Foreword to the special issue: climate change impacts, adaptation and vulnerability in the Arctic

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Abstract

The Arctic climate is changing, carrying wide-ranging implications for indigenous and non-indigenous inhabitants, businesses, industry and government across the circumpolar region. The latest scientific assessments indicate that change is happening faster than previously thought, and that the Arctic will continue to experience dramatic climate change in the future. This special edition of *Polar Research* brings together nine papers on climate change impacts, adaptation and vulnerability in the Arctic, providing important insights on the nature of the risks and opportunities posed by climate change in the circumpolar region, highlighting opportunities for policy response and providing insights on how to conduct effective climate change research with Arctic communities.

Climate change: the problem

The Arctic is now experiencing some of the most rapid changes in climate on Earth (Symon et al. 2005; Solomon et al. 2007), changes which have been documented by both the indigenous and the non-indigenous residents of the Arctic. In northern Canada, Inuvialuit hunters have witnessed more unstable and unpredictable ice conditions; in Norway, reindeer herders have noted changes in the accessibility of forage; in Russia, Viliui Sakha communities report that extreme cold, the so-called "bull of winter", is no longer as intense or prolonged; and fishermen in western Greenland report the changing abundance of commercial fish (Pearce 2005; Nickels et al. 2006; Tyler et al. 2007; Crate 2008; Ford, Smit et al. 2008; Keskitalo 2008a; Nuttall 2008). Many of these changes are locally described as having no precedent in living memory or oral history—a similar conclusion to that of scientists studying the instrumental data record (Stroeve et al. 2007 ; Comiso et al. 2008; Ford et al. 2009; Laidler et al. in press). Global climate models predict the continued and accelerated climate change in response to rising concentrations of greenhouse gases. The severity of these changes will depend on the extent to which emissions can be stabilized, although some degree of climate change is inevitable as a result of historic emissions (Parry et al. 2007). Lenton et al. (2008) illustrate that the Arctic is sensitive to even small changes in climatic conditions, because of the significant changes in climate already experienced and the sensitivity of the biophysical systems.

The majority of the Arctic's residents live in small to medium-sized communities, in many cases located in remote regions and dependent upon climate-sensitive livelihoods, including hunting, fishing, herding and forestry (Einarsson et al. 2004). This dependence on climate-sensitive resources and infrastructure will make the Arctic particularly sensitive to climate change (McCarthy et al. 2001; Symon et al. 2005; Parry et al. 2007). For example, hunting is an important economic and cultural activity for many of the Arctic's indigenous peoples, with success, safety and the ability to hunt being dependent on ice and snow conditions, and the availability and health of animals. Climate change is already threatening such activities, and raising questions about the long-term sustainability of traditional ways (Krupnik & Jolly 2002; Nickels et al. 2006; Krupnik & Ray 2007; Ford, Smit et al. 2008; Furgal & Prowse 2008; Seguin 2008). Likewise, the health of Northern residents is closely linked to environmental conditions, and there is evidence of new health risks as the climate changes (Furgal & Seguin 2006; Furgal 2008; Seguin 2008). On the other hand, benefits have also been noted by communities, including improved access to some wildlife species and reduced exposure to extreme cold.

Industrial activities, including resource extraction, forestry, manufacturing, and commercial fishing and whaling, are also important activities for indigenous and non-indigenous peoples in the Arctic. For these activities, climate change presents numerous risks: permafrost thaw is already damaging the infrastructure, including pipelines, airstrips, roads, buildings and water supplies; shorter ice seasons are reducing the ability to use ice roads to access remote mines and communities; and the changing composition of fish stocks is affecting the fishing industry (Nelson et al. 2002; Instanes et al. 2005; Couture & Pollard 2007; Martin et al. 2007; Ford, Pearce, Prno et al. 2008; Furgal & Prowse 2008; Keskitalo 2008a, b; Lange 2008; Nuttall 2008; Seguin 2008). New opportunities are also beginning to emerge for industry, as a longer ice-free, open-water season increases opportunities for shipping and mineral exploration (Stewart et al. 2007; Nuttall 2008). As Nuttall (2008) argues for Greenland, the continued melting of the inland ice cap and reduced sea-ice extent is increasing the opportunities for resource development, and with it the chances of political self-determination, and is being presented as such by the Home Rule Government of Greenland.

Climate change: the response and research contributions

International and national efforts to respond to the problem of climate change are guided by the United Nations Framework Convention on Climate Change (FCCC). The main focus of the FCCC has been to stabilize or reduce emissions responsible for climate change (known as mitigation), as embodied in the Kyoto Protocol to the FCCC. Adaptation, which seeks to develop measures to reduce or moderate the negative effects of climate change, and to take advantage of the opportunities, is also becoming important in climate policy (Smit & Wandel 2006; Ford et al. 2007; Pielke et al. 2007). This is driven in part by the realization that some degree of climate change is inevitable, and by the current impacts of climate change in vulnerable regions, particularly the Arctic (Pielke et al. 2007; Ford 2008a, b).

In the Arctic, *adaptation* is increasingly prominent in policy discussions, with national and regional governments, non-governmental organizations, communities, and national and international research bodies stressing the need to strengthen the ability of communities, regions, and economic sectors to adapt to current and future climate change (Budreau & McBean 2007; Ford et al. 2007; Ford 2008a, b). The Arctic Council, for example, identified "taking action to develop and implement local adaptation strategies for Arctic areas" as a key priority and objective for the council for the period 2006–2012 (Arctic Council 2007), and one of the main conclusions of the Arctic Climate Impact Assessment project (see Symon et al. 2005) was the need for research to support adaptation policy development. Moreover, adaptation research is increasingly important in major national and international research programmes with an Arctic focus, and is a guiding principle in the Arctic Council's Vulnerability and Adaptation to Climate Change in the Arctic initiative (Kelman & van Dam 2008).

To identify adaptation needs and inform the development of policies to reduce the negative impacts of climate change, it is crucial to identify and characterize *vulnerability* (Ford & Smit 2004; Furgal & Seguin 2006; Smit & Wandel 2006). Vulnerability can be thought of as the capacity to be wounded: it is a measure of the susceptibility to harm in a system in response to a stimulus or stimuli (Smit & Pilifosova 2003; Adger 2006). In the case of climate change—the focus of this special edition—the stimuli are climate-related risks, and the "system" can range from an individual or household unit to the nation state. It is widely accepted in the climate and environmental change literature that vulnerability is related to both exposure and sensitivity to climatic risks, and the adaptive capacity to deal with those risks (Kelly & Adger 2000; Turner et al. 2003; Reid & Vogel 2006; Smit & Wandel 2006; Ford in press).

The recognition of the role of adaptive capacity and sensitivity in vulnerability research emphasizes the importance of non-climatic factors, including sources of livelihoods, assets, access to resources, globalization, institutional networks, education, gender, race, ethnicity and poverty, in amplifying or attenuating vulnerability alongside the nature of the climatic stress. These determinants of vulnerability are influenced by social, economic, cultural and political conditions, and processes operating at multiple scales over time and space, and change in these non-climatic conditions play an important role in determining vulnerability to climate change (Ford & Smit 2004; O'Brien et al. 2004; O'Brien et al. 2007; Keskitalo 2008a). The complex nature of climate change vulnerability, shaped by climatic and non-climatic stresses at various scales, requires vulnerability assessment to include scholars with a wide range of disciplinary backgrounds, co-operation between the social and physical sciences, and working closely with communities and stakeholders (Turner et al. 2003).

In the field of climate change in general, vulnerability science is a well-established focus of research. Theoretical and methodological issues surrounding vulnerability have been discussed at length (Burton et al. 2002; Cutter 2003; Turner et al. 2003; Ford & Smit 2004; Adger 2006; Furgal & Seguin 2006; Fussel & Klein 2006; Smit & Wandel 2006; O'Brien et al. 2007; Polsky et al. 2007).

There is also an expanding body of research operationalizing the concept of vulnerability, and linking research to policy (Adger et al. 2001; Leichenko & O'Brien 2002; Pelling 2002; Bouwer & Aerts 2006; Thomalla et al. 2006; Leary et al. 2008). A key feature of this research is the integration of biophysical and social science perspectives, to understand and characterize climate change vulnerability.

Climate change vulnerability research in the Arctic has, however, been slow to develop and apply vulnerability approaches to climate change. Indeed, the majority of climate change research in the Arctic to date has focused on identifying and characterizing the nature of changes already observed, and modelling future impacts, with a strong biophysical focus (Ford & Smit 2004; Ford, Pearce, Gilligan et al. 2008). This is reflected in the largely technological and engineering-based responses that have been proposed for climate change adaptation, aimed at controlling and/or modifying physical conditions and processes. As highlighted by the Arctic Climate Impact Assessment project (see Symon et al. 2005) and the Intergovernmental Panel on Climate Change (Parry et al. 2007), only a limited number of empirical studies of climate change vulnerability in the Arctic have been published. This has limited the ability of international, national and regional government and organizations in identifying opportunities to adaptation. New research drawing upon vulnerability science, however, is beginning to conceptualize the complexities of human–environment interactions that shape vulnerability to a changing climate (Berkes et al. 2005; Huntington et al. 2007; Krupnik & Ray 2007; Ford, Smit et al. 2008; Furgal & Prowse 2008; Keskitalo 2008a, b). This is particularly the case in projects being conducted under the International Polar Year and national/regional initiatives, including ArcticNet, Global Change Vulnerabilities in the Barents Region: Linking Arctic Natural Resources, Climate Change and Economies (BALANCE), and Human Dimensions of the Arctic System (HARC).

The special issue, and new directions for *Polar Research*

This special edition of *Polar Research* sits in the context of the problems posed by climate change to indigenous and non-indigenous peoples in the Arctic, and the need for research to characterize climate change impacts, vulnerability, and to identify entry points for adaptation planning. The collection of nine papers brings together cutting-edge climate change vulnerability, impacts and adaptation research from across the Arctic. A number of key features characterize the papers in this edition. Firstly, they utilize community case studies to assess vulnerability to climate change. Place-based studies are essential for understanding the dynamics of vulnerability, and for linking research to policy (Ford & Smit 2004; Furgal & Seguin 2006; Keskitalo 2008b). Secondly, the research reported here involves significant interaction with communities, with local people acting as researchers, sources of information and reviewers of findings. Thirdly, many of the studies use multiple methods to develop insights on how communities experience and respond to change, with the authors representing multiple disciplines from the social and biophysical sciences. Fourthly, the focus is largely on characterizing the multi-scale determinants and processes shaping vulnerability, drawing upon rich descriptions and narratives of how people experience and respond to change. The aim is not to rank or develop indices of vulnerability, but rather to understand determinants and change over time. Finally, although the empirical work is conducted in an Arctic context, the insights and methodological development will be of interest to the climate change community in general.

The journal *Polar Research* strives to publish high quality and leading-edge work conducted in a variety of disciplinary fields focused on the polar regions of the world. Most recently, *Polar Research* has renewed its commitment to publishing research from all scientific disciplines, including the human and social sciences. Not since 2000, when a special issue of *Polar Research* comprised papers stemming from the Human Role in Reindeer/Caribou Systems Workshop (vol. 19, no. 1), has there been such a concentration of social science in the journal as is found in the current edition. As a truly multidisciplinary journal, *Polar Research* is the perfect vehicle for this series of papers, drawing on work in a variety of disciplines, and focused on the nexus of human, social, economic and natural systems in the Arctic.

The contributions

The special issue is divided into five sections: perspectives on climate change vulnerability research; resource management in a changing climate; traditional economy and climate change, natural hazards; and community sustainability in a changing climate. Figure 1 highlights the regional distribution of the research presented here.

Perspectives on climate change vulnerability research

The special edition begins with a paper by geographer Tristan Pearce, at the University of Guelph, and colleagues that outlines conceptual and methodological issues surrounding vulnerability research. The core of the paper is the development of a five-stage model for involv-

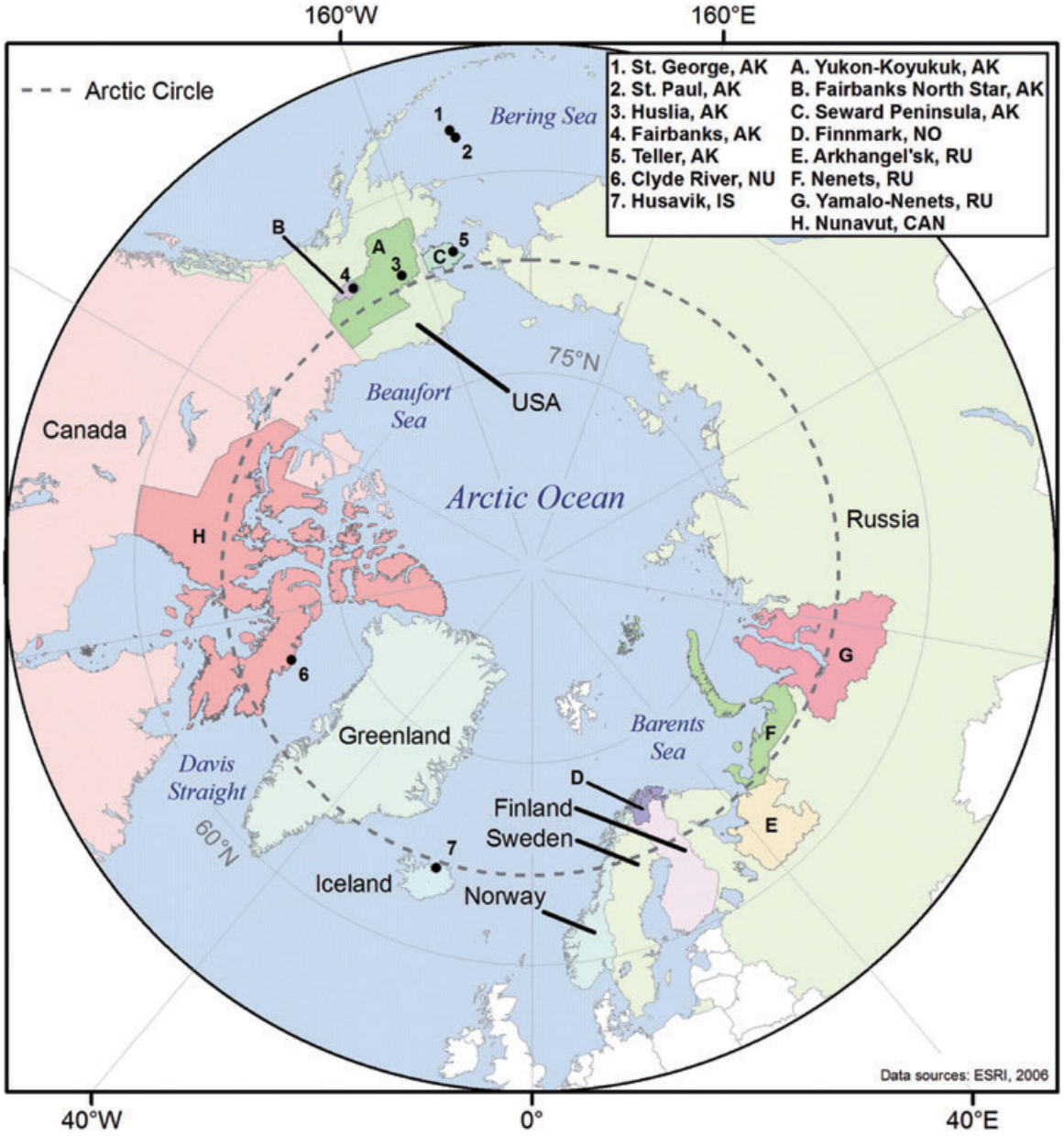

Fig. 1 Communities and regions covered by the contributions in this special issue.

ing communities in vulnerability research. Drawing upon the experiences of researchers, community members and representatives of indigenous organizations, the model provides a step-by-step practical guide of how to do vulnerability research and link research to the policy process. Although the article draws upon examples and experience from a Canadian Inuit context, the broad features of the model are applicable to participatory climate change research in general. Many of the subsequent contributions in this edition use key components of the participatory research described in this paper.

The second paper, by Bruce Forbes and Florian Stammler, of the University of Lapland, problematizes climate change vulnerability research in a Russian context. They point out that the majority of climate change vulnerability research in the Arctic has been conducted in a North American and European context, where indigenous groups are actively involved in academic and political discourse surrounding climate change and resource management. They argue that in a Russian context, however, Western scientific approaches and concepts used in climate change research elsewhere are not

viable, particularly with regards to Nenets reindeer herders. What they offer is a critique of the theory and practice of community-orientated research in modern Arctic Russia, presenting climate change discourse as a Western-framed concept that communities often do not perceive as happening, or see as being a topic of only marginal interest. The authors review a number of projects that have been undertaken with Nenets reindeer herders, and argue that projects that best fit local needs are those developed to address locally-identified priorities. Land rights, oil and gas development, and meeting everyday needs emerge as key issues in this regard, not climate change, which they argue is a scientifically framed problem and not a community concern in the Yamal–Nenets region of Russia. In this regard, Forbes and Stammler argue that climate change insights can be developed from projects focusing on broader social and economic concerns, as opposed to climate change per se.

Resource management in a changing climate

Next, three papers examine climate change vulnerability, impacts and adaptation in the context of resource management. Natural resources are particularly important in an Arctic context, underpinning subsistence livelihoods, and providing jobs through commercial activities. Their management in light of climate change and other stresses represents one of the major challenges facing communities and policy makers in the 21st century. The first paper in this section is by geographer Martha Dowsley of Lakehead University. The paper puts forward the idea of a new level of governance in co-management systems that would provide a vertical link between individual traditional ecological knowledge holders and legislated co-management bodies. This new level (termed a community cluster) would also provide a horizontal link between communities involved in the management of a shared resource. Using examples from the polar bear co-management system in Nunavut, Canada, Dowsley shows how community clusters can improve equity for resource users in management, improve efficiency in resource monitoring and management decision making, and improve system response times in an era of rapid environmental change.

The fishing industry is an important economic activity for communities across the circumpolar North, and is an activity that is sensitive to changing ocean temperatures. Political scientist Carina Keskitalo and economist Antonina Kulyasova assess the vulnerability of this important sector to climate change, drawing upon empirical research with communities in northern Norway and north-western Russia. The paper begins, however, on a more theoretical tone, examining how adaptive capacity at the local level is shaped by multi-level governance structures. This is an important point: the ability of individuals and communities to adapt, in many instances, will be constrained by political decisions made at regional, national and international levels. The empirical work highlights the vulnerability of the fishing sector to climate change, particularly in Russia, where limited social security provisions limit the possibilities for adaptation. Moreover, local vulnerability is observed to differ on the individual level, depending on fisherfolk's access to quotas. Ultimately, adaptive capacity for coastal fishing is constrained by conditions beyond the local community; adaptation action should focus on these broader constraints.

The final paper focusing on wildlife resources in a changing climate assesses the vulnerability of reindeer herding in the Seward Peninsula, Alaska. In this paper, Kumi Rattenbury, of the National Park Service, and colleagues at the University of Alaska Fairbanks follow native herder James Noyakuk through a complete annual herding cycle. Interviews are complemented with the collection of real-time weather station data to develop an understanding of how socio-economic and climatic factors affect reindeer herding. In particular, the study focuses on vulnerability and adaptive capacity of reindeer herding in the context of a recent downturn in reindeer herding caused by the mixing and outmigration of domesticated reindeer with wild caribou herds. The research documents a number of strategies that are currently being employed to manage the downturn in reindeer numbers, all of which involve preventing reindeer mixing with caribou. Tactics include the monitoring of reindeer and caribou locations through satellite collars and increased travel to the ranges, combined with moving reindeer when necessary, and/or retaining reindeer in caribou-safe refugia or enclosures. A number of constraints to adaptation are identified, including the small size and low economic returns associated with having a small herd of a few hundred animals and a low market price for reindeer: constraints that in this case have forced James Noyakuk to seek alternative sources of income to support his reindeer-herding activities. Equally, local and national institutions, alongside collaboration with university-based researchers, have facilitated some adaptive responses.

Traditional economy and climate change

Moving from the management of wildlife to the cultural implications of climate change, George Wenzel, at McGill University, brings an anthropologist's perspective to the debate, drawing upon over 30 years of research in Clyde River, Nunavut. Specifically, the paper focuses on the

intersection between climate change and the material aspects of Inuit resource production and the traditional economy. Situating current climate change in the context of the palaeoclimatic record, he argues that, theoretically, the Inuit should be able to adapt to climate change. In particular, he highlights how the Canadian Arctic's Thule Culture peoples thrived during the warmer conditions of the Neo-Atlantic Period (also known as the Medieval Warm Period). However, Wenzel identifies a number of factors that will constrain the ability of the Inuit to adapt to climate change in a contemporary setting. In particular, national and international wildlife management regulations, the vulnerability of "fall-back species", including ringed seal, to climate change, and the sedentary nature of contemporary Inuit habitation are identified as potential adaptation constraints. The conclusion that Inuit can adapt, but that considerable negotiation will be required between the Inuit and the non-Inuit at multiple levels, is particularly pertinent.

Natural hazards

Climate change will alter the magnitude and frequency of natural hazards across the Arctic. Sarah Trainor, of the Alaska Center for Climate Assessment and Policy, and colleagues explore differences in vulnerability to climate-induced changes in the fire regime in Alaska. Using a multiple-methods approach, they highlight how sensitivity to an altered fire regime will be greater in rural areas because of weak governance and limited fire suppression by individuals. Urban areas generally have a well-developed fire management programme, based on strategically directing fire response to protection through the removal of forest fire fuel. This regime has evolved significantly in recent years, moving away from a traditional focus on firefighting, the limits of which have become evident in the context of limited resources and growth of the wildland–urban interface. Although this evolution in management regime has not occurred in response to climate change, it nevertheless highlights the importance of social learning in the context of changing conditions. The paper finishes by making a number of recommendations for fire management in the context of a changing climate, including continued fuel reduction programming and land-use zoning to reduce exposure in urban areas.

Community sustainability in a changing climate

Communities on the Pribilof Islands in Alaska—like many regions of the Arctic—have undergone rapid social and economic change in the last few decades, with the end of the commercial fur seal hunt in 1984 challenging the economic sustainability of small resource-dependent villages. Henry Huntington and colleagues collected baseline social and economic data for the communities of St. Paul and St. George to develop an understanding of the social–ecological system of the two communities. One of the paper's major findings is that environmental conditions and population trends are not connected; indeed, the relationship between environmental conditions and socio-economic indicators in general is weak. The findings suggest that social–ecological systems in the Pribilofs are resilient to changes in environmental and economic conditions. Several explanations are offered for this resilience, including the importance of transfer payments and support from the government, the ability of the communities to leverage financial support from government, and the tolerance for uncertainty and attachment to place. Notwithstanding, pockets of vulnerabilities among certain groups were detected at periods of stress, such as the decline of the snow-crab fishery, although the vulnerability is constrained to individuals and directed by personal circumstances. The authors caution about the need for more data to reinforce key arguments, but these preliminary findings suggest a high level of adaptability in the Pribilof Islands to change, including climate change.

Understanding the complex interactions and linkages of social and ecological systems and institutions, at various scales, provides an important baseline from which to examine community vulnerability and resilience to climate change. To this end, Niels Einarsson, of the Stefansson Arctic Institute, examines how local inhabitants in the fishing village of Húsavík in north-east Iceland reconcile opposing views of whales, whaling and the emerging whale-based tourism sector at a time of environmental and economic stress. The article documents how changes in the Icelandic fisheries management system, including the reduction of quotas, resulted in decreased flexibility and greater responsiveness to external shocks in the social and ecological systems of coastal Icelandic communities. In the case of Húsavík, this externally imposed shock did not lead to a chaotic collapse, but rather to reorganization, with innovation and new opportunities. The paper highlights the adaptability of Northern communities to externally imposed change, with the local open-ness for alternatives and diversification combined with an enabling political environment, underpinning community adaptability.

Conclusion

The papers in this special edition demonstrate that climate change is being observed in all regions of the Arctic, posing risks and opportunities. Moreover, the research provides generic insight into how communities

experience and manage change in general. The studies highlight that the specific nature of vulnerability to change differs widely across the Arctic, depending on community structure, dynamics, history, economy and dependence on natural resources. Notwithstanding, there are many similarities in terms of the determinants of vulnerability and how systems in general respond to change.

Firstly, despite pronouncements of the high vulnerability of Arctic communities to climate change (McCarthy et al. 2001; Symon et al. 2005; Parry et al. 2007), many of the studies described in this special issue show a high degree of adaptability to change. Indeed, change in many instances has resulted in community reorganization with innovation, to take advantage of new opportunities and to minimize risks. In other cases, changing conditions have been exploited for the new opportunities provided. Commonly identified facilitators of adaptability include flexibility in resource use, strong community networks, acceptance of and experience with uncertainty, social learning and government support. However, caution must be taken when extrapolating these findings so as to understand vulnerability to future climate change. Constraints to adaptation were noted in all of the papers, and continuing social, economic and political change is likely to have implications for future adaptive capacity, some of which will undoubtedly be negative. Moreover, models indicate that future climate change will be of a higher magnitude and occur faster than the changes experienced so far (Holland et al. 2006; Comiso et al. 2008); in this context adaptability to changes already experienced, although providing important insights, may not necessarily enable communities to adapt to future climate change.

Secondly, vulnerability to climate change in the Arctic is determined by the complex interaction between human and biophysical systems, shaped by processes and changes at multiple spatial and temporal scales. As Keskitalo and Kulyasova argue in this issue, adaptation policy must take into account these cross-scale determinants of vulnerability if it is to be effective. Indeed, in the majority of studies reported here it is broader-scale social, cultural and economic stresses that will constrain or enable adaptability to future climate change. With many Arctic communities existing on the periphery of national and globalized political and economic systems, the ability to control or have a direct say in these broader developments is likely to be limited.

Thirdly, the papers in this special edition are from researchers in diverse disciplines, highlighting the importance of interdisciplinary perspectives when assessing climate change vulnerability and adaptation. Moreover, the papers represent contributions from researchers working in diverse regions. As Forbes and Stammler caution, however, approaches for assessing vulnerability in the North American and European Arctic may not be directly transferable in a Russian context. Indeed, as Pearce and colleagues note, tailoring research objectives and approaches to suit local needs, priorities and context should be a priority for future climate change vulnerability research.

What this special edition has ultimately demonstrated is that climate change vulnerability and adaptation research is an emerging field of Arctic research, the importance of which is increasingly being recognized. A number of projects being conducted under the International Polar Year, for example, specifically aim to further understand vulnerability (e.g., Community Adaptation and Vulnerability in Arctic Regrions [CAVIAR]). It is important that climate change vulnerability and adaptation continues to be funded once the International Polar Year is complete.

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