ICARP II – SCIENCE PLAN 10

A RESEARCH PLAN FOR THE STUDY OF RAPID CHANGE, RESILIENCE AND VULNERABILITY IN SOCIAL-ECOLOGICAL SYSTEMS OF THE ARCTIC

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PREFACE

The Second International Conference on Arctic Research Planning (ICARP II) was held in Copenhagen, Denmark from 10 November through 12 November 2005 and brought together over 450 scientists, policy makers, research managers, indigenous peoples, and others interested in and concerned about the future of arctic research. Through plenary sessions, breakout sessions and informal discussions, conference participants addressed long-term research planning challenges documented in twelve draft research plans. Following the conference drafting groups modified the plans to reflect input from the conference discussions and input from the ICARP II web site. This science plan is the culmination of the process.

ICARP II Science Plans

Science Plan 1	Arctic Economies and Sustainable Development
Science Plan 2	Indigenous Peoples and Change in the Arctic: Adaptation, Adjustment and Empowerment
Science Plan 3	Arctic Coastal Processes
Science Plan 4	Deep Central Basin of the Arctic Ocean
Science Plan 5	Arctic Margins and Gateways
Science Plan 6	Arctic Shelf Seas
Science Plan 7	Terrestrial Cryospheric & Hydrologic Processes and Systems
Science Plan 8	Terrestrial and Freshwater Biosphere and Biodiversity
Science Plan 9	Modeling and Predicting Arctic Weather and Climate
Science Plan 10	A Research Plan for the Study of Rapid Change, Resilience and Vulnerability in Social-Ecological Systems of the Arctic
Science Plan 11	Arctic Science in the Public Interest
Background Document	Contaminants

10.1. Introduction

How should research best address the challenges of arctic sustainability in a world of rapid change? What determines the limitations of adaptation when a system is approaching a critical threshold? What are the social-ecological consequences when critical thresholds are crossed and new conditions emerge? How best do we determine the indicators of social-ecological resilience and frame the analysis of vulnerabilities? How can we best structure human institutions and social organization to build resilience while facilitating adaptation in conditions of rapid change? And how should arctic residents and researchers collaborate to answer these questions?

This ICARP II science plan outlines key research questions concerning the study of rapid change, resilience and vulnerability in social-ecological systems of the Arctic and proposes an approach for implementing this research. There is a particular focus on the resilience and vulnerability of rapid change to local communities of the Arctic. This science plan is not intended to restrict individual research efforts that may deviate from the ideas expressed here, nor is it considered to be all-inclusive in scope. Instead, this science plan is intended to identify a broad set of themes and questions worthy of research over the next decade, and to provide a unifying framework that will help coordinate comparative integrated international research. Given the interdisciplinary cross-cutting nature of this science plan, it is proposed that this also serves as an overarching framework for linking the full set of ICARP II science plans.

The definition of "the Arctic" used in this ICARP II science plan is aimed at capturing the social, economic, political, and ecological processes that are critical properties for the functioning of the Arctic System. Thus, it is not limited to more restrictive definitions, such as that region north of the Arctic Circle or north of tree line, but is viewed as a region integrated within the Global System.

10.2. A Rapidly Changing Arctic

The Arctic Climate Impact Assessment (ACIA, 2004), the Arctic Human Development Report (AHDR, 2004), and Reindeer Herding and Hunting Economies and the Status and Management of Wild Reindeer/Caribou Populations (Ulvevadet and Klokov, 2004) are three recent Arctic Council reports that document conditions of bio-physical, ecological, social, and economic change in the Arctic, and provide a starting point for the work proposed in this ICARP II science plan. Arctic climate trends show a dramatic change, including an increase in annual average temperature of 3 to 4 ºC in some regions of the Arctic, which is nearly twice that of other regions of the world. Gross-level landscape responses include the thawing of permafrost, the melting of glaciers, and changes in hydrological processes that are affecting ground cover vegetation and oil and gas exploration. In several cases, climate change has caused a shift in the distribution of some keystone species (e.g., moose and salmon), making access to some traditionally used resources more difficult and risky, while making other resources more available. Climate change has also extended the life cycle and geographic range of certain wildlife parasites, and has put some species, such as polar bear and Peary caribou, at serous risk.

A warmer and dryer Arctic is likely to result in an increase in the frequency, severity, and duration of wildfires – with implications for ecosystem services (Chapin et al., 2003, 2004). An increase in storm surges in coastal areas is likely to result in an increase in the rate of coastal erosion and this has already forced residents of some Alaskan communities to move forward in assessing options for costly village relocation. Some of the most dramatic issues raised in the Arctic Climate Impact Assessment (ACIA, 2004) are projections by some climate models of an almost complete loss of summer sea-ice cover by the end of this century. Seasonal opening of the Northern Sea Route is likely to make trans-Arctic shipping during summer feasible within several decades. This would open new northern shipping trade routes and would bring significant economic activity to coastal regions both at sea and on land, however it would also create new risks (e.g., oil spills) and a potential need for marine protected areas in the Arctic. These protected areas would be likely to lead to internationally contested claims for property and struggles to assert local harvesting rights. And while the impacts of a rapidly

warming Arctic may be important to the North, they also have implications for the Global System by potentially modifying ocean salinity and currents, and reducing rates of carbon sequestration, and thus, increasing emissions of greenhouse gases to the atmosphere.

From a more human perspective, the Arctic Human Development Report (AHDR, 2004) noted that the continued interest in exploitation of northern resources is bringing an increase in human infrastructure and an expansion of the human footprint. In many cases these changes are occurring with inadequate environmental policies for assessing impacts and conducting land- and sea-use planning. Human in- and out-migration trends show a modest overall population increase in the Arctic, with a trend towards greater urbanization, an increase in the outflow of residents, and a shift by several groups from tundra dwelling to city dwelling. If the current trend of urbanization continues, it is likely to lead to an increased demand for harvested fish and wildlife resources and thus, future challenges to rural and indigenous subsistence harvesting rights. Social trends in the Arctic also show an ongoing loss of indigenous language and an overall transformation of traditional ways of living.

In Russia, where around 15,000 people continue to follow a nomadic way of life, the problems of rapid change are striking. The collapse of the Soviet Union's highly centralized political system reduced and in some cases eliminated support for residents in northern hinterland regions, leaving many in dire conditions with limited opportunities for improvement. In many parts of the Russian Arctic and other northern regions, people struggle with poor living conditions, limited political rights for self determination, and problems associated with general social dysfunction, such as alcoholism and suicide.

However, the Arctic also provides many examples of institutional innovation through indigenous governance, devolution, and community–state power sharing, such as the Sámi Council, the many co-management regimes for marine mammals in Alaska, the system of governance for Nunavut in Canada, and the implementation of Home Rule in Greenland. The results of these innovations have been mixed, and there is considerable speculation as to their effectiveness and future development. These institutions do, however, represent important changes to previous political processes and provide opportunities for research to understand their implications to resource sustainability and human wellbeing in the Arctic and beyond. The Arctic Human Development Report (AHDR, 2004) calls attention to global–to–local level processes, and highlights the concern that global environmental and social changes may overwhelm efforts to implement regional initiatives successfully.

The Reindeer/Caribou Report of the Arctic Council (Ulvevadet and Klokov, 2004) gave examples of arctic social-ecological change and feedback effects. The collapse of the Soviet Union removed many of the government-maintained markets for reindeer meat, which in turn quickly and dramatically reduced traditional herding activities in many but not all regions, and later led to increases in wild reindeer populations. These conditions contrast with the Alaskan Arctic where an increase in the population of the Western Arctic Caribou herd led to an expansion of the herd's range, which overwhelmed domestic reindeer herds of the Seward Peninsula, reduced the number of domestic reindeer, and dramatically affected the viability of commercial herding. What is noteworthy about both these cases is how social and ecological feedbacks contributed to the crossing of critical thresholds, which in turn, dramatically transformed the systems and led to new sets of problems.

All three reports show that the Arctic is closely coupled to the external (non-Arctic) environment and is highly dynamic. Also, that the drivers of change in the Arctic, while dominated by external processes, are increasingly internal as greater interdependence emerges through processes of globalization. Thus, rapid change in the Arctic raises questions about how the various forces for change may interact and affect the capacity for human adaptation. These conditions also highlight questions regarding which variables ultimately govern the fundamental properties of the Arctic System and what is the potential of humans and or climate change to modify those processes in an environment of low biological diversity, limited human and material resources, and limited political and economic autonomy.

Concern regarding rapid change in the Arctic is not new; rapid change has been a central theme in arctic research for decades. Since the Second World War much of this research has focused on social and environmental change and their impacts on northern society. In retrospect, it is apparent how centralized institutions controlled by governments further south and with policies of colonialism, have promoted an open access view of the Northern Commons. In many respects, the colonialist view has contributed to the dramatic transformation of northern indigenous cultures. Today, permanent human settlements have replaced hunter-gatherer nomadism, rigid political boundaries delineate jurisdictions, local cash-subsistence economies are well integrated and highly dependent on central government transfer payments from wealthy Nation States (except for Russia), and processes of economic globalization extend to the most remote settlements. Ironically, social anthropology of the Arctic of that early era (and before) highlighted the highly adaptable characteristics of traditional indigenous arctic cultures, noting geographic mobility, opportunistic forms of subsistence hunting and gathering, and flexible forms of social organization. The characterization of arctic indigenous peoples as exceptionally resilient persists (AHDR, 2004), yet the types and overall rate of change in the Arctic today is unprecedented. This suggests the need to move away from a framing of indigenous northern people as inherently adaptive, and towards a focus on today's unique co-evolution of social and ecological systems.

10.3. Social-Ecological Systems as a Recommended Unit of Analysis

Addressing these problems requires that ecological, economic, and social dimensions be considered in an integrated fashion. Several groups have been at the forefront in developing interdisciplinary approaches in the study of human-environment relations and sustainability (Berkes et al., 2003a; Chapin et al., 2004; Folke et al., 2002), yet the challenges of undertaking research in conditions of rapid change in the Arctic make for special analytical problems and a rethinking of commonly held assumptions (e.g., assumptions of equilibrium, linearity of change, and/or immediate response).

To achieve an integrated analysis of rapid change, this ICARP II science plan proposes that *social-ecological systems* serve as a primary unit of analysis, on which an interdisciplinary program of northern research can build on recent theoretical developments in theories of resilience, vulnerability, and complexity (Adger, 2000, 2006; Berkes et al., 2003b; Gunderson and Holling, 2002), and proposes research that considers the linkages of change across various scales of time and space. This approach calls for an understanding of emergence and the behavior of complex adaptive systems (Janssen, 2002), and a need to identify the feedbacks between and among social and ecological aspects of the system. Finally, there is a need to understand the properties that govern these processes to appreciate better the implications of rapid change and its novel conditions to human wellbeing.

This ICARP II science plan makes the assumption that sustainability is a dynamic and normative construct that is inextricably tied to human objectives and human-defined targets. Recent research in North American arctic communities identified five sustainability goals including: 1) use of, and respect for, the land and animals in their homelands; 2) a cash economy that is compatible with, and supports, continued local use of the land, sea, and animals; 3) local control and responsibility for what is done in village homelands and what happens to resources used by the community; 4) education of younger people in both traditional knowledge and western science, and education of the outside world about community goals and ways of living; and 5) a thriving culture that has a clear identity and is based on time on the land and respect of elders (Kruse et al., 2005). Similarly, interviews conducted by RAIPON (Russian Association of Indigenous Peoples of the North) of 400 indigenous residents throughout the Russian North, Siberia, and the Far East identified five dimensions of sustainability, including spiritual, social, economic, environmental, and legal elements (Haruchi, 2001).

While the underlying values and targets of sustainability differ among individuals and culture groups and may change over time, all residents of the Arctic are dependent upon ecosystem services, which in turn, are critical to human development. For this reason, it is important to clarify human values and to ascertain the interrelated links between sustainable ecosystem services, human development, and social institutions that foster that development and resilience to change. While a focus on social-

ecological systems and their relationship to resilience may provide insights that are useful for successful adaptation, researchers must also break new theoretical and methodological ground to understand better the processes of social learning and the opportunities for and limits to mitigation. Moreover, there is a need to understand how rapid change occurs across different scales of time and space.

10.4. Key Concepts of Resilience and Vulnerability

The focus of this ICARP II science plan on resilience and vulnerability follows from interdisciplinary scholars who approach questions of sustainability with the assumption that all social-ecological systems have inherently complex and on-going dynamic processes. *Resilience* is defined here as the capacity of a system to absorb disturbance and reorganize while undergoing change so as to retain essentially the same function, structure, identity, and feedbacks (Walker et al., 2004). This definition is distinct from that of engineering applications, which assume resilience as a rebounding to a previous condition. A resilient social-ecological system can withstand shocks and rebuild itself and may undergo those changes incrementally and or through dramatic modifications. Thus, the concept of resilience provides a way of studying how systems persist, transform themselves, or collapse. While several studies have applied resilience theory to northern case studies, a systematic and comprehensive application in arctic research has not been undertaken.

The boundaries of coupled social-ecological systems are best defined by the specific problems and subsystems being addressed in research. For example, the study of the effects of rapid change on subsistence in local communities of the Arctic would include the analysis of a broad set of variables, such as global climate trends and their effects on ecosystems, hunting and herding patterns and users' access to resources, the community's wage economy and its contribution to the support of hunting along with its impacts on ecosystems, a group's sense of identity as hunters and herders, their local knowledge of resources, institutions that support the tradition of sharing, the protection of species, and interactions with state agencies charged with jurisdiction over shared resources. Social-ecological systems represent an interaction of processes occurring at multiple scales (termed "panarchy") and within and across scales that manifest a unique complex of emergent conditions (Gunderson and Holling, 2002). Figure 10.1 illustrates key factors to be considered in a social-ecological system. Future theoretical development will require more explicit linkages between the Arctic and other global components.

Resilience theory suggests that social-ecological systems have *domains of attraction* in which the system remains constant in its functionality. Thus, the modification of properties beyond critical thresholds can move social-ecological systems to a variety of stable states. Critical in the assessment of social-ecological systems and their transformation is the identification of "control variables," which are typically slow to change and which regulate key systemic properties (e.g., nitrogen levels in soil, building of social capital or trust relations among social groups, rate of lichen growth). These variables are typically not adequately considered by policy makers, with faster changing variables capturing public attention.

The concepts of *adaptability* and *transformability* add to the vocabulary of resilience theory, with *adaptability* being the capacity of actors to influence resilience; and *transformability* being the capacity to create a fundamentally new system (Walker et al., 2004). *The adaptive cycle* describes sequential patterns of growth or exploitation (r), conservation (K), collapse or release (Ω), and reorganization (α) (Figure 10.2) The back loop of the adaptive cycle is useful in explaining the emergence of innovation and novel change, which may follow from the system's dysfunctional rigidity (Berkes et al., 2003a). However, the adaptive cycle model is probably best applied to closed systems, and may need further modification to address the Arctic as a recipient of global forces for change. Following from the conditions of the Arctic, the current ideas of resilience may also need to accommodate better the patterns or "waves of arctic exploitation model," explored by Sugden (1982) and others (e.g., Berkes, 1989).

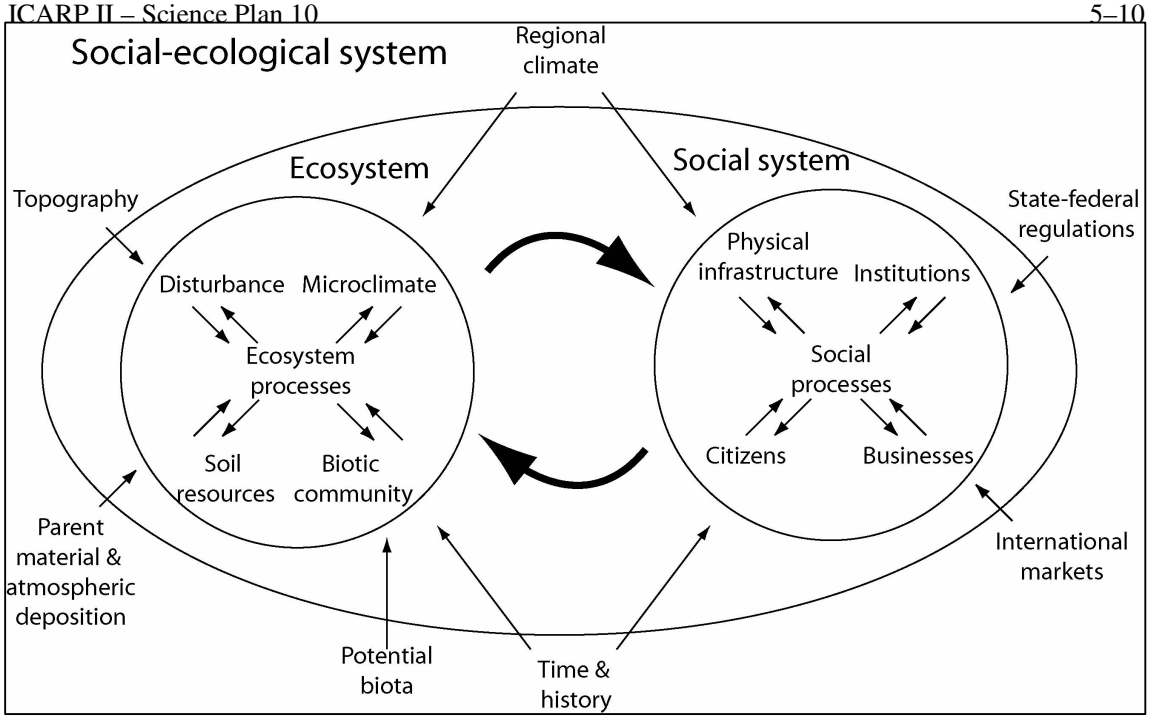

Figure 10.1. A social-ecological system consists of ecological and social subsystems that strongly influence one another at local and regional scales. For each subsystem there are external factors (e.g., regional climate and international markets) that are not influenced by local conditions (known as state factors by ecologists) and internal factors (e.g., institutions or disturbances), which respond to external factors and which both affect, and are affected by local processes (known as interactive controls by ecologists) (Whiteman et al., 2004).

The focus on resilience also has potential to contribute to the long debates on whether northern ecosystems are "fragile" and/or robust in their response to human activity (e.g., oil and gas development). In many cases these debates have been underpinned by preservationist ideologies and rhetorical discourse. A resilience approach to social-ecological systems applied to the study of rapid change promises better analytical precision and depth.

This ICARP II science plan suggests that the concept of vulnerability is complementary to resilience considerations, by forcing clarity in a system's sensitivity to various types of change and their consequence, while concurrently accounting for the system's capacity to buffer against change (Polsky et al., 2003). Vulnerability is therefore a function of the exposure to effects of change on a social-ecological system plus the capacity of that system to deal with that exposure (Ford and Smit, 2004). In this respect, vulnerability is measured not only by exposure to hazards alone, but also resides in the resilience of the system experiencing the hazard (Turner et al., 2003). Much of the literature on resilience and vulnerability has been segregated to date by exploring each concept separately (Janssen et al., 2005). There has been recent interest in linking these two streams and a preliminary framework for the analysis of arctic vulnerability, such as that developed by McCarthy and Long Martello (2005). But these considerations raise the question of whether resilience and vulnerability should be considered an inverse relationship (as suggested by Folke et al., 2002), whereby an increase in resilience results in a decrease in vulnerability. These questions remain unanswered, and the integration of these two streams of analysis is an area ripe for intellectual development.

10.5. Linking Resilience, Institutions, and the Policy Process

Since many of the key control variables that determine the properties of high-latitude ecosystems are undergoing rapid directional change, it is virtually certain that the current properties of these systems will continue to change and that efforts to keep the Arctic in its current state will fail (Chapin et al.,

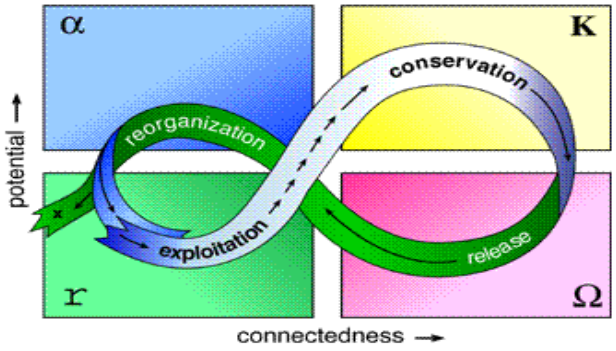

Figure 10.2. The adaptive cycle (Gunderson and Holling, 2002).

2006). Given the trajectories of change already underway, policies aimed only at preserving the system, such as reducing greenhouse gas emissions, are less likely to be successful if they are not linked to the enhancement of the system's resilience and adaptive capacity. To address this issue, it is suggested that future arctic research be organized to examine human responses to change, and specific strategies and their effectiveness in dealing with the potential effects of rapid change.

Formal and informal institutions for resource governance represent human strategies that have been framed in functionalist terms to explore if and how "rules of the game" serve social collectives to economize transaction costs, monitor ecosystems (including humans), resolve conflicts, network parties, and allow for local self organization, while coordinating decision making at greater scales (e.g., local-decision making bodies to regional and national level processes of governance) (National Research Council, 2002; Ostrom, 1990). Many studies of arctic institutions have in the past included a strong emphasis on periphery-core power relations, the effectiveness of power-sharing or co-management arrangements, and the socio-cultural and psycho-social benefits of self determination. Some research has addressed the role of informal institutions (e.g., customary laws), their functional qualities in the adaptive process, and interaction (and sometimes erosion) when confronting formal state systems. The current conditions of rapid change suggest the need to shift the focus of future studies to understand how human institutions and social organization function as adaptive systems that promote social learning and resilience building (Berkes et al., 2005). The link between sustainability, resilience, and the responsiveness between local groups who are close to resources, and regional, national, and international level bodies has been noted (Berkes et al., 2005; Folke et al., 2002; Young, 2002). Recent research has identified design principles of robust institutions in social-ecological systems (Anderies et al., 2004), explored the problems of adaptive governance of commonly shared resources in a global context (Dietz et al., 2003), and examined institutional and organizational characteristics of adaptive capacity that build resilience (Berkes et al., 2003b). However, while the objectives of resilience building and adaptive co-management are laudable, in practice elected governments typically strive towards maintaining conditions of stability. How can social actors striving toward a system of adaptive governance overcome these and other barriers? To what extent are these barriers related to societal views of uncertainty?

An overarching hypothesis explored by the working group in drawing up this ICARP II science plan is that the overall vulnerability of social-ecological systems to negative change can be reduced by maintaining a focus on local communities. A corollary is that communities with the capacity to slow the key drivers of change are more likely to cope with change and maintain the flow of important ecosystem services. Much evidence indicates that institutions that are close to the resources, and that are flexible, diverse, and receptive to feedback from the environment stand a better chance of success in responding to change than top-down, centralized management systems (Berkes and Folke, 1998). The working group also hypothesized that a community-based focus helps build grounded theory and practice, and at the same time, helps develop a more sophisticated understanding of how cross-scale

linkages and external drivers shape interactions. To this end, this ICARP II science plan proposes that future research examines the role of social institutions in broad-scale social learning in the arctic context. In endorsing this new area of research the working group noted that it has been suggested that some northern institutional arrangements in North America, which were hailed at implementation as important innovations towards sustainability (e.g., co-management and self governance arrangements) are today falling short of meeting their stated basic objectives. In other areas, systems of indigenous governance continue to struggle in securing the rights necessary for future development of traditional ways of life (e.g., in Fennoscandia and the Russian Arctic) (Forbes, 2004, 2006; Golovnev and Osherenko, 1999). This suggests that there is also need for a systematic retrospective review of institutional performance and its implications for sustainable futures.

It should also be pointed out that although there are strengths in a resilience approach, the current work of resilience theory generally does not adequately address issues of equity. Like the study of sustainability, any study of social-ecological change must include explicit mention of the questions, "resilient for whom and to what?" Yet as suggested above, a balance in the distribution of power in human decision-making potentially enhances systematic resilience. The diversity of common property management arrangements in the Arctic and the prominent role of indigenous peoples of the north will provide a strong basis for this research, as will its non-indigenous communities (e.g., fishing communities of northern Norway). This work cannot be passive in its approach. To make meaningful links between research and policy will require the involvement of stakeholders and decision makers in all phases of the research process.

10.6. Key Questions and Research Themes

To focus this research, this ICARP II science plan identifies a set of five general research questions.

How do we best characterize patterns of rapid social-ecological change in the Arctic?

Descriptions of rapid change in the Arctic are often presented with little specificity regarding temporal and spatial scales. Rapid change measured at a regional scale may be revealed as a mosaic of heterogeneity with high variability. Rapid annual change may be shown to be insignificant when portrayed at a decadal or multi-decadal scale. Also, change is experienced and perceived by different people in different ways. Indigenous perspectives on rapid social-ecological change in the Arctic are often based on long-term relationships with land and animistic views of nature. Such perspectives can be in tension with those deriving from short-term and quantitatively based data and western science.

Therefore, this ICARP II science plan encourages systematic studies of the characterization of forces for rapid change in the Arctic that include quantitatively based bio-physical analyses of trends coupled with cultural perspectives and psycho-social considerations. Excellent work has been initiated in this area but more is needed. Climate studies show how trajectories of rapid warming are accompanied by increased variability and extreme weather events. Other studies suggest the possibility of abrupt regime shifts in climate. How do we compare rates of change of urbanization, climate, and land use? How do they interact and how do their rates of change affect those interactions? At what point do we move from modest to rapid rates of change? How should we portray multiple and interacting forces for change in research, and thus begin the analysis of cumulative effects? To what extent is rapid change in the Arctic internally and/or externally driven? To what extent is rapid change the result of individual choice or collective action?

What are the attributes of social-ecological sub-systems and their linkages to the Arctic System that are vulnerable or resilient to rapid change?

What are the vulnerabilities of arctic communities to the rapid onset of infusions of cash both from jobs, transfer payments, and or royalties? What are the sources of resilience to large-scale resource development, external boycotts of marine mammal products, shifts in national policies relating to reductions in transfer payments, and other forces for change? What are the sources for building

resilience in arctic systems? This ICARP II science plan suggests that all social-ecological systems can be endowed with assets that both contribute to their resilience and make them vulnerable, depending on their context and forces for change. In many cases there is a mix of conditions that both contribute and constrain an adaptive response. For example, an arctic social-ecological system may have high landscape diversity fostering ecological adjustment, but may also have low species diversity that can lead to large shifts in biological communities. Its residents may have jack-of-all-trades skills, which allow for adjustment to a range of employment opportunities, but which also make them relatively unskilled and thus unable to capture high-end salaries. Elucidating these attributes is a first step in identifying broader patterns that will lead to more generalizable principles.

How are the attributes of resilience modified in rapid, abrupt, or gradual change? Rapid change is likely to generate a unique type of stress because of the constraints it places on response time for detection, learning, and adaptation. Do resource management systems operating at maximum levels of production, such as those currently employed in some "rationalized" fisheries or reindeer management regimes, leave less room for adjustment? Do precautionary approaches allow more room for error and modification of policies in response to uncertainties? What are the trade offs associated with these approaches?

This work needs to be explicit about how to quantify and recognize resilience and vulnerability. For example, research could analyze patterns of change to determine which response variables changed to a greater extent (vulnerable) or lesser extent (resilient) than the rates of change in drivers. Empirical research is needed to test the hypothesis that slow variables of the Arctic are the most critical in assessing resilience. Similar analyses could be undertaken with respect to response to multiple stressors, to look for interactions. To meet this objective, extensive work must be undertaken to identify key *indicators of resilience and vulnerability*. This work should be undertaken with the development of arctic observation systems, currently proposed by programs such as SEARCH (A Study of Environmental Arctic Change). This research will require extensive comparative analyses to establish the extent to which indicators are context specific and are transferable across several social-ecological systems.

What are the critical thresholds of change, domains of attraction, and recurring patterns?

This area is perhaps the most challenging because it requires the identification of key drivers and the development of simulation models that identify tipping points at which systems move into a new domain of attraction. To date, much of the resilience theory has been metaphorical in its approach (Carpenter et al., 2001). To make such theories operational, this ICARP II science plan proposes an extensive retrospective analysis of cases that are both short- and long-term (e.g., changes in human settlement patterns and resource uses, resilience of small fishing communities, vulnerabilities of subsistence-based communities that face industrial development in village homelands), and which are coupled with modeling-based analyses. This line of enquiry should include *the assessment of irreversibility* – those conditions in which points-of-no-return are crossed (e.g., the loss of keystone species and the loss of indigenous language). Study of critical thresholds should also include analysis of unanticipated incidents and their outcomes: *"The study of surprise"*.

What are the factors that account for variance in systems and subsystems?

Why do some local communities develop strategies that lead them to negotiate problems successfully and/or learn from experience while others repeatedly fail? Why have some regions prospered economically and maintained their natural capital while others flounder and repeatedly fail to engage in commercial activities? What are the strategies for mitigating the negative impacts of rapid change? To what extent are differences related to the drivers of change, the rates of change, or the properties of the systems undergoing change? The great diversity of national, regional, and local conditions across the Arctic serve as natural experiments and thus, facilitate comparative studies that lead to more generalized principles about resilience of the Arctic.

How should the study of resilience and vulnerability inform public policy?

This aspect of the science plan has two parts. First, is the need for future research to break with past traditions that separate science and decision making, and to work more directly with policy makers and local stakeholders in the formulation, implementation, and evaluation of public policy. This objective is suggested with great humility and considerable caution, recognizing the history of problems of past efforts by science to shape public policy. That said, this approach differs from past efforts by promoting local stakeholder involvement in all phases of research and viewing studies as part of an adaptive co-management process. Thus, it is likely that research can contribute to the policy process without prescribing specific policy choices and by helping to create a program in which policy outcomes are examined as experiments and points of reflective learning in ongoing decision making. Moreover, given current rapid rates of change, it is prudent to incorporate improvements in understanding into policy as expeditiously as possible. Second, there is an ongoing need to conduct comparative policy analysis to understand human responsiveness to rapid change and processes of social learning. New participatory methods of institutional analysis are needed to conduct this work in such a manner that its lessons are transferred to policy makers.

10.7. Research Approach and Philosophy

How research is undertaken in the Arctic is critical to its success, especially given the strong traditional cultures, the deep-rooted issues of conflicting epistemologies (i.e., "Whose science?"), and the history of colonialism in the Arctic. Operating principles and a general methodological approach to guide the research program are as follows:

- Be interdisciplinary, meaning that research should seek to address questions that require the integration of social, economic, and ecological perspectives on sustainability. While progress has been made in recent years in the development of interdisciplinary research methods, institutional incentives (e.g., conventional university settings) generally do not reward those working in this arena. Interdisciplinary research therefore must be conducted by the support of funding agencies and employers of researchers. Graduate programs should also be designed to reflect this need.

- Ensure the co-production of knowledge through the meaningful involvement of arctic residents, indigenous peoples, agency management practitioners, and academic researchers. The co-production of knowledge addresses the problems of scale and provides enriched and/or alternative explanations of change. The co-production of knowledge is recognized as a complex process that comes with potential vulnerabilities related to co-option of knowledge by the more powerful players. While much attention has been given to indigenous knowledge, great opportunities exist through the involvement of local residents of all backgrounds (e.g., oil field workers, environmental groups). Key in the success of this process is an open discussion about those hazards and formalized agreements that protect community knowledge holders so that they have a key role in the research process and are appropriately compensated.

- Develop innovative methods that facilitate cross-scale and cross-cultural comparisons, integration, and synergies. For example, use satellite imagery with local indigenous knowledge of environmental change as a means of prompting exchanges between resource users and researchers. Launch research with close discussions with local residents to formulate hypotheses and refine methods. The methodological frontiers for integrated research are ripe for further development in the Arctic because of its composition and position as a recipient of forces for change from the global context.

- Foster the training of young scholars in the skills of multi- and interdisciplinary collaborative research and in the skills of building partnerships with arctic residents. A network of universities offering graduate studies should be established to facilitate sharing among methods and exchanges

between students interested in social-ecological linkages and interdisciplinarity. This program could function independently or as a component of the University of the Arctic.

- Foster the direct participation of arctic residents in all aspects of research, including the collection of data and interpretation of findings, and use research as a means of building the human capital of arctic communities. The development of human capital and organizational capacity should be an additional objective of all arctic research in the study of rapid change.

- Have direct links to decision makers so that the process and products of research are policy relevant. Improved methods are needed to link research and the policy process. Work in this area could represent a significant contribution.

There are significant cultural differences among international scientists in their approach to research, with some assuming an experimental approach and others a more descriptive method. While these differences have created difficulties in international research collaborations, they are not insurmountable. It is imperative that a higher level of common understanding on the respective paradigms be achieved, and a comparative approach for international research on rapid change could help to achieve more productive studies.

Specific practical steps, organization, and infrastructure to be considered in this initiative include the following.

- *Establish coordinated and integrated arctic observation systems that focus on social, biophysical, and ecological dimensions and include local- to global-scale monitoring.* These arctic observation systems need a balance of effort in all dimensions. If appropriately coordinated, they could ultimately be the foundation for an interdisciplinary research program in social-ecological systems. Arctic observation systems will also need to make data available quickly so they can support rapid appraisal of regional differences on an ongoing basis and support the construction and development of computational simulation models and their ongoing validation and modification. Indicator identification and evaluation is integral in this process, since indicators of change reflect basic *a priori* assumptions about the system's behavior. The process of indicator identification should be participatory and the evaluation of indicators should be ongoing.

- *Build a meta-database of case studies on social-ecological change and use it to identify a standardized format and common set of key variables.* Case studies provide detailed descriptions of change and adaptation and opportunities for holistic and intensive monitoring. Contributions by historians, and ethnographers should be a part of this work. Combined with simulation models, case studies provide opportunities to focus on key variables and the critical dynamics of generalized social-ecological systems. The database would include both descriptions and analysis, and be quantitative and qualitative in content. It must be accompanied by a strong database management program to ensure its legacy for future research.

- *Develop rule- and quantitatively-based simulation models that represent the dynamics of key social-ecological systems.* The development of models should be undertaken in two ways. First, a set of simple models would serve the purpose of rapid prototyping – to address emerging questions and explore new relationships. A second set of models would be more elaborate and refined as informed by the observation system for the ongoing testing of specific hypotheses. The transparency of models and interdisciplinary collaboration in their construction will make them more accessible to policy makers and facilitate their use as decision support tools. Other aspects of this work should be aimed at addressing the problems of spatial and temporal scales through models, and in determining the level of detail needed for models to be helpful in the research-to-policy process.

- *Develop and use scenario analysis and vulnerability frameworks to develop decision-support tools that link research and decision making.* These activities, along with the components of model development described above, would serve as the primary means by which this program informs the policy process. This work would require active participation by decision makers and where appropriate, local communities. Numeric scoring of vulnerability levels may not be especially helpful in building resilience; special attention needs to be made to unique contexts and relevant opportunities for adaptation. If undertaken with inter-local and inter-regional collaboration, vulnerability analyses can cultivate a strong awareness of broad patterns of change and provide lessons about coping with and mitigating emergent conditions. Finally, it cannot be overstated that trust relations between key parties of the process are essential for research findings to be considered creditable by stakeholders and policy makers.

10.8. Linkages and Potential Users

Linkages exist between the ideas presented in this ICARP II science plan and in the other ICARP II science plans and between this science plan and several existing organizations, initiatives, and research programs. Examples of researchable questions that are relevant to other programs are as follows.

10.8.1. Linkage within the ICARP II Process

ICARP II Science Plan 1

- *What forms of "economic development" retain the ecological resilience of arctic systems and limit the human vulnerabilities to surprise?*
- *Can the current vulnerabilities of arctic residents that follow from dependencies on government financial support be reduced through new forms of economic development?*

ICARP II Science Plan 2

- *How can desired traditional institutions be retained in conditions of globalization?*
- *How does history of culture change inform contemporary processes of indigenous adaptation to rapid change?*

ICARP II Science Plan 3

- *How does settlement relocation because of coastal erosion increase the vulnerability of arctic residents?*
- *What coastal zone policies provide the most robust strategies for arctic coastal communities?*

ICARP II Science Plan 5

- *Are gateway areas more vulnerable to rapid change than other arctic regions? If so, how and why will they affect human residents?*
- *What are the implications of the changes of these areas to human aspects of the global system?*

ICARP II Science Plan 6

- *How will decreasing sea ice affect human exploration and use of arctic marine areas?*
- *What are the interactions of forces change with respect to land-sea activities?*

ICARP II Science Plan 7

- *Will changes in the hydrologic cycle of the Arctic affect human communities?*

- *What are the perceived risks of these changes, how are those perceptions changing, and what are their implications for present and future resource uses?*

ICARP II Science Plan 8

- *What are the human feedbacks to terrestrial biosphere processes and to what extent are they eroding the resilience of arctic ecosystems?*
- *How will climate change affect parasites and diseases that are important to arctic subsistence harvesters, and how are local populations likely to respond if those changes are dramatic?*

ICARP II Science Plan 9

- *Can scenarios of rapid, abrupt, and gradual arctic change be used with retrospectively based models to explore options for human responses to change?*
- *Can integrated models of social and natural arctic systems address issues of uncertainty in a manner that informs the policy process?*

ICARP II Science Plan 11

- *What structures and processes can be used by the arctic community to move beyond cultural conflicts of "western" and "local/traditional" knowledge and towards an overall improved capacity for problem-solving?*
- *What methods can researchers use to effectively communicate the difference between "good science" and "poorly undertaken" research?*

10.8.2. Linkage with other Established Research Groups

- Resilience Alliance. A consortium of academic researchers interested in theoretical issues of resilience and adaptation of systems (http://resalliance.org).
- International Arctic Science Committee (http://www.iasc.no/).
- International Arctic Social Sciences Association. The organization is increasingly interested in social-ecological approaches and it is hoped that this ICARP II science plan will stimulate new research (http://www.iassa.gl).
- International Polar Year. The IPY is proposed as a period of intensive international cooperation from 2007-2008. Several IPY initiatives have been proposed to address the "Human Dimensions" theme (http://www.ipy.org/). These include (but are not limited to):
  - Northern Perspectives on Climate Vulnerability and Adaptation (proposal no. 435);
  - Vulnerability of Human Communities to Environmental Change across the Arctic (proposal no. 454);
  - CARMA – the Circum-Arctic Rangifer Monitoring and Assessment Network (proposal no. 162);
  - Arctic Vulnerability Network Study: Reindeer Herding in a Changing Climate - Coping Mechanisms and Adaptive Capacity (proposal no. 531);
  - Adaptation and Resilience of Arctic Communities to Oil and Gas Development (proposal no. 218).
- SEARCH. The Study of Environmental Arctic Change, an initiative of the US National Science Foundation that is interdisciplinary in scope and initially interested in the establishment of a network of arctic observation systems (http://www.arcus.org/SEARCH/).
- BOREAS. A new international research initiative and funding program coordinated by the European Science Foundation, which encourages interdisciplinary studies with a strong social science and humanities component (http://www.esf.org/esf_article.php?activity=7&article=511&domain=4).
- Initiative on Science and Technology for Sustainability. An international network to facilitate information exchange and discussion among the growing and diverse group of individuals,

institutions, and networks engaged in the field of science and technology for sustainability (http://sustsci.aaas.org/).
- International Geosphere-Biosphere Programme. The IGBP was established by the International Council for Science in 1986 to help meet the challenge of global sustainability (http://www.igbp.kva.se/).
- International Human Dimensions Programme on Global Environmental Change. The IHDP is an international, interdisciplinary and non-governmental research program, aiming at "the development and integration of research on the human dimensions of global environmental change" (http://www.ihdp.uni-bonn.de/).

10.9. Conclusions

The study of rapid change in the Arctic is critical given the extent to which various stressors may transform the Arctic System and how changes in the Arctic may in turn affect the Global System. This ICARP II science plan proposes that resilience and vulnerability serve as organizing frameworks in the study of rapid change in the Arctic with several analytical advantages. First, resilience helps provide an integrated approach consistent with trends in the vulnerability and hazards literature to evaluate holistically the impacts of all the combined shocks and stresses that act on the system. Resilience as an organizing concept provides an approach to carry out a comprehensive analysis by avoiding the artificial divide between biophysical and social systems. Second, resilience puts the emphasis on the ability of a system to deal with change. It allows for the multiple ways in which a response may occur, including the ability of the system to absorb the disturbance, or to learn from it and to adapt to it, or to reorganize following the impact. Resilience thinking is in many ways consistent with a worldview of constant change and evolution, and is also consistent with indigenous conceptualizations of the universe. By emphasizing uncertainty and constant change, and by looking at change as opportunity, resilience thinking challenges widely held notions about stability and resistance to change. Stability is a bad target for policy purposes. Arctic societies and ecosystems are in constant change, and they are vulnerable to pressures and incentives that originate outside the Arctic, at higher levels of political and economic organization. Third, because resilience deals with the dynamics of response to change, resilience is forward-looking and helps explore policy options for dealing with uncertainty and change. As Tompkins and Adger (2004) noted, building resilience into human-environment systems is an effective way to cope with change characterized by future surprises or unknowable risks. Resilience provides a way of thinking about policies for future environmental change, an important consideration in a world characterized by unprecedented hazards and transformations (Folke et al., 2002).

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