# Understanding community vulnerability and adaptation: methodological challenges in analysing coupled social-ecological systems

Grete K. Hovelsrud*, Helene Amundsen & Jennifer West

CICERO (Centre for International Climate and Environmental Research - Oslo)
Gaustadalleen 21 P.O. Box 1129, Blindern, N-0318 OSLO, Norway.
Phone: +47 22 85 87 50; Fax: +47 22 85 87 51

*Corresponding author (g.k.hovelsrud@cicero.uio.no)

Paper to be presented at the 2008 Berlin Conference on the Human Dimensions of Global Environmental Change – Long-term policies: Governing social-ecological change

**Abstract**:

Global climate change has local consequences. In the Arctic the observed rate of warming is double that of other regions (ACIA, 2005). Many communities in the Arctic are dependent on natural resources for their livelihoods, and changes in environmental conditions due to climate change will affect the Arctic communities who depend on these resources. We argue that a coupled social-ecological systems (SES) approach is necessary to understand the complexity of interactions between Arctic communities and their environments, as well as to identify and understand the driving forces of change within these dynamic systems. While a growing body of work shows that climate change is already affecting the local people and indigenous communities in the Arctic**,** few studies have applied a common methodology to compare community vulnerability and adaptation to change across Arctic communities. Furthermore, there is little knowledge that can be generalised about the interactions between environmental, social and political conditions to which communities in the Arctic are sensitive, and how the complex interactions that characterise coupled systems might affect the vulnerability and adaptation of particular communities to climate change. We argue that answering these questions requires investigating how the local SES is embedded within coupled systems at higher levels of organisation, paying close attention to issues of scale, local involvement in the research, and the incorporation of different knowledge domains.

In this paper we discuss the three methodological challenges in relation to three case studies in Northern Norway. The research is a part of several ongoing projects at CICERO, including the DAMOCLES project (EU 6$^{th}$Framework Programme), the PLAN project (Norwegian Research Council), the NorACIA project (the Norwegian Ministry of Environment) and the international IPY CAVIAR consortium (Community Adaptation and Vulnerability in the Arctic Regions, IPY 2007-08). The methodology we discuss is anchored in the Pan-Arctic CAVIAR project (See the CAVIAR framework document by Smit, Hovelsrud and Wandel, 2007).

# Introduction

The goal of this paper is to advance a rigorous method for studying community adaptation and vulnerability to climate change in coupled social-ecological systems (SES) of the Arctic, through a discussion of the research considerations and challenges that underpin the research. The point of departure is place-based climate change adaptation and vulnerability studies in three coastal communities in Northern Norway. We discuss the methodological challenges of addressing scale, involving communities, and integrating local knowledge in the research.

## *1.1 Coupled social-ecological systems (SES)*

Research on community adaptation and vulnerability to the consequences of climate change in the context of other environmental, social and political conditions faces a number of methodological challenges. Changes in the environmental, social and political conditions to which communities are sensitive are often interlinked, and may occur and interact across temporal and spatial scales. A coupled SES approach is useful for exploring the complex dynamics and interlinkages between social and ecological systems – whose components include biophysical processes, institutions and governance regimes, and economic and social processes at a variety of scales – all of which help to frame and understand community vulnerability and adaptation to climate change, (e.g. Tyler et al., 2007).

As other authors have noted, SES research is interdisciplinary by default, brings together knowledge from both the social and natural sciences (and other relevant bodies of knowledge), and encompasses the complexity of interlinkages between environmental and social systems ( Berkes & Jolly, 2001; Folke, 2006; Turner, Matson et al., 2003; Tyler et al., 2007). Coupled social-ecological systems may be described in simple terms as 'integrated systems in which people interact with natural components' (Liu et al., 2007, p. 1513). In our current research cases in Northern Norway, it is clear that communities are closely connected to and dependent upon natural resources such as fisheries, oil and gas activities, reindeer herding and the production and consumption of country foods. In this paper we link studies of coupled social-ecological systems with place-based research on adaptation and vulnerability to climate change in our case communities, building on previous work that has explored these linkages (e.g. Chapin et al., 2004; Turner, Kasperson et al., 2003; Turner, Matson et al., 2003).

Our research on and for understanding community vulnerability and adaptation to climate change is fundamentally interdisciplinary, which is necessary to produce results that are relevant, meaningful and useful to local communities and decision-makers. While our research is designed to be policy relevant we have not at this early stage analysed the policy implications of our community based approach in our case studies. Nevertheless we will suggest that, for example in the context of fisheries management, our research approach will provide results useful for resource managers and the fishers themselves. The results from the project will yield insights into understanding coupled social-ecological systems at and across scales that could be used in developing policies.

## 2 Study Areas

In this paper we focus on the Norwegian contribution to the CAVIAR project through ongoing research projects being carried out by CICERO in three communities in Finnmark County, Northern Norway. The cases are described below. All three are coastal communities, and in each the focus is on understanding and documenting community adaptation and vulnerability to climate change by exploring important linkages between the community, natural resources, and other relevant social, economic, institutional, and other factors that might facilitate or constrain adaptive capacity locally. Analysis is undertaken within the frame of the CAVIAR methodology, using a coupled social-ecological systems approach.


Map of case study sites in Norway: Hammerfest, Kjøllefjord and Nesseby (the map includes 2 CAVIAR case study sites in Russia; these are not discussed in this paper).

**Case 1 Nesseby/Unjárgga**: A case where the focus is on the coastal Sámi and cultural aspects of vulnerability and adaptation to climate change. The combination of coastal fisheries, reindeer herding, agriculture and hunting has been a fundamental resource base for the coastal Sámi in Nesseby for centuries. This combination of activities does not provide the same livelihood sustenance in the municipality today, but different kinds of harvesting remain of great significance for the inhabitants, both as economic activities and for recreation. In recent years a variety of possible climate triggered events have been registered in Nesseby. Increasing Autumnal Moth (Epirrita autumnata) attacks are destroying vast areas of birch wood and berry plants, and the ecosystem in the Varanger Fjord is changing: blue whiting and king crab are now parts of the ecosystem. The Nesseby Sámi have traditionally adapted to environmental and social changes. The

current political, socioeconomic and biophysical conditions, combined with the rapid rate of change in climate, may warrant new adaptation strategies. In developing new strategies for enhancing the adaptive capacity to climate change in Nesseby, traditional knowledge will be an important factor

**Case 2 Kjøllefjord**: A case of climate change, vulnerability and adaptation in the coastal fisheries, where changes in ocean temperature, sea ice extent, and surface temperatures in the Barents Sea region have been linked to changes in the distribution and migration of key commercial fish stocks. These changes affect the ability of fishermen to earn a living from the sea. While variations in ocean temperatures and fish stocks in the Barents Sea area are not new phenomena, over the past century, the fishing industry has seen radical technological changes. Fishermen not only adjust their activities in response to changes in climate and weather, but must also account for shifts in technology, new and changing fishing regulations, and variable access to local, regional and distant markets. At the same time, out-migration and a relative lack of skilled young men and women who are interested in entering the fishing trade strains the capacity of the profession to cope with change. Local knowledge of tides, winds, and sea conditions, once essential to livelihoods and survival along the northern coast, have been replaced by modern navigational technologies such as GPS and sonar devices. Climate change is an additional factor that affects the ability of fishermen to respond to a changing resource base.

**Case 3: Hammerfest:** A case exploring the impacts of climate change on oil and gas development and shipping activity in a small coastal community. A major increase in economic activity due to recent offshore gas and petroleum activities in Hammerfest poses challenges to the social cohesiveness and environmental sustainability of this coastal community. Uncertainties over changes in sea level, wave height, storm surges and ocean currents – and the implications for pollution, whether in the harbour, along the coastline or within fish stocks, represent additional challenges. The large influx of migrant workers on a temporary basis is (potentially) changing the social and economic composition of the community. In the near future, the possibility of a reduction in sea ice extent in the Arctic due to higher sea and surface air temperatures renders the Northern Sea Route more navigable, and makes environmental conditions more favourable for increased oil and gas exploration, development and transportation along the Finnmark coast. This will have implications for the coastal communities (West, Amundsen, Hovelsrud, & Rybråten, 2007).

# 3. Methodology

The research presented in this paper draws on the methodology and research questions from the CAVIAR project developed in response to the need for a pan-Arctic understanding of community vulnerability and adaptation to climate change (Smit, Hovelsrud, & Wandel, 2007). The following key aspects of the CAVIAR methodological framework guide our research in Northern Norway.

## *3.1 Methodological framework:*

The CAVIAR framework (Smit, Hovelsrud & Wandel, 2007) builds on experiences illustrated in Lim et al.(2004), Berkes and Jolly (2001), Turner et al. (2003), Keskitalo (2004) and Ford and Smit (2004). It is an integrative and interdisciplinary research methodology designed to facilitate and guide comparative research on community adaptation and vulnerability in the Arctic.

The key lines of inquiry within the research are 1) analysing past and current exposure sensitivities to, and current adaptive strategies for dealing with, change (including but not limited to climate change) locally, and 2) determining future exposure-sensitivities and future adaptive capacity within communities. It is only by gaining an understanding of how past and current exposure-sensitivities are responded to locally, that it is fruitful to discuss how potential future changes could affect communities and how these changes might be effectively addressed. A coupled social-ecological approach captures the myriad of interlinked processes that we seek to understand in order to analyse how the local system in question is affected by, and could respond to, climate change. Although a coupled systems approach is not an explicit element of the CAVIAR methodology, we find it helpful to apply an SES theoretical framework to contextualise our research.

In the CAVIAR methodology, the analysis of the various components (exposure-sensitivities/adaptive strategies and capacity) is undertaken in close collaboration between local stakeholders and community partners, as well as natural and social scientists. To undertake this kind of research and to enable comparison between several case studies across the Arctic, a range of methods and activities are carried out in the case communities at each stage of the research. An initial visit to the community to meet with potential local partners and establish legitimacy is the starting point for the research. In consultation with communities, the research is then framed within the overarching themes of past, current and future exposure-sensitivities, and current and future adaptive strategies and capacity. The research questions are framed in cooperation between researchers and local stakeholders. Field work is then undertaken in the communities to collect data in order to gain more in-depth understanding of current exposure-sensitivities and adaptive strategies. The research is undertaken in collaboration with local participants. Various methods that are deemed appropriate for the specific context are applied, drawing on methods from both the social and natural sciences. The focus of the research will vary according to the particular concerns of the local community.

As an example, we initiate a dialogue with local partners about observed changes in weather patterns that are important and relevant to their livelihoods. The Norwegian meteorological office (met.no) develops scenarios of the various climate elements of interest to the community. These are presented for feedback to community members, resulting in a discussion about present and future challenges and opportunities within the community to deal with current and expected changes in climate and other important non-climatic elements.

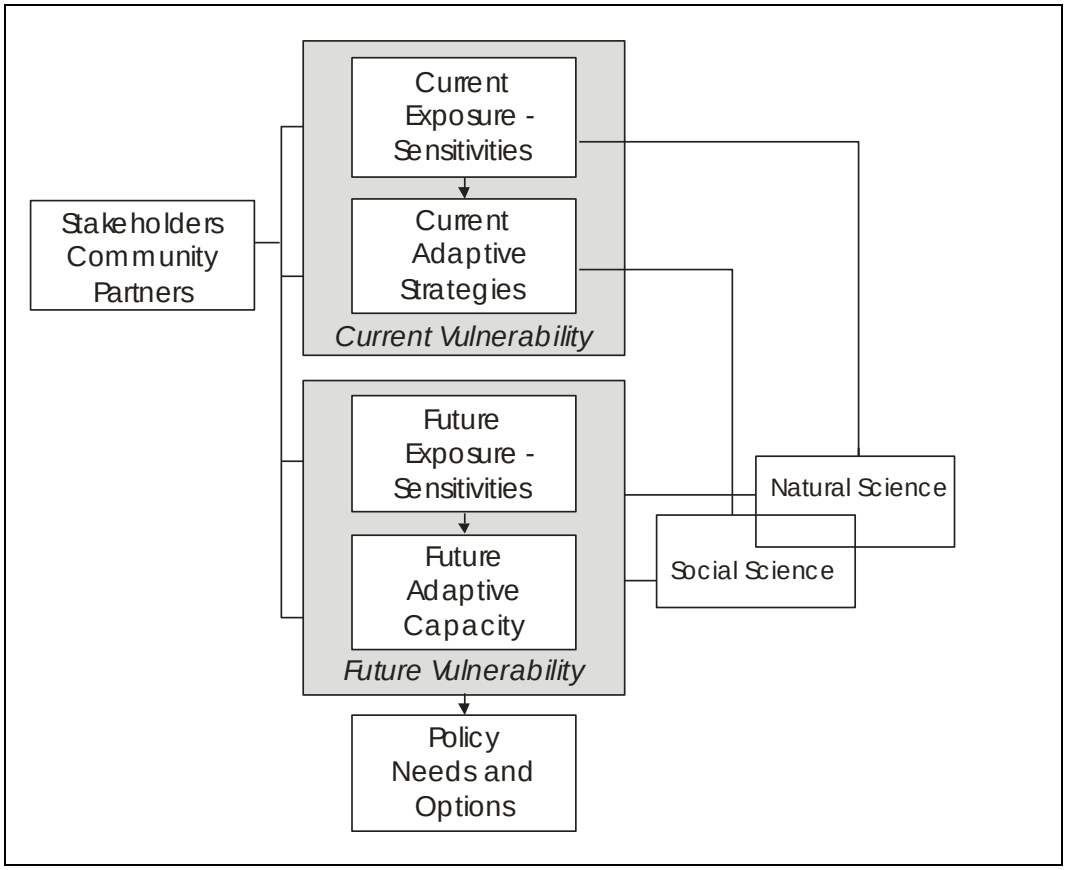


Figure 1: Key Elements in the Vulnerability Assessment Framework (Smit, Hovelsrud and Wandel 2007:6).

The research aims to be relevant to communities, and close collaboration with local stakeholder is therefore crucial. This is an iterative process, and presenting preliminary results to the community for feedback are important aspects of the methodology. Findings from the case studies across the Arctic are compared, and lessons learned will be presented for evaluation to the communities. We have noted that there is a pronounced interest within communities to learn more about how other communities in the Arctic are responding to changes in their social-ecological environments. Sharing of experiences across communities facing similar challenges is expected to facilitate the introduction of new responses to challenges that the individual communities are facing.

### *3.2 Research questions*

*"The assessment of vulnerabilities and adaptations has been identified as a priority area for research by policy makers, local and indigenous communities, the Arctic Climate Impact Assessment, the Arctic Human Development Report, and the International Polar Year planning committee (ACIA, 2005; AHDR, 2004; Denmark Ministry of Environment., 2004; Ford & Smit, 2004; Government of Nunavut., 2003; ICARP., 2005; IPY, 2005; McCarthy & Martello, 2005; Watt-Cloutier, Fenge, & Crowley, 2005) .*

Our research on case studies in Northern Norway, presented here, is guided by the research questions identified in the CAVIAR Framework:

- *What aspects of people's livelihoods are at risk, and to what?*
- *What conditions are problematic for people and the ecosystems on which they depend?*

- *What changes can be accommodated by existing ways of life?*
- *What is the ability of local communities to manage changing conditions?*
- *What local and external factors influence vulnerability and in what ways?*
- *What are the critical thresholds of adaptability or resilience?*
- *How do social, cultural, economic, and political processes operating at multiple scales affect sensitivity to climate change and adaptive capacity?*
- *What is the effectiveness of adaptive strategies across the Arctic?*
- *How do conditions affecting communities and their adaptive capacities vary among communities*
- *What can be done to enhance community adaptability?*
- *How can lessons be shared among Arctic communities?*

(Smit, Hovelsrud & Wandel, 2007, p. 2).

Text box 1: Definitions of vulnerability, exposure-sensitivity and adaptive capacity (CAVIAR Framework).

*"**Vulnerability** refers to the manner and degree to which a community is susceptible to conditions that directly or indirectly affect the well-being or sustainability of the community. This includes the sensitivity or resilience of the ecosystem of which the community is part. Vulnerability is a function of both exposure-sensitivity and adaptive capacity (Adger & Kelly, 1999; Ford & Smit, 2004; Ford, Smit, Wandel, & MacDonald, 2006; Keskitalo, 2004; Kofinas, 2005; Smit & Pilifosova, 2001, 2003; Turner, Kasperson et al., 2003; Turner, Matson et al., 2003; Wisner, Blaikie, Cannon, & Davis, 2004).*

***Exposure-sensitivity** reflects the likelihood of climatic conditions or natural hazards occurring in a particular place over time and also the situational characteristics of places and people which make them sensitive to conditions or hazards. Thus, exposure-sensitivity is related to potential stimulus or stress, physical location and characteristics, governance, economic situation, social parameters and political systems.*

***Adaptive capacity** is closely related to resilience, and reflects an individual's or community's ability to cope with or adjust to or recover from perturbation. It is reflected in the community's management of current and past stresses, its ability to anticipate and plan for future change, and its resilience to perturbations.*

*A community's exposure-sensitivity and adaptive capacity reflect the interactions of local conditions and forces at broader scales. Broader environmental processes have local manifestations, and the particular local conditions which shape exposure-sensitivities and adaptive capacity reflect regional, national and global social and economic conditions or trends. The functional relationship between exposure-sensitivity and adaptive capacity will vary by context and over time, but it is expected that vulnerability is positively related to exposure-sensitivity and negatively related to adaptive capacity." (Smit et al., 2007)*.

## 4. Methodological Considerations and Challenges:

A number of methodological considerations and challenges are raised when undertaking research on community vulnerability and adaptation in coupled SES. The text box below provides a general overview of some of these research challenges. In the following section, we focus on three of these methodological challenges: Scale, local involvement in research design, and integration of local knowledge.

Text box 2: Overview of methodological considerations and challenges in studying local adaptation and vulnerability in coupled social-ecological systems

- Interdisciplinary approach
- Policy relevance of the research
- ***Scale (spatial and temporal aspects)***
- ***Engaging local communities***
- Ensuring accurate representation of local views and perceptions
- Understanding drivers of and responses within coupled systems
- Understanding multiple change factors
- Choosing appropriate data and information
- Uncertainty in data and in scenarios
- ***Integrating different knowledge domains*** and data formats
- Understanding historical contexts of change in coupled systems
- Local relevance of the research
- End-users and outputs of the research

## Methodological challenge # 1: Scale

Studying interlinkages between people and their environments in the context of climate and other changes, requires investigating the temporal and spatial scales across which social, economic and environmental phenomena vary (e.g. Turner, Kasperson et al., 2003). We know that *vulnerability* to climate change varies by region, sector, and social group (ACIA, 2005; IPCC, 2001). It follows that research on community responses to climate change requires understanding how exposure-sensitivity and adaptive capacity (the determinants of vulnerability) at the community level are connected to socio-ecological systems and changes at different spatial and temporal scales.

Our methodology integrates data and information within and across scales, which is necessary in order to understand the salient social and ecological elements that shape vulnerability and adaptation to climate change locally. However, several challenges arise when considering scale within the research. The first challenge involves selecting and examining information and indicators of vulnerability and adaptation at an appropriate scale. It is important to understand how certain kinds of data that are relevant to the research might vary across scales. Choosing to focus on one scale rather than another may change the interpretations or conclusions reached. An example is the share of employment in the fisheries sector in Northern Norway. Northern counties, and the country as a whole, may appear to have a low sensitivity to climate change with respect to having a low proportion of the workforce employed in a climate-sensitive industry such as fisheries. While at the municipal and local scales, employment and income from climate-sensitive fisheries varies widely, with some municipalities being highly dependent on income and employment from fisheries (West & Hovelsrud, unpublished).

The second challenge is to deduce at what scale the social and ecological drivers of community vulnerability and adaptation originate and interact to affect local adaptation options and adaptive capacity. Determinants of adaptive capacity in local communities include institutional, social, economic, cultural and livelihood arrangements (IPCC, 2001). These elements are dynamic in space and time; they make up the coupled socio-economic system of which communities are a part, and frame the way people interact with their biophysical surroundings. While some of the elements of coupled systems originate locally, others are generated at higher scales. In combination, the different elements, and the outcomes of interactions between them, then intersect at a local scale to produce particular place-based vulnerabilities and adaptation options. Examples of linked factors that may affect vulnerability and adaptation to climate change in fishing communities in Norway are quota regulations (set at a national scale, in cooperation with Russia), market price of fish (national, regional and global regulation elements); demographic trends (declining populations in small coastal settlements), change in distribution of fish stocks and local perceptions and attitudes towards change (West, Hovelsrud, & Amundsen, 2008).

### Methodological challenge # 2: Involving local communities in the research development

The CAVIAR project, along with other recent publications (e.g. Flax, Jackson, & Stein, 2002; Ford & Smit, 2004; Keskitalo, 2004), present frameworks for involving local stakeholders in studies of community vulnerability and adaptation to climate change. A number of methodological challenges are associated with engaging communities in the research. When discussing with local communities how to frame the research we encounter different interest groups and stakeholders and many, or only a few, voices may be represented. In our case areas these may include: coastal fishermen, representatives of fish landing and processing businesses, local residents engaged in mixed cash-subsistence-recreational activities, oil and gas interests, municipal decision-makers, city planners, local entrepreneurs, local organizations and community groups, various age groups, and newly immigrated residents. Our research start by casting a wide net in order to catch the range of voices and experiences represented within the communities. Each of these groups may have different interests, levels of knowledge and understandings of the linkages between their own activities, natural resources, and the potential implications of current and future climate change upon these.

The first challenge is to ensure that a representative range of views are included in community consultations. To illustrate the range of interests, a coastal Sámi in Nesseby, for example, may tell a story about his connections to the environment, an oil and gas industry representative in Hammerfest could present technical engineering considerations of offshore gas facilities, and a municipal official in Kjøllefjord might discuss the challenges her town faces to keep roads open during winter storms. It is important to pay attention to the fact that individuals may differ in how they communicate (the Sámi may withdraw in a group situation, while the oil and gas representative might use technical or economic jargon). There is therefore necessary to further develop the particular methods that are needed to ensure a comfortable setting and level of trust, and effective local engagement, in the research.

A related challenge is to identify the major interest groups in the community, based on a combination of broad community discussions, interviews, and informal meetings in order to ensure representation and not exclude valuable expertise, opinions, and novel or marginalized perspectives

(the road maintenance worker in Hammerfest may not consider that his knowledge about weather is valuable to the climate change researchers). The inclusion and engagement of a broad range of perspectives, while necessary to capture a range of views and interests, may also make the research less manageable, as there are likely to be competing values and opinions. It is a challenge for the researcher, for example, to balance the interests of oil and gas developers versus the fishing industry when it comes to the understanding and utilisation of the marine environment. The third challenge is therefore to engage the community participants in identifying important core issues that are broadly representative of the community's interests, keeping in mind the trade-offs between collective and individual interests. Discussions between local community stakeholders and researchers on determining the focus of climate change research may also lead to discussions about the various motivations and expectations of the project. The fourth challenge will therefore be to balance the differing motivations and expectations of the researchers and the community. This is to ensure that research *on* adaptation and *for* adaptation is relevant and of value to the communities and the local decision-makers (e.g. municipal decision-makers, fishermen, the fishing industry, oil and gas developers, Sámi who travels on land and ice). It is a further goal that the results of the research will cascade up through the institutional chain to the county and national levels where additional decisions about adaptation strategies and their potential financing are made.

### Methodological challenge #3: Integrating local and traditional knowledge

Place-based, or community-based, research on adaptation and vulnerability to climate change must involve local stakeholders and view local and traditional knowledge as an intrinsic part of the study of coupled social-ecological systems. Partnerships between local resource users and scientists in creating knowledge are not commonly applied in research on coupled social-ecological systems, despite the fact that such partnerships are increasingly recognised as being crucial to success (Berkes, 2002; Ludwig, 2001; Tyler et al., 2007). In order to best identify the factors that influence local vulnerability and adaptation it is necessary to understand the priorities and perspectives of local people experiencing this change (Hovelsrud & Winsnes, 2006; Tyler et al., 2007).

Local residents hold a wealth of knowledge about their own region, and about the environmental, socio-economic and political conditions that may not be included in scientific investigations. Instead, this knowledge is often seen as anecdotal and fundamentally subjective. Local knowledge is gained through the experiences and interactions of people with their local environment, are passed down through generations, often in an oral tradition, and may not be recorded in the same way as is scientific knowledge (Hovelsrud & Winsnes, 2006). Local knowledge is a valuable source of information, and may provide guidance and experience to the scientific method and aid the interpretation of results (Hovelsrud & Winsnes, 2006:7). Such knowledge should be considered as being parallel to scientific knowledge; local and scientific knowledge representing two different, yet complimentary, knowledge systems. Both types of knowledge are critical elements in studies of community adaptation and vulnerability to climate change, and integrating and relying on both will enhance our understanding of the opportunities that exist locally to better deal with changing conditions (Smit, Hovelsrud and Wandel 2007: 1).

There are a number of challenges involved in integrating local and scientific knowledge. The first challenge is to accept local knowledge as a valuable resource that can contribute to and help

evaluate scientific results. For example, local knowledge on fish stocks and changes in fish species represent important information for marine biologists when assessing the consequences of climate change. A local fisherman is likely to observe the shift in the species composition of his catch before the scientists. Local knowledge is often interdisciplinary, incorporating social and ecological elements. Therefore the second challenge is to understand the linkages between the social and the ecological elements of coupled systems as they are seen and experienced from both local and scientific angles. Local knowledge is often anecdotal and context dependent, and the fishermen's observations of change are not easily quantified and represented as useful information from a scientist's perspective. Thus, the third challenge is to find appropriate methods for understanding, collecting and analysing local knowledge. The fourth challenge lies in the integration of local knowledge into scientific approaches at an equal level with the scientific knowledge without loosing the particulars and understandings contained within the two knowledge domains. A wealth of local and indigenous knowledge and information with respect to climate change in the Arctic has been documented in a number of recent studies, but it has yet to be integrated with scientific knowledge (Hovelsrud & Winsnes, 2006). Thus, the final challenge lies in transferring knowledge across scales and cases while respecting both forms of knowledge.

## Conclusion

In this paper we have highlighted some of the methodological research challenges we are currently facing when conducting place based research on community adaptation and vulnerability to climate change in Northern Norway. The challenges of addressing scale, ensuring effective local involvement, and including traditional and local knowledge in the research, as outlined in this paper, are strongly emerging themes in our ongoing case studies. These challenges are also among the suite of research considerations identified in the CAVIAR Research Framework (see textbox 2). It is clear from examining the methodological challenges we face in our research that there is a great need for further advancing a rigorous method for conducting such studies. We have briefly reported on three ongoing case studies in which the framework and methods presented here are currently being implemented. With respect to scale we find that the data we collect on fisheries (whether qualitative or quantitative) will yield different results about the value of fisheries depending on the societal focus; the monetary value of fisheries at a county level for example, may belie its importance at the local community level. We argue that identifying the relevant scales at which different data should be collected can only be done in collaboration with local communities, and must be coupled with an understanding of the relevant interactions between the different societal scales (fishermen at the local level are connected to fisheries management at the national and regional levels – and even internationally). From this follows the challenge of engaging the local communities in both defining the research focus and in identifying the most significant relationships in the coupled social-ecological systems. With respect to involving local communities in defining the research agenda, we find that it is important to balance the heterogeneous voices and interests of the different stakeholders within communities. This balance is challenging and requires understanding and acknowledging power relations and differences in the types and extent of knowledge held by various community stakeholders (the oil and gas companies may have a different starting-point and bundle

of knowledge than the individual coastal fisherman). Our research recognises that local stakeholders hold essential knowledge and information about local vulnerability and adaptation. The challenge of utilising the different strands of knowledge in the research pertains to the different structures of local and scientific knowledge and to the difficulties in "translating" local knowledge into a format suitable for analysis while also ensuring that the particulars are not lost.

The methodological challenges of conducting research on community adaptation and vulnerability to climate change within an SES approach, three of which we have outlined here, illustrate the complex interlinkages that emerge within and between societal scales, within and between stakeholders, and between different systems of knowledge. Case studies are a critical first stage of testing such an approach and will provide important grounds for comparing and learning across sites and scales. We argue that applying a coupled social-ecological systems approach, regardless of the methodological challenges, will provide a better understanding of community adaptation and vulnerability to climatic and other social and environmental changes and facilitate understanding of linkages to wider regional, national and international contexts.

## References


ACIA. (2005). *Arctic Climate Impact Assessment*: Cambridge University Press.

Adger, W. N., & Kelly, P. M. (1999). Social vulnerability to climate change and the architecture of entitlements. *Mitigation and Adaptation Strategies for Global Change, 4*, 253-266.

AHDR. (2004). *Arctic Human Development Report*. Akureyri, Iceland: Stefansson Arctic Institute. Cambridge University Press.

Berkes, F. (2002). Epilogue: making sense of arctic environmental change? In I. Krupnik & D. Jolly (Eds.), *The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change*. Fairbanks, Alaska: Arctic Research Consortium of the United States.

Berkes, F., & Jolly, D. (2001). Adapting to climate change: social-ecological resilience in a Canadian Western Arctic community. *Conservation Ecology, 5*(2).

Chapin, F. S., Peterson, G., Berkes, F., Callaghan, T. V., Anglestam, P., Apps, M., et al. (2004). Resilience and vulnerability of northern regions to social and environmental change *Ambio, 33*(6), 344-349.

Denmark Ministry of Environment. (2004). Adapting to the Climate of the Future. Environmental Essays 29: Ministry of Environment and Environmental Protection Agency, Copenhagen.

Flax, L. K., Jackson, R. W., & Stein, D. N. (2002). Community vulnerability assessment tool methodology. *Natural Hazards Review, 3*(4), 163-176.

Folke, C. (2006). Resilience: The emergence of a perspective for social-ecological systems analysis. *Global Environmental Change, 16*, 253-267.

Ford, J., & Smit, B. (2004). A framework for assessing the vulnerability of communities in the Canadian Arctic to risks associated with climate change. *Arctic, 57*, 389-400.

Ford, J., Smit, B., Wandel, J., & MacDonald, J. (2006). Vulnerability to climate change in Igloolik, Nunavut: what can we learn from the past and present. *Polar Record, 42*, 127-138.

Government of Nunavut. (2003). *Nunavut Climate Change Strategy*: Government of Nunavut, Iqaluit, Nunavut.

Hovelsrud, G. K., & Winsnes, C. (2006). Conference Proceedings: NAMMCO Conference on User Knowledge and Scientific Knowledge in Management Decision Making (pp. 95p). Reykjavik, Iceland 4-7 January 2003: The North Atlantic Marine Mammal Commission.

ICARP. (2005). *A research plan for the study of rapid change, resilience and vulnerability in social-ecological systems of the Arctic*: Report from working group 10 of the Second International Conference on Arctic Research Planning IPY)

IPCC. (2001). *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK and New York, USA: Cambridge University Press.

IPY. (2005). International Polar Year Themes.

Keskitalo, E. C. H. (2004). A framework for multi-level stakeholder studies in response to global change *Local Environment, 9*(5), 425-435.

Kofinas, G. (2005). A research plan for the study of rapid change, resilience and vulnerability in social-ecological systems of the Arctic. *The Common Property Resource Digest, 73*, 1-10.

Lim, B., Spanger-Siegfried, E., Burton, I., E., M., & Huq, S. (2004). *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures* Cambridge: Cambridge University Press.

Liu, J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., et al. (2007). Complexity of Coupled Human and Natural Systems. *Science, 317*, 1513-1516.

Ludwig, D. (2001). The era of management is over. *Ecosystems, 4*, 758-764.

McCarthy, J., & Martello, M. L. (2005). Climate change in the context of multiple stressors and resilience. In *ACIA, Impacts of a Warming Arctic: Arctic Climate Impact Assessment* (pp. Chapter 17: 945-988). Cambridge: Cambridge University Press.

Smit, B., Hovelsrud, G. K., & Wandel, J. (2007). Community Adaptation and Vulnerability in Arctic Regions (CAVIAR). A Pan-Arctic Research Collaboration under the International Polar Year. CAVIAR Framework Document: University of Guelph. Occasional Paper No 28.

Smit, B., & Pilifosova, O. (2001). Adaptation to climate change in the context of sustainable development and equity. . In *Climate Change 2001: Impacts, Adaptation, and Vulnerability - Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* (pp. Chapter 18). Cambridge, UK: Cambridge University Press.

Smit, B., & Pilifosova, O. (2003). From adaptation to adaptive capacity and vulnerability reduction. In J. B. Smith, R. J. T. Klein & S. Huq (Eds.), *Climate Change, Adaptive Capacity and Development*. London: Imperial College Press.

Turner, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., et al. (2003). A framework for vulnerability analysis in sustainability science. *PNAS, 100*(14), 8074-8079.

Turner, B. L., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., et al. (2003). Illustrating the Coupled Human-Environment System for Vulnerability Analysis: Three Case Studies. *Proceedings of the National Academy of Sciences of the United States of America, 100*(14), 8080-8085.

Tyler, N. J. C., Turi, J. M., Sundset, M. A., Strom Bull, K., Sara, M. N., Reinert, E., et al. (2007). Saami reindeer pastoralism under climate change: Applying a generalized framework for vulnerability studies to a sub-arctic social-ecological system. *Global Environmental Change, 17*(2), 191-206.

Watt-Cloutier, S., Fenge, T., & Crowley, P. (2005). Responding to Global Climate Change: The Perspective of the Inuit Circumpolar Conference on the Arctic Climate Impact Assessment [Electronic Version],

West, J. J., Amundsen, H., Hovelsrud, G. K., & Rybråten, S. (2007). Global climate change, regional coastal management and local communities: research considerations and challenges: Poster Presented at Arctic Coastal Zones at Risk, Tromsø.

West, J. J., & Hovelsrud, G. K. (unpublished). Climate change in Northern Norway: toward an understanding of socio-economic vulnerability of natural resource-dependent sectors and communities. En rapport til den norske oppfølgingen av ACIA - NorACIA, Temagruppe 4, Virkninger på Folk og Samfunn, June 2007.

West, J. J., Hovelsrud, G. K., & Amundsen, H. (2008). Contexts for local adaptation: research considerations and challenges. Poster presented at Living with climate change: Are there limits to adaptation. Royal Geographical Society, London, 7-8 February.

Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). *At Risk*. London: Routledge.