

State of the Arctic Coast 2010

Scientific Review and Outlook

**International Arctic Science Committee
Land-Ocean Interactions in the Coastal Zone
Arctic Monitoring and Assessment Programme
International Permafrost Association**

April 2011



State of the Arctic Coast 2010

Scientific Review and Outlook

Published for:

International Arctic Science Committee
Land-Ocean Interactions in the Coastal Zone
Arctic Monitoring and Assessment Programme
International Permafrost Association

Published by:

Helmholtz-Zentrum Geesthacht
LOICZ International Project Office
Institute of Coastal Research
Max-Planck-Strasse 1
D-21502 Geesthacht, Germany
April 2011

The Land-Ocean Interactions in the Coastal Zone Project, LOICZ, is a Core Project of the “International Geosphere-Biosphere Programme” (IGBP) and the “International Human Dimensions Programme on Global Environmental Change” (IHDP) of the International Council for Science and the International Social Science Council. The LOICZ IPO is hosted and financially supported by the Institute of Coastal Research, at the Helmholtz-Zentrum Geesthacht, Germany, a member of the Helmholtz Association of National Research Centres.

Reproduction of this publication for educational or other, non-commercial purposes is authorized without prior permission from the copyright holders. Reproduction for resale or other purposes is prohibited without the prior, written permission of the copyright holders.

Lead Editor: Donald L. Forbes

Editorial Board: Volker Rachold, Hartwig Kremer, Hugues Lantuit

Layout and Design: Sandy Riel, Studio X Design, Beaumont, Alberta www.studioxdesign.ca

Reviewers: Jerry Brown, Margareta Johansson, Leslie King

Suggested Citation: Forbes, D.L. (editor). 2011. *State of the Arctic Coast 2010 – Scientific Review and Outlook*. International Arctic Science Committee, Land-Ocean Interactions in the Coastal Zone, Arctic Monitoring and Assessment Programme, International Permafrost Association. Helmholtz-Zentrum, Geesthacht, Germany, 178 p. <http://arcticcoasts.org>

Cover photography and chapter lead images: Covers and Chapters 1, 2, 3 (Donald Forbes); Chapter 4 (Henry Huntington).

ISBN 978-3-9813637-2-2

© IASC/LOICZ/AMAP/IPA 2011

Disclaimer: The designations employed and the presentation of the material contained in this report do not imply the expression of any opinion whatsoever on the part of IASC, LOICZ, AMAP or IPA concerning the legal status of any state, territory, city or area, or concerning the delimitations of their frontiers or boundaries. This report contains the views expressed by the authors and may not necessarily reflect the views of IASC, LOICZ, AMAP or IPA.

Executive Summary

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 and sea, 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.

This report addresses a recognized need for a more detailed assessment of the impacts of environmental and social change in the Arctic coastal zone. The Arctic Climate Impact Assessment (ACIA, 2005) provided an overall synthesis of observed and anticipated impacts on social and ecological systems in the Arctic, but did not attempt a focused treatment of the coastal zone. Five years on, the circumpolar Arctic coast is arguably one of the most critical zones in terms of the rapidity and the severity of environmental change and the implications for human communities dependent on coastal resources.

Rapid environmental, social, economic, political and institutional changes are defining characteristics of the past decade in the Arctic basin. In the physical environment, the prospect of a seasonally ice-free Arctic Ocean appears more likely and imminent, as previous records for annual minimum sea ice extent have been broken successively in recent years and the trajectory of ice loss is more rapid than the most extreme model projections in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007a). The past decade has also been the warmest on record for global surface air temperature and some Arctic regions have grown warmer at an even faster pace than the global mean, validating projections in earlier assessment reports that foresaw earlier and more severe climate change at high latitudes. In the face of unprecedented and jarring changes in the local environment on which traditional livelihoods and cultures depend, Arctic coastal communities are coping with rapid population growth, technological change, economic transformation, confounding social and health challenges and, in much of the Arctic, rapid political and institutional change.

It is evident that the coast is a critical component of the Arctic system requiring explicit attention. As a focus of human activity with attendant hazards, the circumpolar Arctic coast is clearly a priority for monitoring and change detection to support proactive adaptation and sustainable development.

This report is organized in four parts. Chapter 1 provides an introduction. Chapter 2 assesses the state of the Arctic coast under three broad disciplinary themes – physical, ecological, and human systems. Chapter 3 considers the need for and progress toward integrative approaches to monitoring, understanding, and managing change in Arctic coastal systems. Chapter 4 provides a synthesis and identifies data gaps and research priorities over the coming decade.

Key Findings

Physical State of the Circum-Arctic Coast

- The evolution of Arctic coasts over the coming decades will be strongly influenced by changes in the natural environment caused by the effects of climate warming.
- Surface air temperatures have reached record levels over the past decade. Record warm air temperatures in 2010 extended across Greenland and the Canadian Arctic.
- The past decade has seen successive new record minima in Arctic sea-ice extent and 2010 had the third smallest summer minimum extent of the past 30 years. At the same time, the mean ice thickness has been decreasing, driven primarily by export of perennial ice.
- Less extensive sea ice creates more open water, allowing stronger wave generation by winds. This, combined with warmer sea-surface and ground temperatures, has the potential to increase erosion along Arctic coasts. Record warm sea-surface temperatures in 2007 contributed to rapid coastal erosion in Alaska.
- Sea-level rise in the Arctic coastal zone is very responsive to freshening and warming of the coastal ocean (leading to increased sea level at the coast) and is highly susceptible to changing large-scale air pressure patterns.
- Relative sea-level change depends on vertical land motion (uplift or subsidence), the patterns of which are predominantly a legacy of former glaciation. The rate of uplift in some regions exceeds the rate of sea-level rise, leading to falling relative sea level.
- Sea-level rise in much of the Arctic is moderated by gravitational effects (fingerprinting) associated with ice loss from regional glaciers and ice caps and especially from the Greenland Ice Sheet.
- Arctic ice shelves will continue the recent rapid pace of collapse due to climate warming and the decrease in multi-year sea ice.
- Carbon entering the coastal system from terrestrial sources appears to be more labile than in the past. Because this organic matter is a direct source of energy for secondary production and a potentially important indirect source once remineralized, the higher lability may have far-reaching, yet unknown consequences for Arctic coastal marine productivity.
- Despite increasing annual freshwater discharge, some Arctic deltas are being progressively flooded, with most of the Mackenzie Delta front (the second largest Arctic delta) retreating at 1-10 m/year or more.
- Storm-surge inundation of low coastal areas and deltas affects coastal communities and can have profound impacts on delta ecology through salinization of freshwater environments. Early-season surges can disrupt waterfowl breeding and winter surges may flood or break up winter ice roads, a critical form of transportation for many northern activities.
- Decadal-scale mean rates of coastal retreat are typically in the 1-2 m/year range, but vary up to 10-30 m/year in some locations. The highest mean erosion rates are in the Beaufort Sea, the East Siberian Sea, and the Laptev Sea.
- Recent results on erosion of ice-rich bluffs point to the importance of interaction between high sea-surface temperatures, which drive thermal

abrasion and undercutting, and the timing of ice break-up and freeze-up in combination with storm dynamics.

- The distribution and stability of gas hydrates in the Arctic coastal zone is poorly documented, but there is concern that climate change and other effects such as coastal erosion may destabilize some hydrate deposits.
- Rocky shorelines comprise 35% of the Arctic coastline and most are effectively stable on timescales relevant to adaptation planning and management.

Ecological State of the Circum-Arctic Coast

- Arctic coastal habitats are the prime lifeline for Arctic communities and provide a wide range of ecosystem services.
- They support very large populations of fish, mammals and birds that are harvested by Arctic and non-Arctic communities.
- The Arctic coastal zone provides habitat to an estimated 500 million seabirds alone.
- Arctic coastal habitats are highly vulnerable to changing environment conditions, including climate change and growing human activities such as oil and gas exploration and development.
- Arctic river deltas are biological hotspots on the circumpolar Arctic coast. They have high biodiversity and are extremely productive in relation to adjacent landscapes. The high biodiversity remains poorly understood, but may be related to the complex natural patterns of water level fluctuation that occur in these vast lake-rich systems.
- Arctic ice shelf microbial mat cryo-ecosystems are severely threatened by ice shelf collapse, with some of the richest examples already lost.

Social, Economic and Institutional State of the Circum-Arctic Coast

- Social, cultural, health and demographic conditions, economic systems, industrial structure and the relative importance of subsistence activities vary across the spectrum of communities on the circumpolar Arctic coast.
- The Arctic economy as a whole is dominated by four major characteristics: the continuing importance of traditional subsistence activities and local living resources in most regions, the lack of manufacturing industries, the local and regional impacts of large-scale natural resource extraction or exploitation projects, and the major importance of the public sector for service provision and transfer payments from the south.
- Disposable household income (DHI) is largest in the Arctic regions where large-scale resource extraction occurs. These are, however, also the regions where the discrepancy is largest between DHI and gross regional product, demonstrating that actors outside of the region reap a large portion of the benefits from the economic activities there.
- Even though the Arctic has a relatively large proportion of people living in a near-traditional manner, close to nature and utilizing the resources there for food and subsistence, it is also well linked to the global economy, in particular as a large supplier of natural resources. The same processes we see in the advanced industrialized regions, of a knowledge-based economy with a focus

on innovations, are also taking place in the Arctic.

- Although climate change and other processes affecting natural resources and environmental conditions impose large impacts on quality of life and economic activity for communities on the Arctic coast, other factors and processes will often be more important, especially in the short run. Where communities are already stressed, even small changes in the availability or quality of natural resources may be critical.
- Recently established integrated marine regional plans, as for example in the Barents Sea, are milestones in the implementation of ecosystem-based management. Laudable as these efforts are, however, it is clear that more work needs to be done, particularly on societal impacts of industrial activities and on the socio-economic impacts of ecosystem changes in the Arctic coastal zone. In each case, a multifactor perspective is essential.
- The Arctic Human Development Report found that, for people in the Arctic, fate control, cultural integrity and contact with nature are central for well-being and should be included in future statistical data collection efforts. The Arctic Social Indicators project has proposed a suite of indicators for these factors, in addition to aspects considered in the United Nations Human Development Index, and is working toward the implementation of these indicators in the Arctic.
- Statistical data specific to coastal regions are difficult to obtain, at least for circumpolar comparisons. Economic, social and demographic connections between coastal and inland areas hinder a clear delineation of what should be included, or excluded, in a coastal-based study such as this.
- At a time of incipient rapid changes in the Arctic coastal zone resulting from climate change and other factors, there are growing health challenges in Arctic communities. Monitoring of the human health situation across the Arctic is critically important, especially for indigenous people in rural areas and remote communities.

Integrated Approaches to Coastal Change in the Arctic

- Arctic coasts may be usefully viewed as complex social-ecological or social-biophysical systems. A social-ecological system is an ecological system intricately linked with and affected by one or more social systems and vice versa.
- The health of Arctic coastal and marine ecosystems is increasingly under pressure, putting at risk ecosystem goods and services that support coastal communities.
- There are major feedback loops in the Arctic system associated with rapid changes in the regional climate. For this reason, the impacts of climate change in the Arctic may extend to a global scale.
- There are two general approaches to more integrated understanding considered in this report:
 - Indigenous communities in general embrace holistic perspectives on the environment and culture.
 - The traditional scientific approach can be applied within a system science framework, with the application of integrated assessments to analyze the interactions in social-ecological systems, as outlined in the risk-based management approach.

- The holistic perspective of indigenous culture suggests that efforts to understand, manage, and respond to change in Arctic coastal systems may benefit from the integration and complementarity of both approaches. Recognizing the value of traditional ecological knowledge may contribute to enhanced resilience and adaptive capacity in coastal communities.

Monitoring, Detecting and Modelling Coastal Change

- Reduction of negative impacts through adaptation to climate change requires new approaches in monitoring strategies to detect and track changes in the Arctic coastal environment. Understanding and prognosis of change is an essential component of resilience in Arctic coastal communities.
- Biophysical and human monitoring both clearly demonstrate that the Arctic environment is changing rapidly – sustained observation and monitoring is essential to document change and validate projections.
- Field-based monitoring in the Arctic coastal zone is challenged by remoteness, accessibility, communications, and instrument performance in extreme cold, but new survey technologies, instrumentation, and higher resolution of remotely sensed data are revolutionizing monitoring capabilities.
- These new techniques, decreasing costs, and higher resolution are enabling better spatial and temporal coverage of coastal change.
- Models represent key tools for understanding current changes and projecting future changes and associated impacts on Arctic coastal ecosystems and human communities.
- Models provide a means of interpolating between periods or locations of observation, a valuable capacity in times of reduced research and monitoring budgets.

Vulnerability, Adaptation, Adaptive Capacity and Resilience

- Increasingly governments, communities, and industry stakeholders are exploring ways to reduce the negative impacts of climate change and take advantage of new opportunities through adaptation.
- Many Arctic coastal communities are experiencing vulnerabilities to decreased or less reliable sea ice, greater wave energy, rising sea levels, changes in winds and storm patterns, storm-surge flooding or coastal erosion, with impacts on travel (on ice or water), subsistence hunting, cultural resources (e.g. archaeological remains, burial sites) and housing and infrastructure in communities.
- In some places, this has necessitated community relocation, which in some cases increased vulnerability.
- In places, coastal erosion is threatening critical infrastructure or contaminated sites, with potential for spreading of pollutants.
- There has been great progress in recent years in the understanding of exposures and identification of elements of adaptive capacity that may enhance resilience, but other challenges including social, technical, financial, and institutional barriers may be inhibiting successful adaptation.
- There is a wide range of adaptive capacity among coastal communities of the circumpolar Arctic. A community with a greater resource base, including physical resources, financial capacity, knowledge (of all kinds), and social cohesion, is in

- a better position to successfully adapt than one that lacks resources and options.
- Arctic indigenous peoples are traditionally resilient. This has allowed them to adapt to a harsh climate and changing environmental conditions over multi-century time-scales.
 - With a faster pace of change and numerous compounding challenges, the indigenous peoples of the Arctic are generally less resilient today, although developments in regional governance and cultural initiatives, as well as growing familiarity with climate change, may be improving the situation to some extent.
 - Quantitative scientific research concerning past, present, and future environmental changes and impacts is a key component informing policy and decision-making.
 - Adaptation strategies perceived as imposed from outside will not be incorporated into the community's reservoir of mechanisms for coping with change, will not form a component of its adaptive capacity, and will thus not contribute to its resilience and ultimate sustainability.

Governance and Adaptation

- National agencies are the main actors in regional governance. In some areas such as northern Canada, regional (or in this case, territorial) agencies may play an equally important part. At national and international scales, almost all international land boundaries are settled, meaning that national jurisdiction at the coast is generally clear.
- There are enormous differences across the circumpolar Arctic in population size and distribution, economy, culture, institutional framework, and other factors.
- There are few Arctic-specific international regimes: the 1973 Polar Bear Treaty is the only legally binding regime.
- The Arctic Council, based on soft law (1996 Declaration), works primarily through assessment programs and projects to develop consensual knowledge and understanding on the status of the Arctic environment and related issues among the eight Arctic countries.
- Integrated coastal area management and integrated ecosystem-based oceans management are desirable strategies for coastal area governance and may embody a number of best practices which have emerged from recent reviews.
- Conclusions from consideration of integrated ecosystem-based management include the following:
 - Management needs to be flexible;
 - Decision-making must be integrated and science-based;
 - National commitment is required for effective management;
 - Area-based approaches and trans-boundary perspectives are necessary;
 - Stakeholder and Arctic resident participation is a key element;
- Adaptive management is critical.
- It has been recommended that future research should focus on increasing support, opportunity, and capacity for local decision-making or effective resident input to decisions on broader institutional policies with local impacts.

Table of Contents

| | |
|---|------------|
| EXECUTIVE SUMMARY | iii |
| KEY FINDINGS..... | iv |
| TABLE OF CONTENTS | ix |
| 1 INTRODUCTION | 1 |
| 1.1 Background | 1 |
| 1.2 The Circumpolar Arctic Coast..... | 4 |
| 1.3 Rationale..... | 5 |
| 1.4 Objectives and Organization of the Report | 7 |
| 2 STATE OF THE ARCTIC COAST 2010 – A Thematic Assessment..... | 11 |
| 2.1. Physical State of the Circum-Arctic Coast | 11 |
| 2.2. Ecological State of the Circum-Arctic Coast..... | 39 |
| 2.3 Social, Economic and Institutional State of the Circum-Arctic Coast..... | 57 |
| 3 INTEGRATED ASSESSMENT AND RESPONSE TO ARCTIC COASTAL CHANGE .. | 79 |
| 3.1 Integrated Approaches to Coastal Change in the Arctic | 79 |
| 3.2 Monitoring, Detecting and Modelling Coastal Change..... | 87 |
| 3.3 Vulnerability, Adaptation, Adaptive Capacity and Resilience..... | 104 |
| 3.4 Governance and Adaptation..... | 115 |
| 4 SYNTHESIS AND FUTURE DIRECTION | 123 |
| 4.1 Introduction | 123 |
| 4.2 ICARP-II Science Plans | 124 |
| 4.3 Knowledge Gaps and Research Priorities..... | 126 |
| 4.4 Building a Road Map to Integrated Coastal Systems Research in the Arctic .. | 129 |
| 4.5 Summary Discussion | 131 |
| 5 REFERENCES | 133 |
| List of Contributors..... | 165 |
| Acknowledgements..... | 168 |