakers and the media. This has been a bit disquieting as one of the priorities for the Responsible Development of the Arctic program was its promise of "building pathways to action" through academic and public interaction. As the projects are still operating as of this writing, perhaps more of this type of discussion and public engagement will be in the offing. It should be pointed out, as well, that several of the chapters in this book do address the need for this cooperation. (See Chaps. 3, 4, 5, 6, 9, 12, 13, 14, and 16).

Finally, most of the NCoE projects suffered somewhat in their early stages from a distinct lack of coordination and development of synergy among and between their several parts. Perhaps this is natural in getting such broad and complex inquiries underway. However, it was apparent from the first SAB interviews with representatives from some of the NCoEs that a "common vision" and direction for their overall inquiry had yet to fully manifest themselves. This condition was to improve over time, but at the Helsinki session it was deemed sufficiently important to propose a focused workshop on research synergy and synthesis for the next gathering in Iceland. There, some of the challenges and opportunities for linking research within and between NCoEs were fully discussed and investigated. Chapter 18 in this volume provides a useful consideration of the need to continue to address these types of issues within all Arctic research.

It should be noted, however, that over time, most of the deficiencies discussed above have been reduced significantly though the NCoEs receiving feedback and advice from the SAB and the Program Committee. Most have responded to the critiques that have been offered by facilitating discussion of such issues within their own NCoE and by providing enhanced annual reports showing how they have endeavored to address these identified shortcomings. As is the case with many other research enterprises, the passage of time has allowed project leaders to encourage their colleagues to address matters which they may have initially not considered. The purpose in outlining some of these project shortcomings is not to underscore the limitations of any project, but to point to the type of assessment and evaluation challenges that can arise within such broad and complex research undertakings.

19.7 A Comparative Look at Assessment and Evaluation as Practiced by the NSF and Other U.S. Funders

As scientific problems have grown in complexity and interdisciplinarity, other nationally-funded research agencies, and consortia of nations (e.g., the Belmont Forum), have supported teams of researchers to address multifaceted science questions. To compare the NordForsk Centers of Excellence (NCoE) approach to the assessment and evaluation of large, natural science programs, we draw upon several examples from the U.S. scientific enterprise and highlight similarities and distinctions.

Science and Technology Centers Similar to the NCoEs, Science and Technology Centers (STCs), funded by the U.S. National Science Foundation (NSF), are large-scale and long-term multi-institutional endeavors that address complex scientific problems over a 10-year period. STCs are one of the most competitive, evaluated, and assessed large-scale natural science programs supported by a U.S. federal funding agency.

STC's consist of teams of individuals, usually from multiple institutions around the U.S. (some with corporate, state and local agency, or international involvement) that conduct transformative research, while also training graduate and undergraduate students, and conducting significant external engagement and outreach, with strong emphasis on broadening participation of underrepresented groups in science. Similar to the NCoEs, scientific exchange among the participating partners – the network of scientists – is a critical component. The initial duration of STCs is 5 years, with funding levels of approximately $5 M USD per year. Renewal for a second five-year period is expected, assuming good progress and significant scientific findings are evident. The peer-review evaluation and selection of STCs is phased, with the first phase consisting of pre-proposals that are submitted and evaluated by panels of external experts, leading to a second round of "invited" full proposals. The full proposals receive additional peer-review, including assessment by a "Blue Ribbon" panel of "big picture" thinkers, and a site visit by peer reviewers and agency officials at the institution of the lead scientist. From the submission of hundreds of pre-proposals, this process results in a small group (perhaps 3–6) of projects selected for funding.

External evaluation of the funded projects is a critical part of the STC program. All STCs must have an external advisory board for guidance. In addition, like the NCoEs, each STC project is evaluated annually through a site visit by a convened group of external experts, organized and led by the sponsoring agency. The STC project teams are expected to be responsive to concerns raised at the site visit, with corrective actions taken during the following year. At the end of the initial 5-year period, STC teams are invited to submit a renewal proposal for an additional 5 years of funding. STC competitions in the U.S. occur at 3–4-year intervals, with 10–12 Centers active at any one time. After 10 years of agency funding, should a significant body of compelling research questions remain in force, scientific teams are expected to develop alternative sources to support their work.

The high profile and significant investment associated with STCs has prompted the US NSF to request external reviews of the program. Within the last 25 years, the program has been reviewed by the United States National Academies (1996) and the American Association for the Advancement of Science (2010).

Long Term Ecological Research Programs In contrast to STCs, the Long Term Ecological Research Program (LTER) also funded by the NSF, is characterized by sustained funding for several decades. As noted on the NSF website, *"NSF established the Long-Term Ecological Research Program (LTER) in 1980. Two components differentiate LTER research from projects supported by other NSF programs: 1) the research is located at specific sites chosen to represent major ecosystem types or natural biomes, and 2) it emphasizes the study of ecological phenomena over long periods of time based on data collected in five core areas. Long-term studies are critical to achieve an integrated understanding of how components of ecosystems interact as well as to test ecological theory" (National Science Foundation LTER website).*

The LTER program currently has 28 sites, in different ecosystems or biomes, ranging from polar deserts to grasslands to coral reefs to urban centers. Similar to NCoEs, the human dimension of environmental change is an important element of these projects. The research teams are generally led by university scientists, and include post docs, graduate and undergraduate students; and may also include government agencies and private entities, again with a strong emphasis on public engagement. To assure rigor within these long duration projects, evaluation and assessment are deemed critical to the success of the program. New research findings and innovative syntheses are integral to each site's success – the research program cannot simply monitor systems.

LTER projects are selected from a national competition. Sometimes the competitions are not system-specified, while at other time there is focus around an ecosystem or biome. For example, a current competition request proposal concerning ecological processes in urban systems (NSF solicitation 19-594). Proposals are evaluated by external reviewers, and their feedback provides advice to NSF concerning the ultimate selection of the successful awardees. Ongoing programs are supported for 6-year intervals at > $1 M USD per year. At the 3-year mark of the funding cycle, an external evaluation team is organized, to visit the LTER science team and site, assess all aspects of the program (scientific productivity and rigor, training, external outreach and engagement) noting successes and making recommendations for improvement. This evaluation provides critical input to the LTER science team for their 'renewal proposal' which is submitted and peer-reviewed during the last year of the 6-year funding duration. Successful renewal proposals are again funded for 6 years; projects with notable deficiencies are put on probation and must submit another renewal proposal 3 years hence.

In the examples cited above, there is direct interaction and vibrant exchange between the assessors and the science team – just as there is for the NordForsk

NCoEs. This dialogue is valuable for obtaining an accurate view of progress, shortcomings, potentially novel new thrusts, as well as areas of improvement. This dialogue is also critical to the hard decision to bring a project to a close earlier than expected.

At present, NordForsk does not provide an avenue for recompeting the Centers of Excellence in a future competition. Such an opportunity may open the door to greater discovery and stronger interactions among the scientific community.

19.8 The Development of Integrated Research Efforts

An early example of an integrated model of research is the integrated model to assess the global environment known as the IMAGE model (Alcamo et al. 1998). Global change scenarios for the twenty-first century were described based on a coupled model covering the industrial emissions, the system earth, the land use change and the resulting air pollution and greenhouse gas emissions. It calculated the temperature change and sea level rise estimated for the years 2000–2100. Reay et al. (2010) and Van Amstel (2012) used the IMAGE model and made calculations to estimate methane, its role in climate change and options for control. The results of each disciplinary part of the model feeds into the other parts to finally get an integrated result. This integrated result was presented to the stakeholders and local communities in the form of scenarios. These scenarios were subsequently discussed in the Delft workshops as pathways to action and thereby helped to provide answers for stakeholders and local communities in attendance.

A consortium as the NCoE's can carry out different work packages of the research. But without feeding the results into a model or a framework it does not help with finding the answers because it is not integrated. It can be considered multi-disciplinary but not integrated. Burgass et al. (2019) in a recent example of a pan-Arctic assessment of the status of marine social ecological systems made use of such an assessment framework. This framework was based on the ecosystem services approach from the Millennium ecosystem assessments. The ecosystem services approach is recognizing the production function, the regulating function, the habitat function and the cultural services function. The last one includes landscape, tourism, education and science. It is gaining importance in Arctic research because it helps finding balanced Pathways to Action. Malinauskaite et al. (2019) published a review of research on ecosystem services in the Arctic. They concluded that the number of studies increased over the years and that they are now abundant. The ecosystem services approach values not only the production function of nature for humanity but also the other important functions like the cultural and the research function. For example, the research into the genetic pool that can be important for future use. The UN recently announced that 2021–2030 will be the decade on Ecosystem Restoration. De Groot et al. (2013) described the benefits of investing in ecosystem restoration. They developed this ecosystem services approach further to argue for investments in landscape restoration in situations of abandoned mines and soil degradation. Numerous successful examples are now available of reforestation to combat droughts as a result of climate change.

19.9 Challenges for Multidisciplinary, Large Team, and Broad Topic Area in Arctic Research

Key barriers to shared understandings of complex issues within research that spans disciplines may be methodological, epistemological, or ontological in nature (Brown 2010; Stock and Burton 2011). In their exploration of these barriers, Aslin and Blackstock (2010) begin with the idea that social and biophysical scientists come from different knowledge "sub-cultures;" these must be bridged, and perspectives must be broadened, to arrive at a necessarily more "holistic" understanding of complex systems and their problems (117). The differences in subcultures are manifested in material and conceptual ways, and include a number of specific barriers to building the holistic perspective necessary for integrated research within the individual/personal context (e.g. internal biases), disciplinary/scientific/technical context (e.g. confusion about jargon), and organizational/power/resource context (e.g. administrative compartmentalization) (ibid.). This suggests that barriers may be both located and addressed at multiple scales, from the individual to the organizational.

To understand the complex interactions between social and ecological components and processes in the Arctic, a systems-based perspective that takes an integrated research approach is warranted (Hinzman et al. 2013; Falardeau and Bennett 2019). This type of approach defies disciplinary boundaries and must instead aim for integration or collaboration across disciplines (Stock and Burton 2011); it must "draw on all our intellectual resources…the academic disciplines as well as other ways in which we construct our knowledge" (Brown et al. 2010, 4). Research taking this approach may be categorized using a range of labels (such as multi-, inter-, trans-disciplinary) and may exemplify varying levels of integration across disciplines and involvement of non-academics (Stock and Burton 2011; Tress et al. 2005). It is beyond our scope to revisit these discussions here. Instead, our goal is to identify the specific challenges associated with undertaking large-scale research that spans disciplinary boundaries, as well potential solutions to these challenges in Arctic research.

Pischke et al. (2017) identify a similar litany of material and conceptual barriers to integrated research in a meta-analysis of existing literature, and also conduct their own research to identify five additional barriers specific to or exacerbated within large-scale, international research (such as is often conducted in the Arctic region): integration (of methodologies, information, and disciplinary foci and perspectives), language differences, fieldwork logistics, personnel and relationships, and time commitment. There also may be particular challenges for collaborative research that spans the divide between the major "scientific cultures" (i.e. the natural sciences, social sciences, and humanities); these include potential mismatches between paradigms or epistemologies, skills and competencies of participating researchers, and institutional contexts, as well as how to organize such collaborations (Tobi and Kampen 2018, 1210). In particular, the necessity of epistemological integration may create challenges not only for individual scientists reaching across the divide, but also for funding agencies and organizational structures, which must figure out how to address and facilitate the specific needs of integrated research projects – including the identification of appropriate peer reviewers and the expansion of financial, logistical, and temporal resources to support epistemic bridge-building (Murphy 2011). Miller et al. (2008) offers a similar critique of epistemological entrenchment, in a case study illustrating how it served as an impediment to integrated research in Arctic Alaska.

19.10 Evaluating the Results from Multidisciplinary, Large Team, and Broad Topic Arctic Research

In identifying these various barriers to large-scale research conducted across disciplines, we can begin to target solutions and best practices for conducting this type of research in the Arctic. These include building capacities at the individual level, such as improving interpersonal communication, team leadership skills, and conflict resolution, and conducting trust-building activities (Aslin and Blackstock 2010; Lynch et al. 2004; Pischke et al. 2017); learning about written and unwritten rules and norms, familiarizing oneself with the fieldsite, culture, and language, and working closely with local stakeholders (Aslin and Blackstock 2010; Guerrero et al. 2018; Lynch et al. 2004; Pischke et al. 2017); and adopting "epistemological pluralism" (Miller et al. 2008) or an "inter-epistemological mindset" (Murphy 2011, 505) in which researchers make time for self-reflection and leave room for respecting and engaging with perspectives that are fundamentally different from their own.

At the disciplinary or scientific level, these approaches may include taking the time to learn about and use methods, tools, theories, and vocabularies outside of one's own discipline, and to allow room for emergent methodological approaches that can help bridge disciplinary perspectives (Aslin and Blackstock 2010; Brown 2010; Guerrero et al. 2018; Stock and Burton 2011; Tress et al. 2005); working more ardently to include historically under-represented perspectives from the humanities and interpretive social sciences (Murphy 2011); engaging with a broad(er) set of social and ecological variables, and considering their bi-directional interactions (Guerrero et al. 2018; Lynch et al. 2004); setting realistic yet flexible expectations (Lynch et al. 2004; Pischke et al. 2017; Stock and Burton 2011); and using a process specifically oriented toward creating integrated research design, such as Tobi and Kampen's Methodology in Interdisciplinary Research framework (2018). Murphy's Interdisciplinary Research Development Framework (2011), or the iterative process described in Lynch et al.'s case study on extreme wind events in Barrow, Alaska (2004).

At the level of organizational structure, this may mean working to ensure everyone is empowered equally, inviting the participation of senior management with the goal of building internal support for this type of research, and having a clear process for communication, inquiry, and debate (Aslin and Blackstock 2010); sharing responsibilities and giving autonomy to partners, and using creative funding solutions, such as sub-contracts, to facilitate this when working with non-academic or foreign research partners (Pischke et al. 2017); and working to expand methodologies sections in publications (to allow room to explain the complexities of this type of research) and to expand the number of quality interdisciplinary publications in which integrated research may be disseminated (Stock and Burton 2011; Tress et al. 2005).

19.11 Research with Indigenous Peoples

"There is a need for a far more robust conceptualization of the involvement of Indigenous communities in research than is currently the case, at all levels of research processes" (Raymond-Yakoubian and Raymond-Yakoubian 2017). This quote comes from a recent Kawerek, Alaska Native non-profit corporation, workshop addressing research processes and Indigenous communities in Western Alaska. However, the sentiment is felt across Indigenous communities in the Arctic. In the United States the National Science Foundation has recently begun a series of funding opportunities titled "Navigating the New Arctic". This request for proposals, similar to many of the parallel arctic funding opportunities in other nations such as Nordforsk, is forward looking and focused on the "newness" of today's Arctic. Indeed, there are definitely new trends in Arctic research as this text notes. In particular large and interdisciplinary groups with integrated research plans have become a feature of the research landscape. Another concept that has arisen is "co-production." In the Arctic this phrase lately refers to the need for research design, implementation, and review of any project to include both academic researchers and the Indigenous peoples whose territories and knowledge may be researched, used, and explained. Co-production need not be exclusively the purview of Indigenous Peoples, as work with citizens, businesses, and other institutions and groups in society is also key to understand social reality as well as develop solutions to policy problems (Østreng 2010). However, in the U.S. and Canadian contexts in particular, as well as the Nordic countries, the last few decades have been ones of serious scientific reflection on the natures of "science", "western-science", "Indigenous Knowledge", and "Traditional Knowledge" and the histories of colonialization in these countries. In the main, co-production in North American discussion is currently focused on these concerns. But the word itself matters perhaps less than the intent: creating new spaces for Indigenous people to be present in asking questions, designing research, managing funded proposals, and becoming in larger numbers "those who are researching" rather than "the researched", or in some cases simply ignored (Daniel et al. 2019a, b). In terms of the NCoEs, some have made progress in this area through their multi-disciplinary approaches, others less so.

Co-production as a general concept is about ensuring de-colonialized relationships and knowledge exchanges between "western" science and Indigenous Knowledge. Of course, Indigenous people themselves can become academics, though depending on where one is located there can be significant hurdles. In fact, at the time of publication the Chair of the Arctic Program Committee of NordForsk is a Sámi woman. While it is beyond the scope of this chapter to include the entirety of this discussion, we do want to highlight the more recent development of research protocols by Indigenous organizations and communities. These have been both *reactive*, pushing back against what, in particular, Indigenous communities view as inappropriate, and sometimes dangerous, activities by scientists and *proactive*, through publications of guidelines and efforts to collaborate. As we all work to navigate a "new Arctic" we need to take care that the "old Arctic" has yet to fade away. This is in part true when one considers climate models, lived experiences, and oral traditions of Indigenous peoples – there is broad interdisciplinary recognition that changes to the cryosphere and related earth system processes have surpassed recorded human history and understanding of the environment in the Arctic. However, the "old" Arctic has not left us, especially when one considers research. There are still people alive in Sami territories, Alaska, and Canada who can recall relocation, boarding schools, and active government-backed discrimination against Indigenous language, knowledge, and people (Marino 2015; Hansen 2015; Koivurova et al. 2015; Müller and Pettersson 2010). No elders are left who can remember a time without externally imposed decisions in their communities. The "new" and "old" Arctics are, in reality, co-existing and are in transition. The convergence of climate forces (e.g. greenhouse gases, temperature rise) have changed the nature of the Arctic and will continue to stress social-environmental systems that have been previously adapted for cold. Yet, there is divergence of opinion on the best way to approach the research of many new human adaptations that will occur. Whereas the approaches of the "old Arctic" stressed a western technocratic approach from southern governments that frequently ignored the Indigenous inhabitants of places, many newer scholars today propose the creation of new tools for research and decision-making that can take in a suite of knowledges (local, Indigenous, western science), evaluate them in relation to stakeholder priorities for the given problem, and produce more effective outcomes for research communities and Indigenous partners.

Scholars of multiple disciplines focused on resilient social-environmental systems recognize that "cross-fertilization among a diversity of knowledge systems can contribute new evidence and also improve the capacity to interpret conditions, change, responses, and in some cases causal relationships in the dynamics of social–ecological systems. Further, it may also lead to innovation and the identification of desirable trajectories or pathways into the future" (Tengö et al. 2014, 582). To this end, it is widely acknowledged (Anderson et al. 2018*)* that research fatigue, poor understanding of Indigenous peoples by researchers, lack of transparency about research goals, misunderstandings related to data, and logistical difficulties are problems that local-scale Arctic communities navigate on a routine basis. A particular direction of research that many Indigenous people in the Arctic recognize as significant due to the industrial development of offshore waters, coasts, and inland areas traditionally used for subsistence is food security (Hossain et al. 2018; Lovecraft and Meek 2019; Spzak 2017). While none of the current NCoEs have a direct research focus on this, they all have related threads in their investigations of mining, tourism, reindeer herding, and climate trends. This research area demonstrates how narrowly focused approaches to Arctic social, geophysical, and natural sciences may not fit well with the research interests of Indigenous peoples. For the Inuit Circumpolar Council, food security is "…characterized by environmental health and is made up of six interconnecting dimensions: (1) Availability, (2) Inuit Culture, (3) Decision Making Power and Management, (4) Health and Wellness, (5) Stability, and (6) Accessibility" (Inuit Circumpolar Council – Alaska 2015: 31). The words subsistence and food security across northern indigenous cultures are clearly tied to food, but more often express as a way of life, the ability of one to be out on the lands and waters, gathering foods, processing them, sharing them, and nourishing communities, cultures and traditions (Natcher 2009; Paci et al. 2004).

Overwhelmingly it is relationships that are at the core of the new conversation between Indigenous people and researchers from outside of their communities (Shin 2006; Cochran et al. 2008; Smith 2012). Recently at the international Arctic Observing Summit 2020 there was a strong call by Indigenous participants from different Arctic nations for changes across the dominant research culture of arctic science production. This effort was, in part, expressed in a policy brief by Dr. Nikoosh Carlo, herself an Alaska Native. She notes three key aspects of achieving equity and representation for Indigenous Peoples in arctic research. First, Indigenous Peoples across the Arctic share the challenges of inequity and lack of representation in research. Second, these disproportionate burdens come from a history of colonialization and continued system pressures present in institutions and countries. Thirdly, looking towards an evolving Arctic, researchers can advance their research and policy aims by showing respect, listening, using Indigenous protocols, financially supporting Indigenous research and leadership, and sharing decision-making (Carlo 2020).

19.12 In Conclusion

This chapter has endeavored to consider the roles which assessment and evaluation play within such a large and complex research endeavor such as the Joint Nordic Arctic Research Initiative. It has noted why and how the process of change within the Arctic has become a major interest of the Nordic community over the last several decades. The expanding Arctic research agenda that has emerged, stems from concern for the environmental health of the North and for the social and economic needs of the peoples who inhabit it. Embedded within it is a sense that important scientific investigations must be undertaken in order to broadly expand our understanding of the challenges that confront the region and to develop appropriate public policy to meet its requirements.

This chapter has considered the particular types of research foci that the Joint Nordic Arctic Research Initiative sought to encourage and the specific methods and approaches it endeavored to facilitate. Its overall purpose was to bring about innovative and policy-relevant research for the Nordic Arctic. Broadly speaking, its mandate was to facilitate a new way of looking at the North and to support a new generation of researchers who would explore its challenges and potentialities. To some degree, we have examined in this chapter how close it has come in meeting these expectations.

Central to this enterprise has been an examination of the process of conducting a useful assessment and evaluation of such research undertakings. We have noted how this effort to measure and account for the impact of such scientific inquiry has had a long tradition within Nordic science and public policy formulation. We have discussed how some of its features were introduced during formulation of the research initiative, the selection of NCoEs to be funded and in the annual consideration given to their progress and specific accomplishments. In regard to the latter, the role of the Scientific Advisory Board has been given broad consideration.

This chapter has also examined how similar efforts at undertaking large and complex research initiatives have been funded, operated and evaluated in other regions of the globe. In this regard, special consideration is given to the undertakings of the National Science Foundation (NSF) in the United States. Here the character and dimensions of the NSF's Science and Technology Centers (STCs) and its Long-Term Ecological Research programs (LTERs) are compared with the features of NordForsk's NCoEs. Comparisons are also made between how evaluation and assessment efforts are conducted in each of these programs.

The chapter has also focused some attention as well on the specific challenges of conducting integrated research across large and complex endeavors as those found in the four NCoEs featured in this volume. It highlights the challenges of conceptualization, coordination and synthesis found in such undertakings and the need for effective coordination, leadership and assessment in facilitating the work of these endeavors. Special consideration is also given to the requirements and impact of multidisciplinary research efforts and how the results of undertakings can be best considered and evaluated. This seems particularly important in the case of research related to the Arctic today.

Providing such a framework for assessment and evaluation of the Joint Nordic Arctic Research Initiative seems important in both considering its overall accomplishments and impact. It also offers an opportunity to examine where we have come from and where we may be going in future Arctic research efforts in the coming decades. The direction for some of these undertakings will be considered in the final chapter of this volume.

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Chapter 20
Findings and Conclusions: Pathways to Action

Douglas C. Nord

Abstract This final chapter of the book provides a summary of the key findings and perspectives that the several contributing authors to the volume offer regarding Nordic perspectives on the responsible development of the Arctic. It presents these within a framework of five interrelated questions. The first of these is: How are Nordic interests and concerns regarding the Arctic being addressed by the efforts of these four NordForsk-sponsored NCoEs? The second one is: What innovative conceptual and methodological insights have emerged from their efforts? The third is dual in character: What have been some of the advantages secured in promoting interdisciplinary research and the use of multi-disciplinary teams of researchers and what are some of the limitations and constraints in their use? The fourth question focuses on: How can participatory bridges be built between researchers and local and indigenous communities? Fifth and finally, the question is addressed regarding: What are to be some of the future directions for policy development in the North that can emerge from such research efforts? The latter concern focuses our attention back on the issue of what are the necessary pathways to action that lay at the heart of all of these inquiries.

Keywords Nordic Centres of Excellence · Interdisciplinary research · Co-production of knowledge · Policy development · Arctic

This volume has sought to address the nature of change within the contemporary Arctic. It has endeavored to examine the environmental and societal forces that, collectively, are shaping the future of the region. More specifically, the several contributors to the book have through their research efforts attempted to bring into

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greater focus some of the major challenges and opportunities that present themselves in securing a responsible development of the Nordic Arctic. Through their investigations they have sought to identify some of the specific steps that must be taken in order to provide pathways to action in meeting the needs of the lands and peoples of the area. The separate chapters of the book have offered some clear insights into the challenges that lay ahead.

In this final chapter of this volume, an effort is made to connect these separate perspectives by placing them within a framework of five pressing questions that require our attention. The first of these is: How are Nordic concerns and interests in the North being addressed by these research efforts? The second focuses its attention on: What have been the innovative conceptual and methodological insights that have emerged from these efforts? The third question of interest is dual in character: What have been some of the advantages secured in promoting interdisciplinary inquiry and the use of multi-disciplinary teams of researchers—and what have been some of limitations and constraints in doing so? The fourth question focuses on: How can participatory bridges of understanding be built between researchers and local and indigenous communities. Fifth and finally, this overall research endeavor raises the question of what should be some of the future directions for inquiry and the development of policy in the Nordic North? This latter concern focuses our attention back on the issue of what are the necessary pathways to action that lay at the heart of the research inquiries featured in this book.

20.1 How Are Nordic Concerns and Interests in the Arctic Being Addressed?

As was discussed in the first chapter of this volume, Nordic concerns and interests regarding the Arctic have grown and developed as the region has received more attention and consideration both within their communities and globally. Such increased attention has directed both the research communities and policymakers to consider the merits of additional strategic and needs-based research efforts. Gunnel Gustafsson in Chap. 2 of this volume describes the currents that led to this new emphasis and how these combined to the launch of NordForsk's Joint Nordic Arctic Initiative. She stresses the point that despite such a strong commitment to undertake such an innovative research effort, there remained certain tensions and unknowns that continued within the implementation of the project. Fortunately, key features of the Nordic research community existed to ease its path toward a successful result.

It has been noted that, in general, Nordic concerns and interest in the Arctic has been oriented around some ten or so primary matters. These include: (1) protection of the environment; (2) addressing issues of climate change; (3) promoting policies of sustainability, adaptation and resilience; (4) providing for economic development; (5) encouraging the development and application of research and technology;

(6) promoting health and safe living conditions; (7) providing for enhanced education and job opportunities especially for the youth of northern communities; (8) addressing gender perspectives and differences in the North; (9) promoting principles of democracy and participation in decision-making; and (10) encouraging Nordic and international collaboration and engagement in solving problems in the Arctic. This is not a totally exhaustive list of priorities, but they can be seen to occur regularly on the lists of Nordic research and political leaders.

They also feature prominently in the research efforts of the four Arctic Nordic Centers of Excellence that are presented in this volume. For example, Astrid Ogilvie and Yonqi Gao and their colleagues in ARCPATH in Chap. 7 of the volume have considered some of the requirements necessary to help protect of the sensitive environment of the Arctic. Shunting Yang and her research colleagues in Chap. 8 have sought to determine how the development of new climate models can help us to better understand the scope and impact of climate change. The need for sustainable, adaptive and resilient approaches to resource utilization are considered by CLINF researchers led by Grete Hovelsrud in Chap. 6 and by Øystein Holand and his ReiGN colleagues in Chap. 11 of this book. Matters related to economic development in the North are addressed by both Dag Avango and Sverker Sörlin of REXSAC in Chaps. 15 and 16, respectively. Encouraging the application of research and technology to northern concerns is amply illustrated by the CLINF research team headed by Gia Destounti and Shaun Quegan in Chap. 5 and by Antti-Juhani Pekkarinen and his colleagues from ReiGN in Chap. 12. Health concerns—especially within the context of the emergence of new CSIs—are amply addressed by CLINF leaders Birgitta Evengård and Tomas Thierfelder in Chaps. 3 and 4 of this book. Providing new and enhanced education and job opportunities in the North is a concern of Laura Malinauskaite and her fellow researchers from ARCPATH in Chap. 9. Encouraging the consideration of gender perspectives in Arctic-based research is an aspect the inquiries pursued by both Catherine Chambers and her colleagues in ARCPATH in Chap. 10 and Kirsten Thisted and Frank Serjested from CLINF in Chap. 17. An interest in democracy and the encouragement of local and indigenous participation in the development of policy related to natural resource utilization are both concerns of Simo Sarkki and his ReiGN researchers in Chap. 13 as well as Tim Horstkotte and his colleagues from ReiGN, CLINF and REXSAC in Chap. 14. Finally, the importance of both Nordic collaboration and international cooperation in addressing the needs of the Arctic are discussed by Leslie King and Astrid Ogilvie from ARCPATH in Chap. 18 and by Andre van Amstel and his fellow Scientific Advisory Board Members in Chap. 19 of this book.

Such a broad representation of these interests and concerns suggest that the present volume provides of strong evidence that Nordic priorities in relation to the Arctic are being addressed by its current generation of researchers. This needs to continue in the future. One of the interesting dimensions of the Joint Nordic Initiative in Arctic Research has been its facilitation of learning and research opportunities for PhD students interested in the field and the encouragement of young scholars to take an active role in both the design and implementation of the research efforts within each of the Arctic Nordic Centers of Excellence.

20.2 What Are Some of Conceptual and Methodological Innovations That Have Emerged?

Each of the four Nordic Centers of Excellence on Arctic research has pioneered and developed a variety of conceptual and methodological innovations in their research efforts. Bringing new insight and methods to the conduct of scientific research is no small achievement. This "cutting-edge" feature of each of the NCoE's work has received significant attention and acclaim. It is not easy to capture the full dimensions of these efforts but a brief summary of some of these can be offered for each undertaking.

20.3 CLINF

The CLINF NCoE has distinguished itself along several avenues. On the conceptual side, due attention has been given to the sheer size of the project's focus. As its group leaders have suggested, this was a project that reaches from Nuuk to Yakutsk. In endeavoring to gather both animal and human infection data from such a wide domain it has been a truly groundbreaking effort. So too has been its undertaking to collate and integrate such information and make it broadly available to researchers and policymakers across a number of countries. Its particular effort to secure and incorporate Russian data from the vast expanse of Siberia as well as the Nordic region is quite remarkable. These efforts are detailed in Chaps. 3 and 4 of this volume. Another conceptual breakthrough has been its consideration of how "multiple stressors" like climate change, the alteration of land use practices and the coming of CSIs can interact with one another in a holistic manner and have cumulative effects on the health and lives of reindeer and their herders. The character of such integrative work is presented in Chap. 6 of this volume with a focus on reindeer herding within northern Norway.

On the methodological front, this project required the deployment and integration of a wide variety of research methods and techniques ranging from the natural and life sciences to the social sciences and humanities. This necessitated the design of a comprehensive and innovative research plan and the careful coordination and implementation of its various dimensions. The challenging and demanding features of such an undertaking is aptly presented in Chap. 4 of this volume. Another methodological challenge that was successfully engaged by CLINF was its ability to address problems of uncertainty within the environmental models that it used in forecasting the future prevalence of CSIs within the Arctic. The nature of the impediments as well as the means by which they can be overcome are set forth in Chap. 5 of the book. All of these undertakings—both conceptual and methodological—have allowed for the provision of research findings that can be of significant use to the broader research community as well as policymakers charged with the responsibility of implementing strategies to address the spread of CSIs in the North.

20.4 ARCPATH

This NCoE also displayed a breadth of conceptual and methodological approaches and techniques in its various undertakings. With regard to the former, it undertook to link and relate several different types of research initiatives that are of significance to a variety of northern coastal communities ranging from Greenland to Iceland and also northern Norway. The leaders of this endeavor sought to pull together and synthesize research inquiries ranging from climate science and modeling to those based in the economic and social sciences. In so doing, they sought to help predict the character and nature of change in these climate-challenged communities and develop suggested science-based responses aimed at facilitating their adaptation and resilience. The dimensions of such a significant undertaking are well-presented in Chap. 7 of this book. Along similar lines, but perhaps on a smaller scale, this NCoE has also fostered the development of integrative research rooted within individual coastal communities. Here the focus has been on considering how such community-based research could be best designed and implemented with input from locals without overtaxing the time or energies of residents. This effort at community engagement in research efforts at an effective and scaled level turned out to provide one of the major insights emerging from the whole project. This effort to conceive and conduct "small science" in an era of "big science" concerns is detailed in Chap. 10 of the volume.

With respect to methodological innovation, the ARCPATH NCoE has also made major headway on a number of fronts. In Chap. 8 of this book, some of the leading researchers involved in the climate modeling dimension of the project outline how the features of certain climate models can be used to understand and predict both historical, contemporary and future changes in climate systems that can have a profound effect on the North Atlantic region. These ARCPATH researchers then applied such decadal climate prediction and regional high-resolution models to provide more accurate information on climate change in the Arctic and Nordic seas over several decades. Such significant and innovative work is of great importance to both stakeholders and residents who live in affected coastal communities of the North. In a similar way, other ARCPATH researchers have made new headway in analyzing how ecosystem services (ES) can be applied in the Arctic in the case of whales. They developed a new model that presents the use of whales both in terms of harvesting and tourism as elements of ES and demonstrated the interconnectedness of social-ecological processes involving natural and human capital that enhance human wellbeing through the co-creation of whale ES. They illustrate how this can be done in their reporting from different coastal communities in Greenland, Iceland and northern Norway. They demonstrate how their efforts can assist in the furtherance of both enhanced research and new management approaches regarding whale resources in the Arctic. An overview of these undertakings are provided in Chap. 9 of this volume.

20.5 ReiGN

This NCoE has also conducted pioneering work both in conceptual and methodological terms. In Chap. 11 of this volume, the project leader and his colleagues outline the ways in which innovative research on reindeer husbandry in the Fennoscandia region can be undertaken by drawing upon a variety of disciplinary perspectives and methods to create a holistic understanding of the challenges confronting both reindeer and their herders in a period of significant climatic, environmental, social and economic change. By integrating perspectives from the natural and social sciences the ReiGN project has been able to (1) identify key drivers of this change; (2) determine how this change has effects on the existing pastoral system and (3) suggest how this change is inevitably linked to the ecological, social and political dimensions of the broader community. In so doing, they seek to provide some direction for the future development of policy and management practices regarding reindeer husbandry with the region. Such efforts must consider the current and future needs of both the animals and the herding communities that depend on them for their social, cultural and economic viability. Following along on similar lines, the ReiGN authors of Chap. 13 seek to advance the concept of reindeer herders as “right-holders” and the consequences that stem from the application of such an idea. They demonstrate why an overreliance on established “stakeholder” theory within natural resource management thinking is inadequate in addressing the broad spectrum of needs and concerns of most herders. They suggest that their alternative conceptualization based on the rights that such individuals enjoy through their indigenous status or their reliance on a traditional way of life provides a more effective means for coming to grips with the real aspirations of such groups. In so doing, they pioneer the idea of reindeer herders as “rights holders”.

In addition to providing such conceptual innovations, the ReiGN NCoE has offered a number of methodological advancements as well. One of the most significant of these comes in providing an enhanced understanding of the interaction between pasture dynamics and economic incentives in reindeer husbandry in Fennoscandia. In Chap. 12 of this book, one of the ReiGN research teams provides an economic-ecological model of reindeer herding that can be used to analyze how these various forces drive reindeer numbers. Using Finland as a case study, they demonstrate how the application of bioeconomic analysis can be used as a tool for understanding the reindeer herding system. This group of researchers shows how current restrictions on the maximum number of reindeer allowed to be herded can relate to economically and ecologically sustainable model solutions. From a different orientation, other ReiGN researchers, bolstered by support from colleagues from both CLINF and REXSAC, sought to enhance methods associated with their research that are rooted in the co-production of knowledge. Their focus of attention, as is discussed in Chap. 14 of the present volume, was how to encourage the participation of reindeer herders in the consideration and discussion of policies and practices related to the supplementary feeding of reindeer. They explored ways to bring these herders to the center of such discussion by designing a specific workshop setting to examine the pros and cons of such efforts. They considered various methods and means to make the herders the focus of the workshop's operation so as to provide them with an effective opportunity to have their voices and opinions heard. From this undertaking they developed a series of suggestions as to how such efforts at the co-production of knowledge could be better designed and developed in the future with the knowledge users' interests and concerns given top priority.

20.6 REXSAC

The last of the NCoEs, REXSAC, also has brought forth important new conceptual views and methodological innovations. As a project focused on the challenges and opportunities associated with resource extraction in the North and the building of sustainable Arctic communities, the researchers involved have advanced a variety of useful insights. In Chap. 15 of this book, one of the project's lead investigator examines the idea of "multiple pressures" being faced by residents of such resource-based communities. He considers how competing environmental, economic, social and political pressures are brought to bear on such residents and results in unwarranted stress on their part. He also notes how this constant over-layering of demands and pressures has been allowed to develop without a real consideration of the perspectives of indigenous and other local communities. He argues that this must be countered by opening up the process of determining the needs and aspirations of such resource-based communities to local voices and opinions. In so doing, greater attention also needs to be given to the potential influence of gender and affect. This latter concern related to the impact of emotions is addressed by another REXSAC research group in Chap. 17 of this book. There they consider how mining activities are deeply entangled in human affects. Drawing upon the so-called "emotional-turn" in social science research, these researchers investigate how affects and emotions as cultural practices empower discourses that connect—or disconnect—resource extraction with community making and nation building processes. Their focus arises from case-studies undertaken in such communities within Greenland and the Sámpi region.

Another REXSAC research team can be seen to advance both conceptual and methodological concerns in Chap. 16 of this volume. In their study of the afterlife of mineral extraction sites within the Nordic North they seek to understand the challenges of dealing with "mines that have gone silent" from environmental, economic, social and cultural perspectives. In so doing, they help to develop concepts such as abandonment, environmental remediation, re-economization and heritage-making and apply them to the conditions faced by resource-based communities struggling to secure value and meaning from their setting and communities. They also demonstrate some of the clear challenges and opportunities that interdisciplinary and cross-disciplinary work on such topics provide. These REXSAC researchers also relate some of the approaches, tools and techniques that can be applied in gathering data and providing a record of both abandoned working mine sites across the Nordic North and in communities facing the challenges of dealing with mine closures or the potential for new mining operations. They indicate how their research will be of use to both policymakers and local communities as they wrestle with the realities of such "boom and bust" socio-economic conditions and the very real environmental consequences that accompany them.

20.7 What Are Some of the Advantages—and Limitations—of Conducting Interdisciplinary Research?

The facilitation of collaborative and cross-disciplinary study has been a central concern of the Joint Nordic Initiative on Arctic Research from the outset. It was one of the chief criteria used in the selection of proposals made to NordForsk and has been a regular area of consideration during the annual assessments of the progress of each NCoE. (See Chaps. 2 and 19). The reasons for doing so have been already discussed somewhat, but as these projects now near their completion certain realities become even more prominent. As has been noted, the broad and complex nature of current change in the Arctic does not lend itself to narrow perspectives or investigations. There is a real need for comprehensive and holistic approaches to understanding the causes and consequences of such change and in devising appropriate scientific and policy responses to them. Arctic research, as demonstrated throughout this volume is not the sole domain of any one academic discipline or methodological approach. All have contributions to make in describing and analyzing its features and in designing new pathways of action to address its needs.

What is required, increasingly, is a sharing of insights and approaches. In undertaking contemporary Arctic research, we, as scientists, need to learn from one another in order to better design and implement our research projects and to fully understand the significance of our discoveries and findings. The days of the lone, bold Arctic explorer operating from the vantage point of a single or a limited number of academic disciplines may be over. Increasingly, we see new and innovative undertakings like those of the NCoEs described in this book. They require the deployment of multi-disciplinary teams of researchers in order to respond to pressing Arctic concerns. Such groups must be able to combine insights from different realms of knowledge and integrate different types of data and information. These efforts at research collaboration and the undertaking of research synthesis will probably become increasingly the norm (See Chaps. 18 and 19). This will likely result in "added value" to those inquiries that recognize the benefits to be secured from such cooperative effort. It will also provide the means for "burden-sharing" necessary in a world faced with the growing costs of research in remote places and a society seeking greater inclusion of non-traditional knowledge sources. (See Chaps. 10 and 18).

This is not to say, however, that such an undertaking will be particularly easy or straightforward. Despite many decades of calling for greater interdisciplinary and multidisciplinary research efforts, for many scientists the idea of operating outside of one's familiar disciplinary "silo" or "fox hole" will remain challenging. As has been noted in several of the chapters included in this volume it will require a willingness to learn new "languages" and perspectives (See Chaps. 2, 4, 7, 10, 14, 17) This openness to the consideration of new viewpoints and methods may be especially challenging for those researchers who have traditionally functioned within only one disciplinary framework or who have not considered either the possible contributions from alternative or non- traditional forms of knowledge or the prospect of the co-production of knowledge with community members. Pulling together these separate strands of awareness and understanding, and encouraging their widespread application, can be challenging and, at times, even frustrating. (See Chaps. 4, 6, 11, 14, 16). However, increasingly, it must be done in order to produce the highest quality of research—especially in the Arctic. This will require a certain amount of leadership from those providing direction and funding for such inquiries. It also needs to be accompanied by new ways of encouraging greater "bottom-up" efforts in the design and implementation of research plans and in the active participation of all who are involved in such efforts (See Chaps. 3, 10, 13, 16).

In the end, the promotion of interdisciplinary investigations and the deployment of multidisciplinary teams of researchers lends itself well to the character and needs of the Arctic. It does not mean, however, the total abandonment of more narrowly focused efforts on the part of scientists from a single academic field. It is more a matter of knowing the focus for one's inquiry what are the necessary tools to be utilized in seeking knowledge. The separate studies presented within the chapters of this book demonstrate the need, at times, for certain single discipline-based inquiries and the utility of applying specific relevant methods and approaches. (See Chaps. 4 and 7). Nonetheless, each of the NCoEs discussed here stand as testimony of the need and relevance of increased scientific collaboration and efforts at research synergy. In recognizing this fact, true progress can be made in addressing the real needs and aspirations of the North.

20.8 Building Bridges of Participation and Inclusion

From the outset, the Joint Nordic Initiative on Arctic Research has been based on the idea of participation and inclusion—not just within the academic research community—but with respect to the wider stakeholder and local communities of the North (See Chap. 2 of this volume.) It has had as one of its chief motivations, the idea that Arctic research should be made more relevant and understandable to both policymakers and local residents as well as other knowledge users. There has been a strong belief in the virtues of strategic research in formulating a response to the needs and potential of North. Having policy-relevant findings emerging from scientific inquiries has been deemed to be one of the ways to build "pathways to action." However, an equally strong impetus for this initiative has been its desire to see that those who live in the Nordic Arctic have a voice in the conduct of such research and in the public policy and practices that emerge from it. As such, there are at least three major audiences that need to be satisfied. One is the traditional broad scientific community that looks to such efforts as a means to advance knowledge of the Arctic across a variety of fields. The second is the policymaking community which seeks information and advice from researchers as to how best to institute programs and practices that are responsive to the challenges and opportunities of the region. The third are the residents of the region who want to know what specific benefit can derived to them from such research and desire to have it be undertaken in response to their needs and aspirations. It is toward these latter two groups—the policymakers and the local communities of the North that this project has sought, in particular, to distinguish itself as opposed to other research undertakings that have not gone beyond normal "academic exercises."

With regard to policymaking community, it has been an ongoing objective of most of the research efforts detailed in this volume to provide useful and necessary data and information to those who will need such in order to design and implement needed policy for the North. It has also been a stated priority to provide useful perspectives and insights that may help to shape the actions of such policy actors (See for instance Chaps. 3, 7, 12, 16 and 19). The means for accomplishing this has expanded as the NCoEs have progressed with their work. It has included briefings for the media and specific government departments and agencies. It has taken the form of specific publications directed toward both the public and private sectors. It has also included the involvement of such actors in seminars and workshop designed both to ensure their input during the actual investigatory process as well as to secure their reaction to the findings that have emerged from it. Throughout the various undertakings of the NCoEs there has been a consistent desire to share data and perspectives with those given the responsibility of formulating policy of relevance to the North. In this manner, researchers can also play a participatory role in such efforts.

Of equal concern, however, has been the researchers' belief that the residents of the Arctic should be included in such inquiries and derive benefit from them. This is particularly the case with regard those groups who in the past may have been excluded from participation or whose concerns have marginalized. It has been important for all of the NCoE researchers that such groups feel they are part of the process and that they have important contributions to make. With this in mind, several of the research groups have sought to share with local communities what their research projects would entail and why it may be of relevance to them. (See Chaps. 4, 9, 10, 12, 15) Many have also reached out to them in the actual design and implementation of their research plans. The concept of a partnership in the co-generation of knowledge between scientists and local residents has been prominent within many of the projects discussed in this volume (See Chaps. 6, 7, 10, 14, 16) So too has been the effort to incorporate traditional and alternative forms of knowledge into their research efforts. In this manner indigenous and local residents can look at the results and feel that they have a clear benefit from them.

A related theme which several of the chapters in this volume speak to is the importance of current, and for that matter, future policy being more open to and engaging of such inputs (See Chaps. 3, 10, 13, 14, 15). Health, mining, reindeer husbandry and marine resource utilization can all be seen to benefit from a more open and inclusive decision-making process in both the public and private sectors. In these processes and in the strategic research that can help to guide and inform them, both scientists and local communities have significant roles to play. This needs to be regularly acknowledged and acted upon as pathways to action in the Nordic Arctic are formulated and constructed.

20.9 Future Directions for Research and Policy Development—Pathways to Action

From this review of the research insights and findings that have emerged from the Joint Nordic Arctic Initiative. it is clear that there are a number of specific efforts that must be continued in order to further solidify and enhance Arctic research among the Nordic countries. These can listed and detailed as follows:

First, there needs to be a continuation of broad support for research on the Nordic North. The region has been understudied and unrepresented in Nordic research funding for decades. The NordForsk initiative has provided an initial re-focusing of concern, but much more needs to be done in the coming years to provide useful information and perspectives on the challenges and opportunities to be found in this region. Like other major Arctic actors including the United States, Canada and the Russia, the Nordic community needs to give serious consideration to creating an ongoing funding mechanism for necessary Arctic research.

Second, this funding support should encourage the type of interdisciplinary and integrative research efforts that have been undertaken by the four NCoEs of the Responsible Development of the Arctic program. The deployment of multidisciplinary research teams working toward commonly identified and shared goals should become more of a norm when conducting Arctic research today and in the future. Significant new insights and research findings have emerged from those undertakings that seek connection and common effort in addressing some of the complex challenges confronting the North today. Also, a clear added Nordic benefit is secured from the pooling of resources, facilities and personnel.

Third, more specific support needs to be provided to examining pressing societal concerns of the region. In addition to needed inquiries into health, employment and infrastructure challenges in the region, more investigatory attention needs to be turned to the provision of education and training options in the Arctic along with addressing the specific concerns of indigenous people, youth and the aged in these communities. Additional concern needs to be directed toward gender differences in perspective and life opportunities in the Arctic. We are increasingly knowing and understanding more about the challenges and needs of the lands and waters of the North. We now need to make an equal commitment to better understanding the socio-economic requirements and aspirations of the residents of the region.

Fourth, in seeking scientific knowledge of the Nordic Arctic we need, as researchers, to make more of a commitment to involving these northern residents in our inquires. This includes reaching out to them in the design and implementation of our research undertakings and in the dissemination of our findings. This also suggests that we take into consideration community interests and priorities as well as our own. It involves a greater emphasis on the co-production of knowledge and the incorporation of traditional knowledge and methods in our work. It necessitates our broad sharing of information with the residents of the North and securing feedback from them regarding our findings and conclusions.

Fifth, this sharing of information needs to be extended to all knowledge users. Our colleagues and the extended academic community need to have data and insights provided to them through the use of open source publication methods. We also need to take more of a pro-active role in working with both the public and private sectors in sharing our results and seeking their input and response to it. As in often said, good policy stems from good science and we need to make sure that policymakers and knowledge users of all types are incorporated in our efforts and in the dissemination of our research findings.

Sixth, we need to reach out to other international research partners both within the Arctic and further away in order to share and pool our information and insights with them. The Arctic is a vast and varied region. We must look for areas of common interests with other researchers in other countries to spread the scope of our inquiry and to share available resources. We also must engage in more comparative analysis so as to better understand what is common, and what is distinct, about phenomena and conditions in the Nordic North as opposed to other parts of the globe. Only in this way can we also derive benefit from the insights of other researchers and other inquiries. The Nordic countries have always believed in the virtues of international cooperation. Now is the time to make Arctic research a prime element of this effort.

Seventh, such commitments of attention and resources, must be accompanied by continued emphasis on the quality of scientific research in the Arctic. As has been discussed several times in this volume a commitment to strategic research does not mean a diminution, in any way, of the quality of research that is to be expected. With the commitment of enhanced focus and funding, so too must there be regular and effective assessment and evaluation of these research efforts. The scientific and public benefit derived from Nordic Arctic research needs to be demonstrated during each step of its growth and advancement.

Eighth and finally, due attention needs to be given to providing support for a new generation of Arctic-focused research scholars within the Nordic region. As the attention to the North grows here as well as other portions of the globe, we need to make sure that we are offering adequate education, training and support for the next cohort of scholars who will carry on the necessary inquiries into the needs and aspirations of the Arctic. This means providing them the highest quality of both discipline-based training and interdisciplinary research experiences that can be offered at a postgraduate level. It also requires sufficient research support for their subsequent inquiries. NordForsk's Responsible Development of the Arctic initiative has contributed to this undertaking and we can see some of the results of this investment in the chapters provided by such young scholars to this volume. This Nordic commitment to young scholarly research in the Arctic must continue.

20.10 Concluding Thoughts

The renowned Norwegian explorer and scientist Fridtjof Nansen is reputed to have suggested that: "The difficult is what takes time; the impossible is what takes a little longer." Nansen's observation seems aptly to fit the current challenges and the opportunities faced by the Nordic North. This volume has outlined some of the specific problems and concerns faced by the region. It also has considered how science and research can be structured and organized to help address these. The investigators whose research efforts are presented in this book are directly involved in helping to build the pathways to action that are required over the coming decades if responsible development of the Arctic is to be achieved both within the Nordic region and throughout the circumpolar community.

In reviewing the contributions of the researchers contained within this volume, it is clear that several forces need to continue to be brought to bear in this collective effort. One of these is the encouragement of collaboration and coordination by scientists engaged in this undertaking. As we have seen the deployment of large multidisciplinary teams of researchers can yield remarkable results. So too can the employment of interdisciplinary perspectives and methods in support of traditional disciplinary-based inquiries. Efforts at connecting these activities and encouraging greater effort at the synthesis of research from the North need to be prioritized even further in the coming years.

The Joint Nordic Initiative in Arctic Research has also demonstrated the benefit derived from reaching out to involve more participants in these efforts. Major insights can be derived from the co-production of knowledge with indigenous communities and local residents. Many of the chapters contained within this volume demonstrate the mutual benefit derived from scientists working in concert with such groups. Similarly, the research results presented here speak to utility of involving pan-Nordic researchers and international partners in such inquiries. Clear added value emerges from the sharing of perspectives, resources and facilities. We need to do more of this type collaboration with researchers and funding agencies from across the Arctic area. We also need to ensure that young scholars and researchers are incorporated into such efforts.

The research results presented in the several chapters of this volume point to the benefit of maintaining a steady focus on the utilization of these findings by other knowledge users, stakeholders and policymakers. In this way, we are ensured that their concerns, questions and needs are being addressed as well as those of individual scholars. There must continue to be a clear demonstration of how Arctic research is responsive to such groups and to northern residents, in particular. In this manner necessary enthusiasm and resources for future studies of their needs and aspirations can be assured. It is absolutely necessary that dedicated support for such efforts continue and grow. In this manner Nansen's vision of undertaking a difficult but necessary path toward action in the North can be achieved.