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*by Magdalena A.K. Muir**

Introduction

Science and policy concerning oceans must be considered as strategies are developed to attempt to buffer the impacts of climate change from the global to the local levels. As discussed in this article, climate change science and policy need to be inserted into the oceans agenda, and oceans science and policy need to be inserted in the climate agenda. Also discussed are the outcomes from the Third Global Conference of Oceans, Coasts, and Islands and the effectiveness of the Arctic Climate Impact Assessment Scientific Report of 2004. Finally, possible impacts and responses to climate change for the Canadian Beaufort Sea, a "hot spot" within the Arctic, is examined.

Global Climate and Oceans Initiatives

The Third Global Conference on Oceans, Coasts, and Islands took place in Paris from January 23 to 28, 2006 and included a panel on oceans and climate issues. A summary of the panel was drafted, which included recommendations arising from the panel and the following discussion.[1] Recognition of and recommendations for oceans and climate issues are crucial, as the need for global mitigative measures (as well as global, regional, and local adaptive measures) are of vital importance. These measures are required to minimize climate impacts on coasts and oceans, coastal and marine ecosystems, and the environmental and economic goods and services these ecosystems provide.

Climate change mitigation is a major challenge and must be considered while formulating energy, economic, technological, and development policy.

Sea Level Rise Impacts

The panel summary began with a discussion of the Intergovernmental Panel on Climate Change ("IPCC"), which will present the Fourth Assessment Report to the Thirteenth Conference of the Parties to the United Nations Framework Convention on Climate Change in December 2007. The panel summary indicated that sea level rise is a significant threat for small islands, coasts, and low-lying lands. Ocean acidification is a new and potentially overwhelming threat that could undermine the marine ecosystems and food web, preclude coral development, and even affect atmospheric and ocean interactions. Irrespective of what mitigative measures are adopted, changed sea levels and acidification will remain for the next few millennia.[2]

Parallel changes are occurring, and parallel approaches will be required for small islands, as well as equatorial and tropical regions. For example, coral reefs, marine fisheries, and marine resources also will be affected by climate change and climate variability. However, small islands with large Exclusive Economic Zones already have limited capacity to manage these zones, and climate change will compound these management issues.[3] Sea level rise due to flooding, salt water intrusion into fresh water, salination of the soils, and declines in water quality and quantity will impact subsistence and commercial agriculture on small islands. Sea level rise and extreme events will affect infrastructure and development in all regions, including tourism, agriculture, transportation, and the delivery of health, fresh water, food, and other essential services.

The Arctic Climate Impact Assessment Scientific Report documents climatic changes for the circumpolar Arctic and is subsequently discussed in this article. The Arctic has been warming rapidly, and larger and more significant changes are projected for the future.[4] Small islands are also vulnerable to the impacts of climate change, sea level rise, and extreme events because of size and exposure to natural hazards and more limited adaptive capacity. According to the Third Assessment Report of the IPCC, islands, like the Arctic, are early indicators of global climate change. Islands often depend on rainwater and are vulnerable to changes in the distribution in rainfall.

Alterations in the Weather

Another emerging and more immediate threat is the impact of high sea surface temperatures on the intensity of tropical cyclones and hurricanes. Understanding of the role of oceans as a regulator of the earth's climate system is also increasing: the oceans control the timing and magnitude of changes in the

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global climate system, primarily through the absorption of carbon dioxide and heat. Other climate impacts include arctic sea ice reduction, cyclonic storms, changes in ocean circulation, intensification of eutrophication in shallow waters and enclosed seas, and inter-related changes in biodiversity and fisheries.[5]

Warming Sea Impacts Extend to Land

Human health is also impacted by climate change. Outbreaks of vector-borne diseases like dengue fever and malaria will increase, with the Caribbean islands and equatorial zones being at greater risk. Shortages of water and drought, as well as contamination of water quality during floods and storms, will increase disease risk, including cholera, diarrhea, and dengue fever.

Africa is very vulnerable to climate change, with negative impacts expected for the watersheds, coasts, and seas of Africa. Worsening desertification in northern and southern Africa is also forecasted to occur. The continent is most vulnerable to the impacts of projected change because of widespread poverty and limited adaptation capabilities. A parallel recognition of the disproportionate impacts of climate change on Latin America and the Caribbean, including coastal and oceans areas exists. A recent report catalogues the impact of climate change and environmental degradation ranging from drought in the Amazon to floods in Haiti and elsewhere; vanishing glaciers in Colombia to extreme cold in the Andes; and hurricanes, not only in Central America and the Caribbean, but also in southern Brazil.[6]

Strategizing Climate Change Policy Solutions

Climate change mitigation is a major challenge, and must be considered while formulating energy, economic, technological, and development policy. The Eleventh Conference of the Parties of the United Nations Framework Convention on Climate Change ("UNFCCC") in Montreal in December 2005 initiated a two-track process to develop future climate strategy with the Kyoto Protocol as the first track. The second track is an informal Convention Dialogue aimed at exchanging experiences and analyzing strategic approaches for long-term cooperative action. This dialogue is not confined to the present Parties to the Kyoto Protocol and will address technology, adaptation, market-based opportunities, the development context, and voluntary action by developing countries.[7]

In short, the UNFCCC process addresses adaptation through understanding of climate impacts, vulnerability, and other possible measures on the one hand and financial and technical assistance to the most vulnerable Parties on the other. For example, proceeds from the Clean Development Mechanism project activities will fund a new Adaptation Fund under the Kyoto Protocol. Additionally, the bulk of two other dedicated funds under the Convention are targeted for adaptation to the impacts of climate change by developing countries.[8]

On a global and regional level, climate change science and policy need to be inserted into the oceans agenda, and oceans science and policy need to be inserted in the climate agenda. Adaptation is not enough; mitigation is also required through reducing greenhouse gases and shifting to renewable energy and

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Map of the Beaufort Sea LOMA, divided into coastal and offshore areas.

increasing energy efficiency. Thinking globally, planning regionally, and acting locally is necessary.

Climate issues are complex and require input from many disciplines and the integration of ecosystem-based and other integrated approaches. In addition, constant dialogue between scientists and decision-makers is required. Scientific data and analysis, from accurate and timely predictions of hurricanes to improved global and regional forecasts of future sea level rise and the impacts of ocean acidification, lay the foundation for adaptation policy discussions and the development of climate strategies. In order to be effective, this data and analysis needs to be communicated to decision-makers on a timely basis and in the appropriate language.

As policies adapt to climate change and variability, opportunities must be considered as well as risks. With accelerating climate change and variability, reliable scientific information becomes crucial for formulating policy on a wide variety of issues, including fisheries, marine infrastructure, and transportation. Therefore, more resources need to be devoted to ocean climate research, paying attention to the short and medium term, regional, and global impacts.

Arctic Climate Change and Oceans

One of the key findings of the Arctic Climate Impact Assessment Scientific Report is that the Arctic has been warming rapidly and much larger changes are projected for the future. Increasing temperatures, melting glaciers, reductions in the

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Beluga whales at an ice edge. The Beaufort Sea LOMA contains three marine protected areas for migratory beluga whales in the Mackenzie Delta.

extent and thickness of sea ice, thawing permafrost, and rising sea level illustrate this warming trend. Chapter 10 of that report, Principles of Conserving the Arctic's Biodiversity, begins the dialogue on management and policy approaches for conserving biodiversity and related ecosystem services in the circum-arctic.

In the Arctic, changes in sea ice are a key indicator and agent of climate change, affecting surface reflectivity, cloudiness, humidity, exchanges of heat and moisture at the ocean surface, and ocean currents. Changes in sea ice have enormous economic, environmental, and social implications. There are negative impacts on ice-dependent wildlife and northern peoples like the Inuit with a traditional subsistence lifestyle based on hunting mammals on, or adjacent to, sea ice. Changes may also have positive economic effects, as it may facilitate increased marine transportation, economic development, and immigration into the region.[9]

The Canadian Beaufort Sea[10]

The Beaufort Sea Large Ocean Management Area ("LOMA") is composed of the Mackenzie Delta and the Canadian Beaufort Sea, extending to the northernmost extent of Canada's jurisdiction. Despite its relatively pristine state, the region is on the brink of significant economic and environmental change. Hydrocarbon activity and is other forms of economic development are underway against a backdrop of the implementation of comprehensive northern land claims and complicated by global and regional climate change and contamination issues. Integrated management under the Beaufort Sea LOMA reflects the commitment under the Canadian Ocean Policy Framework to manage oceans so as not to compromise coastal and marine ecosystems while encouraging multiple uses of ocean spaces and resources.[11]

The Arctic Ocean receives significant freshwater input from rivers, and the Beaufort Sea receives freshwater inputs from the Mackenzie River year-round, resulting in the "Mackenzie Lake" beneath the ice in the winter and the Mackenzie freshwater plume in the summer. Given the extent of the freshwater input year-round, it is difficult to separate the impacts of the Mackenzie River from coastal and ocean processes. With the deltaic nature of the terrain, aquatic and terrestrial ecosystems are difficult to differentiate. There are vast arrays of freshwater lakes and rivers in the summer, land-fast ice and ice on river, coasts and land in the winter, continuous permafrost underlying the land, the coasts, and the Beaufort Sea, and a highly unstable, shifting and eroding coastline formed of consolidated ice, gravel, and sand.

Complexities of the Beaufort Sea Climate System

Sea ice is an important component of the global, Arctic, and Beaufort Sea climate system. Sea ice variability not only indicates climate change but also is directly driven by and feeds into the atmospheric, oceanic, and hydrologic cycle. Sea ice, particularly the diminishing summer sea ice conditions, has the potential to drastically alter the cycles of atmosphere, ocean, hydrology, and other components in the Beaufort Sea LOMA. Examining sea ice, including flaw leads and polynyas[12] can be a good way to understand climate change and how ocean warming, or a longer open season, affects biologic productivity. The mechanisms and impacts of long-term variability and trends for Arctic sea ice are not fully understood and developing an integrative understanding of the past, current, and possible future influences of polar sea ice on climate systems is necessary.

Interactions of freshwater, marine water, and brackish water, including mixing and stratification and the implications of these interactions with climatic changes are useful considerations. Unlike tropical oceans, which are temperature stratified, the Arctic Ocean is salinity stratified, with a halocline where salinity increases with depth. This is important for the formation of sea ice, as saltwater is most dense just before freezing, and sea ice is largely salt free.

Salinity influences the presence of marine species directly through salinity preferences of particular species and indirectly through its effects on stratification, water movements, and phytoplankton productivity. Differences in the density of seawater throughout the water column, or stratification, affect the aggregation of biological matter in the upper layers of the ocean. Density is a function of salinity, temperature, and pressure and varies with depth. Temperature is another important environmental factor because many species have narrow temperature tolerance, which will affect their spatial distribution. Temperature also influences metabolism, growth rate, and reproductive output.[13]

Land Claims and Economic Activities Influence Beaufort Sea Management

When one imagines the Beaufort Sea LOMA, the complexity and overlapping land claims agreements are an important consideration. All the land claims agreements in northern Canada are constitutionally protected and override inconsistent federal and territorial legislation and policy. The Canadian federal government has a strong commitment to Inuit and First Nation involvement and participation under the Oceans Act and the Oceans Action Plan, and thus in the Beaufort Sea Partnership and other initiatives for the LOMA. There are also international cooperative management arrangements between Canada and the United States for migratory and ice dependent marine species such as bowhead and beluga whales, seals, and polar bears. The Gwich'in and Inupiat of Alaska could also participate to reflect and support these international wildlife management arrangements.[14]

The Oceans Policy Framework commits Canada to manage impacting activities in oceans in a way that does not compromise marine and coastal ecosystems, while encouraging multiple uses of oceans spaces and resources. The Beaufort Sea LOMA is subject to multiple use designations, with extensive economic development on the horizon, at a time when climate and contaminant impacts are increasing. Significant hydrocarbon development is on the horizon, with the proposed Mackenzie Gas Project. Though this project is currently limited to three fields in the Mackenzie River delta and the construction of an extensive natural gas and natural liquids pipeline from that delta to northern Alberta, there are significant impacts from the construction of the pipeline and the likelihood of extensive future developments and habitat and landscape fragmentation over time.[15]

Multiple use designations will remain the norm in the LOMA, except where certain uses are excluded or restricted by marine protected areas or other designations. As indicated by the implementation of the proposed marine protected areas in the LOMA, it is important to provide early information to federal and territorial government departments of potential ecological and biologically significant areas and species in order to condition or to limit the issuance of economic rights and developments in these areas.[16]

National Management of an Arctic "Hot Spot"

Identifying areas that have particularly high ecological or biological significance is necessary to facilitate provision of greater than usual degree of risk aversion in the management of activities in these areas. Providing early information to federal and territorial governments of potential ecological and biologically significant areas and species, and conditioning or limiting the issuance of rights and subsequent developments in these or adjacent areas is important.[17]

The Beaufort Sea is a climatic hot spot for the Arctic. Observation and scientific experiments have shown that climate change is affecting permanent, seasonal, and land-fast ice; permafrost and coastal erosion; fresh water inputs, flows, and sediment deposits; and temperatures, stratification, and salinity. Climate change may be one of the biggest challenges facing the Beaufort Sea LOMA, and its institutions and processes. This challenge may drive much of the management, monitoring, and research efforts for the Beaufort Sea Partnership and Regulatory Coordination Committee that are being established to manage the LOMA. Much of the biology, biodiversity, and ecosystems in the Beaufort Sea LOMA is not extensively known or studied. All are likely to be affected in some way by climate change, whether adversely or positively.

On a global and regional level, climate change science and policy need to be inserted into the oceans agenda, and oceans science and policy need to be inserted in the climate agenda.

Coastal change in the Beaufort Sea is a product of the interaction between local geological and geo-morphological conditions and waves and storm surges driven by winds. Sea ice formation and movement may also play a subordinate role. Also, it is possible that the severity, not number, of storms has increased in this area. Decreasing ice concentration and increasing wind speeds together suggest a more severe wave climate in Beaufort. Observations of land loss along the coast, including subsidence and slumping, have been made. There will be a decreased sea ice that previously protected infrastructure and inhibited wave formation. If sea ice is mobile, it could cause ice scour, more coastal erosion, and damage to infrastructure.

There may be increasing hazards to coastal infrastructure in the Beaufort Sea, but not in a catastrophic way and without risk of loss of life. Instead, it will be a slow and very predictable process. There are some positive aspects in that very limited infrastructure is currently in place, and thus, one can plan and defend for climate change. For example, roads and pipelines can be constructed away from coasts, with a similar planning approach for communities. Coastal change is occurring in Tuktoyaktuk, which is the only northern community with coastal defenses. Erosion has been reduced but with other implications, and there is concern for the inner harbor.[18]

Considering the scope of federal activities in the Beaufort Sea LOMA, several Canadian government departments are

likely to have complimentary activities on climate and marine issues. Fisheries and Oceans Canada is the coordinating agency for oceans matters, as well responsible for fisheries and marine resources. The Department of Indian Affairs and Northern Development is involved in northern communities in all the territories as the major landowner on land and in the offshore, as well as specifically focusing on contaminants and climate interaction.[19] Environment Canada and the Canadian Ice Service focus on sea ice and climate issues, including ice thickness and extent, ice modeling and climate science. Transport Canada is interested in the regulation of marine shipping, which is affected by all sea ice issues.

Natural Resources Canada is involved in programs such as Reducing Canada's Vulnerability to Climate Change Program, which has been re-named, Enhancing Canada's Resilience to Climate Change Program. This program covers everything from sea ice and permafrost response to municipal case studies and integrated socio-economic assessments. Much of the Mackenzie Delta work focuses on permafrost's impacts and costs to communities. Natural Resources Canada's Climate Change Impacts & Adaptation Program has funded several projects in the Beaufort Sea. Currently, there are three projects underway, two of which are transportation projects and the other is a coastal management project.[20]

Conclusion

Climate change is a global concern. The Beaufort Sea can be used as a microcosm to demonstrate the impact of climate change on our oceans, and forecast the problems we might have to face in the future. Currently, steps are underway to understand the impacts of the changing climate and to provide adaptive management approaches. Likewise, mitigative measures are also underway in global, regional, and national forums.

Endnotes: Oceans and Climate Change

[1] GlobalOceans.org, Oceans and Climate Panel, http://www.globaloceans.org/globalconferences/2006/pdf/NextStepsClimate.pdf (last visited Oct. 30, 2006). The panel summary was prepared by the author and reports on Third Global Conference on Oceans, Coasts and Islands, January 23 to 28, 2006, UNESCO, Paris and relies on the underlying expertise of the panel members and their presentations for that panel.

[2] *See* German Advisory Council on Climate Change, The Future Oceans, Rising Up, Warming Up and Turning Sour (2006), *available at* http://www.wbgu.de/wbgu_sn2006_voll_en.html (last visited Oct. 12, 2006).

[3] *See* Millennium Ecosystem Assessment, Ch.10: Principles of Conserving the Artic's Biodiversity (2005), *available at* http://www.acia.uaf.edu/PDFS/ACIA_Science_chapters_final/ACIA_CL10_Final.pdf.

[4] ACIA, Arctic Climate Impact Assessment Scientific Report (Feb. 2006), *available at* http://www.amap.no (last visited Oct. 30, 2006) [hereinafter Arctic Climate Report].

[5] Real Climate website, http://www.realclimate.org (last visited Oct. 12, 2006).

[6] *Up in Smoke? Latin America and the Caribbean: The Threat from Climate Change to the Environment and Human Development*, Third Report from the Working Group on Climate Change and Development (Aug. 2006), *available at* http://www.neweconomics.org/gen/uploads/15erpvfzxbbipu552pnoo1f128082006213002.pdf (last visited Oct. 12, 2006); see also *Africa-Up in Smoke*, the UK Working Group on Climate Change and Development, *available at* http://www.oxfam.org.uk/what_we_do/issues/climate_change/africa_up_in_smoke.htm. (last visited Oct. 12, 2006).

[7] UNFCCC website, http://unfccc.int (last visited Oct. 12, 2006).

[8] Important measures are also underway in the European Union to adapt to climate change through the Impacts and Adaptation Working Group, including climate change for coastal and marine areas, under the European Climate Change Programme II. These measures are proceeding towards a draft Green Paper, an eventual White Paper, and perhaps either new or revised EU Directives and policies.

[9] *See* Arctic Climate Report, *supra* note 4. For further and more extensive information on the Scientific Report see http://www.amap.no (last visited Oct. 12, 2006).

[10] This analysis of the Beaufort Sea Large Ocean Management Area draws upon the author's work for Fisheries and Oceans Canada, Beaufort Sea Large Ocean Management Area Ecosystem Assessment and Overview: Volume 2, Final Draft Remarks, 2006. Aspects of this report will be incorporated in the final ecosystem assessment for the Beaufort Sea.

[11] Fisheries and Oceans Canada, Canada's Oceans Action Plan, 2005; Fisheries and Oceans Canada, *Tarium Niryutait* Regulatory Intent, 2005; *Tarium Niryutait Management* Plan, 2005 and Powelles H., et.al., Proceedings of the Canadian Ecoregions Workshop, CSAS Proceedings Series 2004/16.

[12] A polynya is an open water or thin ice area surrounded by thicker ice.

[13] For a discussion of the Mackenzie River, the freshwater plume and "Mackenzie Lake," as well as oceanographic features, see Macdonald R. et al, *The Mackenzie Estuary of the Arctic Ocean*, Hdb Env. Chem., vol. 5 (2005).

[14] *See* M. Muir, *Analysis of the Inuvialuit Final Agreement and Marine Protected Areas under the Oceans Act*, (1997); *see also* Arctic Institute of North America and the Canadian Institute of Resources Law, *Comprehensive Land Claims Agreements for the Northwest Territories: Implications for Land and Water Management* (Nov. 1994); The Beaufort Sea Partnership, *An Integrated Management Initiative for the Beaufort Sea* (2005).

[15] The Mackenzie Gas Project, *available at* http://www.mackenziegasproject.com/theProject/regulatoryProcess/index.html (last visited Oct. 12, 2006), and the Canadian Arctic Resources Committee report filed November 9, 2005 with the Joint Review Panel: Petr Cizek, A Choice of Futures: Cumulative Impact Scenarios of the Mackenzie Gas Project.

[16] *See* Fisheries and Oceans Canada, *supra* note 11. This overall discussion relies upon a report by the author entitled, Beaufort Sea Large Ocean Management Area Ecosytem Overview and Assessment: Volume 2, Final Draft Remarks, 2006.

[17] Fisheries and Oceans Canada, *Identification of Ecologically and Biologically Significant Areas*, Ecosystem Status Reports (2004).

[18] S.M. Solomon, Effects of Climate Variability and Change on Arctic Coasts and Coastal Infrastructure (Coastal Zone Canada 2006 Conference and Youth Forum 2006); D. Whalen et. al., Past, Present and Future Coastal Flooding in the Western Canadian Artic (Coastal Zone Canada 1006 Conference and Youth Forum 2006); G. K. Manson & S. M. Solomon, Predicting the Impacts of Changing Climate on Beaufort Sea Shorelines (Coastal Zone Canada 2006 Conference and Youth Forum 2006).

[19] For example, climate interactions may be a useful focus in order to understand the observed increased methyl mercury levels in marine mammals in the Beaufort Sea region, either through local erosion or permafrost degradation, or the transport of mercury through the Mackenzie River from that watershed. *See* G. Stern et al., *Riverine and Coastal Erosional Input of Mercury to the Beaufort Sea under a Changing Climate*, Coastal Zone Canada (2006).

[20] Natural Resources Canada website, http://www.adaptation.nrcan.gc.ca/home2_e.asp?CaID=9&PgID=23.