# 4 Synthesis and Future Directions

## 4.1 Introduction

The past decade has seen rapid growth in environmental and social research throughout the Arctic, combined with a growing number of assessments and reports. Various assessment reports noted in Chapter 1 included the Arctic Human Development Report, the Arctic Climate Impact Assessment, and a range of others pertaining to contaminants, oil and gas, shipping, and sustainable development, among others. The International Conference on Arctic Research Planning in 2005 (ICARP-II, 2007) spurred the development of a discussion paper on grand research challenges in the Arctic region (Corell et al., 2005) and a set of 11 science plans (SPs) covering a wide range of topics:

1. Arctic economies and sustainable development.
2. Indigenous peoples and change in the Arctic: adaptation, adjustment and empowerment.
3. Arctic coastal processes.
4. Deep central basin of the Arctic Ocean.
5. Arctic margins and gateways.
6. Arctic shelf seas.

7. Terrestrial cryosphere and hydrological processes and systems.
8. Terrestrial and freshwater biosphere and biodiversity.
9. Modelling and Predicting Arctic weather and climate.
10. Research plan for the study of rapid change, resilience and vulnerability in social-ecological systems in the Arctic.
11. Arctic science in the public interest.

The inclusion of a plan specifically addressing Arctic coastal processes was an important recognition of the importance of the coastal zone. At the same time, several of the other science plans bear directly on issues of importance in coastal regions and are considered in this report. Not the least of these was SP10, which proposed an integrated approach to the study of resilience and vulnerability of social-ecological systems in the face of rapid environmental and social change. Following on ICARP-II, the array of projects developed and pursued over the multi-year effort of the International Polar Year dramatically increased the research effort on a number of fronts (Krupnik et al., 2011). IPY in turn drove the series of SAON workshops on measures to promote sustained observation networks to monitor change in the Arctic region.

Pertinent recent reports include the following:

- Sustainable Development Working Group (Arctic Council), Workshop Report *Vulnerability and Adaptation to Climate Change in the Arctic*, February 2009
- Senior Arctic Officials Report to Ministers, Tromsø, April 2009
- *Tromsø Declaration* from Sixth Ministerial Meeting of the Arctic Council, April 2009
- WWF Report *Arctic Climate Feedbacks: Global Implications*, August 2009.
- Norwegian Polar Institute, *Melting Snow and Ice* (Koç et al., 2009), December 2009
- American Meteorological Society, *State of the Climate in 2009* (Arndt et al., 2010), July 2010.
- Circumpolar Biodiversity Monitoring Program (CBMP), Conservation of Flora and Fauna Working Group (Arctic Council), *Arctic Report Card: Update for 2010* (Richter-Menge and Overland, 2010), October 2010.

## 4.2 ICARP-II Science Plans

### 4.2.1 Monitoring coastal change in the circumpolar Arctic

Science Plan 3 (SP3) of ICARP-II (2007) addressed coastal issues explicitly. This plan noted the extreme vulnerability of the Arctic coastal zone to ongoing and anticipated environmental change and identified the need for coastal monitoring. As a primary objective, the plan proposed the establishment of "an internationally coordinated network of coastal observatories," a vision that was carried forward in the SAON discussions but remains largely unrealized. Specific changes anticipated in SP3 included changes in sea-ice extent and thickness, sea level, storm frequency, coastal stability, biodiversity, and other changes induced by human activity. Changes resulting from ongoing processes were recognized to include rapid coastal retreat of permafrost coasts with large proportions of ground ice, with implications for coastal habitats and human settlements. Other important issues were recognized to include potential release of gas hydrates through permafrost degradation, particularly in the coastal zone, and

the contribution of coastal erosion to fluxes of sediment, carbon, and nutrients, which play an important role in the material budget of the Arctic Ocean.

Four general outcomes were proposed:

- improved understanding of biophysical processes and possible impacts on ecosystems;
- ecoregion-based coastal-zone management;
- scientific support of sustainable development in the Arctic coastal zone; and
- improved web access to basic data for coastal-zone research and education.

SP3 also envisaged the preparation of this report to provide context and a snapshot of the state of the Arctic coastal zone five years on from the ACIA (2005). In other respects, this report constitutes a report card on the challenges of implementing SP3 and limited progress on some fronts, demonstrating the ongoing need to address the objectives highlighted in that plan.

### 4.2.2 Measures for assessing human community issues in the Arctic coastal zone

Science Plan 1 (SP1) of ICARP-II (2007) addressed issues of sustainable development in the Arctic. SP1 focused on Arctic peoples, particularly indigenous peoples with close ties to the land, as being among the most vulnerable to environmental, social, and economic change. While this plan did not explicitly address coastal issues, a large proportion of the Arctic population resides in large or small settlements located on or close to the coast (Fig. 2). SP1 identified eight determinants of sustainable development in the Arctic, including communities and demographics, large-scale resource extraction or other industrial development, infrastructure and technology, governance including policies and implementation, economic systems including subsistence and globalization, and environmental change including climate change. Climate change and other environmental changes in the coastal zone pose challenges to sustainable development in Arctic communities, but the impacts are dependent on resilience, which is affected by all the other determinants of sustainable development (see Section 3.3).

Considerations of trade-offs, equity, and cultural vitality are also important in this context. SP1 did not explicitly list knowledge gaps but identified a number of research and related priorities, relevant to both coastal and non-coastal communities, including:

- Identification of a suite of indicators of sustainable development applicable across the circumpolar Arctic, which would facilitate creation of a database (or initially regional databases) to enable development of long-term time series to support planning, policy development, decision-making.
- Synthetic and comparative studies drawing on the collective experiences of many researchers and projects.
- Development of appropriate education, outreach, and communication efforts reaching beyond the scientific community.

Science Plan 2 (SP2) of ICARP-II (2007) concerned indigenous peoples and change in the Arctic, including adaptation, adjustment and empowerment, and touched on many of the same issues identified in Science Plan 1. SP2 noted “the unique ability of Arctic cultures to exhibit resilience and thereby occupy new physical and social

environments" (SP2, p.3). It referred to three issues considered critical to Arctic residents, as identified in the Arctic Human Development Report (AHDR, 2004): control of personal destiny, maintenance of cultural identity, and living close to nature, which in the Arctic often means close to living marine resources in the coastal zone.

Science Plan 10 (SP10) of ICARP-II (2007) was presented as a research plan for the study of rapid change, resilience and vulnerability in social-ecological systems of the Arctic and also provides useful guidance relevant to the present report.

Since 2005, parts of SP1, SP2, and SP10 have been addressed through the *Vulnerability and Adaptation to Climate Change in the Arctic* (VACCA) project (Kelman and van Dam, 2008), the *Survey of Living Conditions in the Arctic* (SLiCA) (Poppel and Kruse, 2009), the *Arctic Social Indicators* project (Larsen et al., 2010), and the IPY *Community Adaptation and Vulnerability in Arctic Regions* (CAVIAR) project (Hovelsrud and Smit, 2010).

## 4.3 Knowledge Gaps and Research Priorities

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### 4.3.1 Physical state of the circum-Arctic coast

- Predictions of sea-level change in the Arctic are poorly constrained compared to lower-latitude regions. Development of more robust projections of sea-level rise for residents and decision makers requires better knowledge of past sea-level change, improved vertical motion data, updated global projections, and better models for regional sea-level rise.
- We have limited understanding of the impacts of a changing sea-ice regime and wave climate on coastal stability, including issues such as sediment entrainment and export by sea ice and the incidence of ice ride-up and pile-up events onshore.
- Anticipating increased coastal erosion in the Arctic, the lack of a systematic circumpolar coastal observing network is a critical gap.
- There is a need for more detailed studies of Arctic storms and how they might change in the future.
- The effects of the changing character of carbon and other inputs on productivity are not known. The role of river-ocean interaction and the filtering/buffering role of deltas on carbon and nutrient delivery are not sufficiently understood.
- There is a need for comprehensive studies of coastal topography and landscape change. In particular, the fate of Arctic deltas and salt marshes faced with rising sea levels and wave energy in the context of growing human development pressure requires more attention.
- The distribution and stability of gas hydrates and other sources of methane venting in the Arctic coastal zone requires more attention.

### 4.3.2 Ecological state of the circum-Arctic coast

- There are still large gaps in understanding of the vulnerability of coastal ecosystems to changes in climate, rapid development, shipping and tourism in the Arctic. Ongoing research efforts and assessments are a priority.
- There is a need to identify prime ecosystem functions and their global, regional and local significance.

- Major stakeholders may, to some extent, self-identify but more effort is required to develop a comprehensive stakeholder inventory.
- There is a need to identify and list major biodiversity indicators for monitoring the sustainable use of Arctic coastal ecosystems

### 4.3.3 Social, economic, and institutional state of the circum-Arctic coast

- New and refined methods and tools are required to perform integrated assessments of socio-economic effects in Arctic regions and communities of environmental changes and societal changes inside and outside the Arctic.
- More work is needed to improve the understanding of societal risks of industrial activities in Arctic coastal regions and the socio-economic impacts of ecosystem changes.
- For many regions and groups of people, the subsistence economy is of great importance, but statistical data remain poor for this component of the economy in many regions. Better systems are needed to collect and compare data on the situation and development of subsistence and non-subsistence activities and employment and their importance for households, communities, and regions.
- More effort is needed on the collection of data pertaining to some indicators proposed in the Arctic Human Development Report and the subsequent Arctic Social Indicators project, including *fate control, cultural integrity* and *contact with nature.* Data need to be collected at regular intervals to detect changes and development patterns.
- Understanding the role and influence of external actors in the Arctic will be important, as the EU and China amongst others are increasingly directly involved in the region, and the policies of these major geopolitical actors have significant indirect effects (e.g. through trade, energy, shipping and fisheries).
- More attention is needed on strategies to develop businesses, industries and communities in the rural north that support social, cultural, economic and ecological sustainability

### 4.3.4 Integrated assessment

- There is a need for scenarios that integrate physical, ecological and social changes.
- A number of projects are moving towards integrated assessment of human-environment relationships, vulnerability, and resilience, but numerous challenges remain to developing frameworks within which different knowledge systems can be integrated (e.g. Lange, 2008).
- Documenting changes in indigenous languages and changes in some specific domains, such as orientation systems, would contribute to a better understanding of the global (climate, technological, or other) influences on human-biogeophysical interactions in the Arctic.

### 4.3.5 Monitoring, detecting and modelling coastal change

- The tools, methods, and research structures for coastal monitoring are currently in place and in use, however challenges still exist. At most sites, monitoring has only been going on for a few decades at most, and sustaining the long term *in situ* monitoring programs is important in order to capture decadal scale processes.

- The SAON process provided a stimulus to renewed efforts to expand circumpolar coastal monitoring. There is a pressing need for resources to support sustained coastal monitoring with innovative methods across a wider, international, circumpolar network, combined with new standards and protocols to enable better comparison of results from all sites.
- A stronger relationship with communities and the development of community-based monitoring can help increase on-the-ground monitoring capabilities.
- Some significant processes are still poorly understood and need to be investigated (e.g. shoreface evolution during winter).
- High resolution remote sensing imagery is now available to provide a good baseline for monitoring efforts and, if not already in place, needs to be secured for important sites.
- Despite important recent progress, the human health situation across the Arctic needs ongoing monitoring, especially for indigenous people outside urban centres. Use of traditional food is important for promoting a wholesome diet, but is at the same time a potential source of contaminants.
- There is a need for an inventory of models applicable to the Arctic coastal zone, as well as what pieces are missing. The inventory should include at least three classes of models: operational (using real-time data), predictive, and hindcast models;
- Significant, directed research effort is required to attain a level of sophistication and computational efficiency necessary to address complex human-biogeophysical interactions inherent in an integrated approach to issues in the Arctic coast zone.

### 4.3.6 Vulnerability, adaptation, and resilience

- The development of effective adaptation strategies requires an understanding of the vulnerability and resilience of human-environment systems in a changing Arctic, in terms of who is vulnerable, to what stresses, what are the determinants of vulnerability and resilience, and what are the opportunities for adaptation policy.
- There is a need for new, integrated monitoring approaches to document the nature of environmental change and human interaction with biophysical conditions in the Arctic coastal zone, assessing current adaptations and identifying constraints and opportunities for future adaptation.
- Future efforts need to focus on adaptive management in the face of change, building of community adaptive capacity and resilience, and recognition that change to both physical and human systems in the Arctic has become constant.
- More work is needed to understand the effects of scale, in particular global- to local-scale effects and their implications for adaptation policies.

### 4.3.7 Governance and adaptation

- Future research needs to focus on increasing support, opportunity, and capacity for local decision-making or effective resident input to decisions.
- More could be done to explore applications of integrated coastal area management strategies in Arctic regions.
- More effort is required to develop lines of communication between the science and policy communities concerned with Arctic coasts.

## 4.4 Building a Road Map to Integrated Coastal Systems Research in the Arctic

It is abundantly clear that the coast is a critical component of the Arctic system requiring explicit attention. Furthermore, as a locus of human activity with attendant hazards, the circumpolar Arctic coast may be seen as a priority for monitoring and change detection to support proactive adaptation.

A number of knowledge gaps and key findings of this report point to the need for an integrated approach to critical questions affecting ecosystems and human communities in the Arctic coastal zone. There is a clear need for intensified observing and monitoring efforts to provide the baseline information required to document rates of change, project the potential for future change, and assess current vulnerability to change. These are needed to support the development of adaptation mechanisms to increase resilience and minimize future impacts. Effective governance and management of coastal resources depends on a solid foundation of robust knowledge. A coordinated approach to monitoring and managing change in coastal landscapes and communities in the Arctic is likely to be more efficient and effective in the acquisition and dissemination of knowledge and in building connections between the science and stakeholder communities (Catto and Parewick, 2008).

The International Council of Scientific Unions (ICSU) recently completed an open consultation on grand challenges in global sustainability research using a systems approach to the identification of global research priorities (http://www.icsu-visioning.org/the-visioning-process/). Broad themes of this visioning blueprint include improving the usefulness and relevance of projections, developing observation systems, developing approaches to coping with environmental change, identifying institutional and behavioural changes to support sustainability, and technological and social innovation. Criteria for selection include scientific importance, relevance, broad support, global coordination and leverage. These criteria can be applied equally well to identifying priorities for coordinated circum-Arctic research in the coastal zone.

As the ICSU visioning process moves to the next stage, a key question is how to move from vision to action. Key questions include how to determine the balance between top-down and bottom-up approaches, how to interact with stakeholders, what sort of ongoing participatory prioritization process is appropriate, and how often it is needed (http://www.icsu-visioning.org/the-visioning-process/).

The SAON (Sustaining Arctic Observing Networks) process over the past 3 years has highlighted the need for enhanced and sustained Arctic observing systems, not only "sustaining … current levels of observing activities and information services" but "making every reasonable effort to increase the scope of those activities in the future" (SAON, 2009).

The challenge for coastal system monitoring and research is the cross-cutting nature of the coast and the absence of a clear model for integrated coastal monitoring in the Arctic. The Arctic Circumpolar Coastal Observing Network (ACCO-Net), an IPY initiative of the Arctic Coastal Dynamics Project, remains the primary model for international coordination of coastal monitoring and change detection (Krupnik et al., 2011). Although coastal issues received limited visibility in the final SAON report,

ACCO-Net was recognized as one of a number of SAON building blocks. As the SAON process has progressed to formation of the SAON Steering Group and completion of a Plan for the Implementation Phase of SAON (SAON Steering Group, 2011), ACCO-Net is not currently included among the 17 SAON task proposals. It may be desirable to have the Arctic coastal community participate more actively in this process.

Several useful components of an action plan were identified by Couture et al. (2008), including the following:

- Building an inventory of existing stations, actors, and networks in the field is a clear step to be taken.
- Building awareness of the coast as a distinct and common entity can be supported by use of the term 'coastal' as a keyword in all relevant metadata.
- The existing ACD circum-Arctic coastal GIS provides a common mapping tool (see Lantuit et al., 2011).
- Government agency support will be critical to allocation of resources to support coastal monitoring.
- Increased communication of coastal issues in the Arctic is a prerequisite to recognition of the need for agency resources.
- Coastal communities represent an important source of demand and potential capacity to support monitoring efforts.

The ICARP-II Science Plan 3 on Arctic coastal processes advocated a network of focal areas and sites for detailed studies within a broader regional and circum-Arctic framework. Critical elements were identified as

- A network of coastal observatories (on- and off-shore), involving physical, ecological, and social observations;
- A broad-scale physical, environmental, and social circum-Arctic characterization to provide context [this report];
- Data management and information systems that include a particular emphasis on data synthesis;
- A cyber infrastructure and sensor technologies at multiple spatial and temporal scales.

A number of initiatives are underway to support governance and sustainability of Arctic communities and regions, including the Northern Research Forum (www.nrf.is), the Sustainable Development Working Group of the Arctic Council (http://arctic-council.org/working_group/sdwg), and the Arctic Governance Project (http://www.arcticgovernance.org/). None of these organizations has an explicit coastal focus, yet coastal issues will impinge in numerous ways on the issues they are attempting to address.

LOICZ is developing a set of major research themes to fit within the framework of the ICSU research vision. One of these themes is the Arctic coastal zone. A road map to integrated coastal systems research in the Arctic could follow this route, integrating physical, ecological, socio-cultural, and integrated monitoring through a revitalized ACCO-Net consortium. A pragmatic approach would see ACCO-Net developed in a modular fashion, with support from national agencies, research funding bodies, academic and community-based initiatives. To be successful, however, there is a need for a steering group and one or more sponsoring bodies or agencies with sufficient resources to ensure a framework of communications, coordinating infrastructure, and

data management. Representation from northern residents, existing northern research consortia, appropriate Arctic Council working groups, LOICZ and IASC would be desirable. Possible models for raising the profile of coastal issues might include the establishment of an IASC coastal research committee (an evolution from the Arctic Coastal Dynamics network) or a Coastal Systems Working Group of the Arctic Council. Other approaches are possible, but to be truly effective, this would require some degree of formal organization and financial resources.

## 4.5 Summary Discussion

The Salekhard Declaration of the Fifth Arctic Council Ministerial Meeting in Salekhard, Russia, in October 2006 (Arctic Council, 2006a) endorsed efforts of the SAOs and Arctic Council working groups "to implement activities, as appropriate, to follow-up the Arctic Climate Impact Assessment" (ACIA, 2005) "and the ACIA Policy Document, adopted by the Fourth Ministerial Meeting. The Tromsø meeting on Arctic Coastal Zones at Risk (Flöser et al., 2007) took up this challenge, initiating the effort to develop this State of the Arctic Coast 2010 report. The intent of this report was to shed further light on the critical, multi-faceted interface zone represented by Arctic coasts and to highlight the challenges of environmental, social, and economic changes five years after the publication of the ACIA.

Arctic coasts cover a broad spectrum of geological and oceanographic settings, resulting in a wide variety of shore-zone geomorphology. Nevertheless, most parts of the circum-Arctic coast share common factors such as strong seasonality, cold temperatures, permafrost, and sea ice, resulting in distinctive high-latitude coastal processes found nowhere else except Antarctica. Arctic coastal biota exhibit distinctive characteristics of low biodiversity but locally high productivity, particularly in the marine and aquatic realm. The human population of the Arctic comprises "more than 40 distinct peoples, cultures and languages" (Arctic Council,, 2006b, p. 4) and a wide range of coastal communities, from European ports and fishing communities (Iceland, Faeroes, Norway and western Russia) to regional administrative centres (e.g. Nuuk, Greenland; Iqaluit, Canada) to small and remote indigenous settlements in Chukotka, Alaska, Canada, and Greenland, in some of which today's older residents were born on the land. Cultural challenges, including rapid introduction of a market economy, globalization, language, relationship to the land and living resources, cultural heritage resources, contaminants and health, education, and other issues create a complex human backdrop to climate change and the challenges it presents to traditional lifestyle, economy, health, and community infrastructure.

Evidence of a warming climate is widespread across the Arctic, with the potential for dramatic impacts on sea levels, sea ice, waves, permafrost, plant and animal species, and human use of the coastal zone. Dramatic reductions of multiyear ice in the Arctic basin have grabbed headlines in recent years, but more subtle changes involving later freeze-up, earlier breakup, altered conditions and safety of landfast ice, changes in storm patterns, increased wave action, accelerated coastal erosion, deeper seasonal thaw, shifts in species composition including the appearance of new "southern" species, and other observations are recognized impacts in Arctic coastal communities.

Managing change on Arctic coasts requires a range of responses at various scales. Many of the impacts of physical (climate) and cultural change are experienced at the human settlement scale and require community adaptation strategies, yet adaptive capacity may be limited. At regional and national scales, co-management systems, ecosystem-based management policies, and national assessments and policy reviews have pointed to new approaches and strategies to manage change. Nevertheless, severe challenges remain in the establishment of appropriate governance, not least because of cultural differences in perception.

Several recent initiatives, under the International Polar Year (IPY) and elsewhere, have addressed issues of vulnerability and the need to foster enhanced resilience at community and regional levels, as described earlier in this report. The Salekhard Declaration (Arctic Council, 2006a) reconfirmed previous commitments to continue efforts to implement ACIA (2005) recommendations on climate-change mitigation, adaptation, research, monitoring, and outreach. The Norwegian Chairmanship Programme (Arctic Council, 2006b) undertook to strengthen "climate change research and monitoring …[and] the adaptive capacities of Arctic residents, including indigenous peoples and local communities … identifying the most vulnerable sectors of society." The Senior Arctic Officials (SAO) Report to Ministers (Arctic Council, 2009) made a number of recommendations for action on these fronts. New international efforts in recent years include the Arctic Monitoring and Assessment Programme (AMAP) project on Snow, Water, Ice and Permafrost in the Arctic (SWIPA) and the *Update on Selected Climate Issues of Concern* (AMAP, 2009b), as well as the *Arctic Report Card: Update for 2010* (Richter-Menge and Overland, 2010), sponsored by the Arctic Council.

Useful as these are, they largely ignore the coastal zone. Yet, as noted in the Introduction, the coast is a key interface in the Arctic environment. It is a locus of human activity, a rich band of biodiversity, critical habitat, and high productivity, and among the most dynamic components of the circumpolar landscape. The Arctic coastal interface is a sensitive and important zone of interaction between land, ocean, and atmosphere, a region that provides essential ecosystem services and supports indigenous human lifestyles; a zone of expanding infrastructure investment and growing security concerns; and an area in which climate warming is expected to trigger landscape instability, rapid responses to change, and increased hazard exposure. A high proportion of Arctic residents live on the coast and many derive their livelihood from marine resources. The coast is a region exposed to natural hazards and is particularly sensitive to climate change; it is thus a high priority for change detection and awareness

A common theme throughout this report is the lack of adequate data and knowledge on which to base appropriate and effective adaptation strategies. It is hoped that this report will provide the stimulus for accelerated efforts to close these information gaps and to mobilize the resulting knowledge in an effective way for the betterment of Arctic coastal ecosystems, the peoples of the north, and the global community.