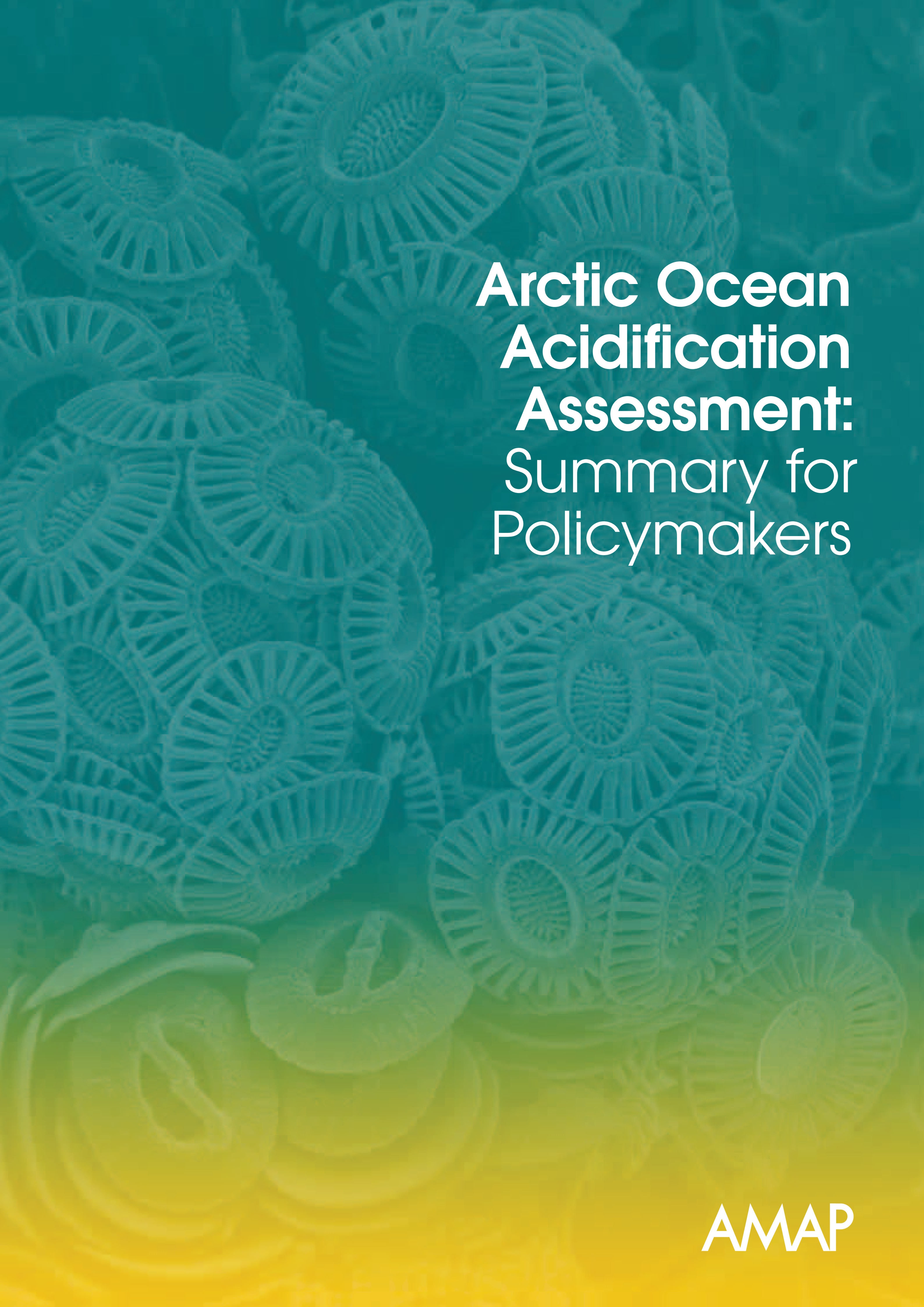

Arctic Ocean Acidification Assessment: Summary for Policymakers

AMAP

What is ocean acidification?

Ocean acidification refers to an increase in the acidity of the ocean over an extended period, typically decades or longer, which is caused primarily by uptake of carbon dioxide from the atmosphere.[1,2]

Why are higher carbon dioxide levels over the world's oceans a global problem?

Higher levels of carbon dioxide in the atmosphere are resulting in greater amounts of carbon dioxide being absorbed by marine waters. The result—ocean acidification—will affect marine ecosystems and organisms, from plankton to fish. The extent and consequences of ocean acidification effects are largely unknown.

Why does this issue matter to the Arctic Nations and its Peoples?

Arctic waters are particularly vulnerable to ocean acidification due to the higher capacity of cold waters to absorb carbon dioxide. Other factors such as loss of sea ice resulting from a changing climate are also contributing to increased absorption of carbon dioxide at high latitudes. Regions of the Arctic Ocean are already showing the effects of acidification.

Ocean acidification within the Arctic has the potential to affect the livelihoods of northern communities, including those that rely on recreational and subsistence fishing and ecotourism.

1 Based on Field, C. and others (Eds.), 2011. ***IPCC Workshop on Impacts of Ocean Acidification on Marine Biology and Ecosystems***.

2 The *acidity* of a liquid is expressed by its pH (a measure of its hydrogen ion content). A liquid with a pH of less than 7 is acidic; a liquid with a pH of more than 7 is alkaline; a pH of 7 is neutral. Surface seawaters in the Arctic have a pH of about 8.1, with a range of about 7.5 to 8.4. The term *ocean acidification* refers to an increase in acidity (i.e., a decrease in pH).

Tor Ivan Karlsen / tikfoto.no

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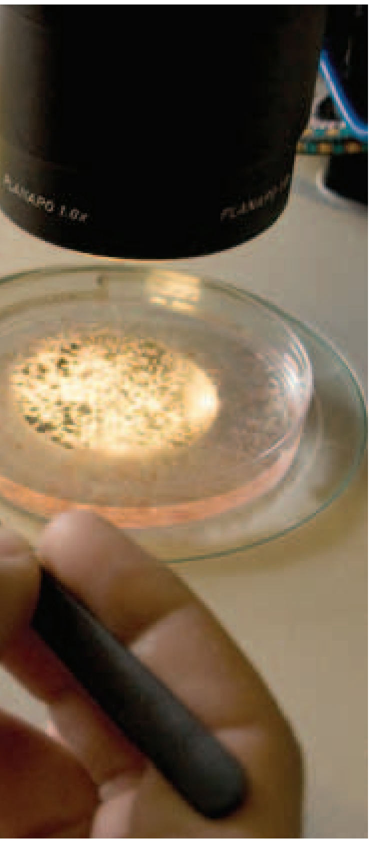

Ocean acidification is occurring at a rapid and accelerating pace, and the Arctic Ocean[3] is on the frontline of this global change. AMAP's 2013 assessment of Arctic Ocean acidification provides the first Arctic-wide perspective on today's progressively increasing seawater acidity. The assessment report presents current scientific knowledge on the changing state of ocean acidification in the Arctic and how these changes are affecting the Arctic marine environment. In addition to reporting on what is happening now, the assessment considers how these changes could continue to develop in the future and what this could mean for Arctic marine plants and animals and Arctic peoples.

Measurements around the globe, in the Arctic Ocean and elsewhere, show that ocean acidity is increasing. These findings are consistent with observed increases of carbon dioxide in the atmosphere and uptake of some of this gas by the oceans. The resulting chemical reactions are well characterized: adding carbon dioxide to seawater increases its acidity.

Like salinity, acidity is a fundamental chemical property of seawater. Ocean acidification is of concern because it has the potential to exert far-reaching effects on marine plants and animals and therefore human societies.

Human activities, in particular the burning of fossil fuels, are the primary cause of the ongoing increase of carbon dioxide in the air and oceans. Natural processes in the ocean counter this increase by eventually burying some of the 'extra' carbon in deep sea sediments, but these processes act very slowly. The legacy of the human activities is therefore long-lived. Scientists project that even after anthropogenic carbon dioxide emissions cease, the acidification fingerprint of human activities will remain in the upper ocean for many tens of thousands of years.

Global ocean acidification is now occurring rapidly, at a pace likely unsurpassed over the past 55 million years. The overall trend of recently increasing acidity is superimposed on naturally wide season-to-season and year-to-year variations. Regional differences are not yet well understood, nor are the biological and ecological consequences. These topics are currently the focus of numerous laboratory, field, and computer-simulation studies. Investigations into the economic, cultural, and societal implications of ocean acidification are only just beginning.

Experts do not yet understand Arctic systems well enough to predict specific consequences of ocean acidification with a high degree of certainty. A growing body of evidence, however, suggests that Arctic ecosystems are facing increasing risk from a combination of major changes—not only ocean acidification but also other environmental drivers such as climate change, harvesting, and habitat degradation.

Arctic-specific studies related to ocean acidification and its effects on organisms and ecosystems are urgently needed. Accurately mapping, tracking, and understanding acidification-related changes will require strategic monitoring and focused research under challenging high-latitude conditions.

The field of ocean acidification research is new and rapidly evolving. The AMAP 2013 Arctic Ocean acidification assessment constitutes an up-to-date synthesis of the latest scientific knowledge regarding the status, trends, processes, and possible consequences of ocean acidification in the Arctic. The results are based primarily on research and monitoring results published since 2006. The key points outlined in the following pages complement and build on the comprehensive sequence of earlier AMAP assessments of climate-related Arctic impacts. The lead authors of the Arctic Ocean Acidification assessment have confirmed that the assessment report and its derivative products, available at amap.no, accurately and fully reflect their scientific assessment.

3 In this summary for policymakers, the term 'Arctic Ocean' refers not only to the central Arctic Ocean basin but also to its marginal seas.

Acidification in the Arctic Ocean

Tor Ivan Karlsen / tikfoto.no

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Key finding 1

Arctic marine waters are experiencing widespread and rapid ocean acidification

Scientists have measured significant rates of acidification at several Arctic Ocean locations. In the Nordic Seas, for example, acidification is taking place over a wide range of depths—most rapidly in surface waters and more slowly in deep waters. Decreases in seawater pH of about 0.02 per decade have been observed since the late 1960s in the Iceland and Barents Seas. Notable chemical effects related to acidification have also been encountered in surface waters of the Bering Strait and the Canada Basin of the central Arctic Ocean.

Key finding 2

The primary driver of ocean acidification is uptake of carbon dioxide emitted to the atmosphere by human activities

When carbon-rich materials such as coal or oil are burned (for example, at power stations), carbon dioxide is released to the atmosphere. Some of this gas is absorbed by the oceans, slowing its build-up in the atmosphere and thus the pace of human-induced climate warming, but at the same time increasing seawater acidity. As a result of human carbon dioxide emissions, the average acidity of surface ocean waters worldwide is now about 30 % higher than at the start of the Industrial Revolution.

Paul Nicklen / Getty Images

Key finding 3

The Arctic Ocean is especially vulnerable to ocean acidification

Owing to the large quantities of freshwater supplied from rivers and melting ice, the Arctic Ocean is less effective at chemically neutralizing carbon dioxide's acidifying effects, and this input is increasing with climate warming. In addition, the Arctic Ocean is cold, which favors the transfer of carbon dioxide from the air into the ocean. As a result of these combined influences, Arctic waters are among the world's most sensitive in terms of their acidification response to increasing levels of carbon dioxide. The recent and projected dramatic decreases in Arctic summer sea-ice cover mean that the amount of open water is increasing every year, allowing for greater transfer of carbon dioxide from the atmosphere into the ocean.

Key finding 4

Acidification is not uniform across the Arctic Ocean

In addition to seawater uptake of carbon dioxide, other processes can be important in determining the pace and extent of ocean acidification. For example, rivers, sea-bottom sediments, and coastal erosion all supply organic material that bacteria can convert to carbon dioxide, thus exacerbating ocean acidification, especially on the shallow continental shelves. Sea-ice cover, freshwater inputs, and plant growth and decay can also influence local ocean acidification. The contributions of these processes vary not only from place to place, but also season to season, and year to year. The result is a complex, unevenly distributed, ever-changing mosaic of Arctic acidification states.

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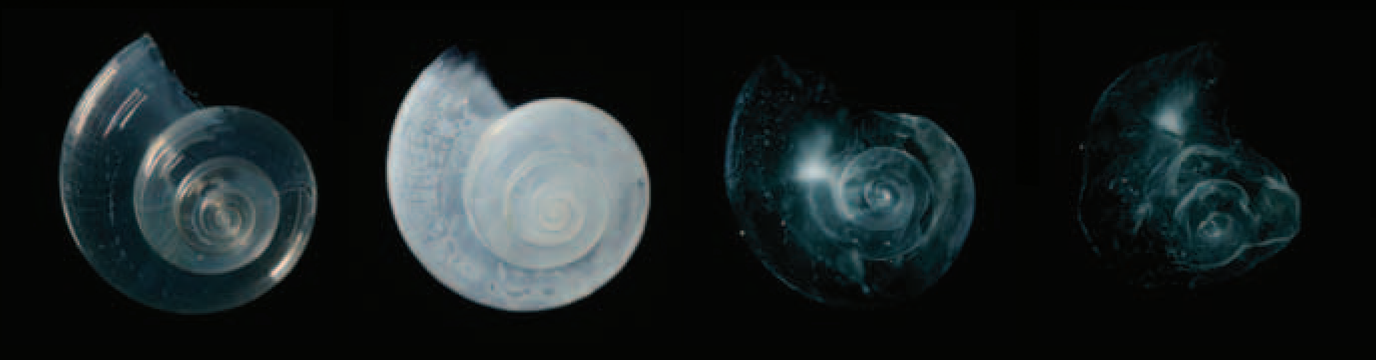

David Littschwager

Biological responses to ocean acidification

Key finding 5

Arctic marine ecosystems are highly likely to undergo significant change due to ocean acidification

Arctic marine ecosystems are generally characterized by short, simple food webs, with energy channeled in just a few steps from small plants and animals to large predators such as seabirds and seals. The integrity of such a simple structure depends greatly on key species such as the Arctic cod. Pteropods (sea butterflies) and echinoderms (sea stars, urchins) are key food-web organisms that may be sensitive to ocean acidification. Too few data are presently available to assess the precise nature and extent of Arctic ecosystem vulnerability, as most biological studies have been undertaken in other ocean regions. Arctic-specific long-term studies are urgently needed.

Key finding 6

Ocean acidification will have direct and indirect effects on Arctic marine life. It is likely that some marine organisms will respond positively to new conditions associated with ocean acidification, while others will be disadvantaged, possibly to the point of local extinction

Examples of direct effects include changes in growth rate or behavior. The best-studied direct effects include effects on shell formation and organism growth: experiments show that a wide variety of animals grow more slowly under the acidification levels projected for coming centuries. Some seagrasses, in contrast, appear to thrive under such conditions. Indirect effects include changes in food supply or other resources. For example, birds and mammals are not likely to be directly affected by acidification but may be indirectly affected if their food sources decline, expand, relocate, or otherwise change in response to ocean acidification. Ocean acidification may alter the extent to which nutrients and essential trace elements in seawater are available to marine organisms.

Some shell-building Arctic mollusks are likely to be negatively affected by ocean acidification, especially at early life stages. Juvenile and adult fishes are thought likely to cope with the acidification levels projected for the next century, but fish eggs and early larval stages may be more sensitive. In general, early life stages are more susceptible to direct effects of ocean acidification than later life stages. Organisms living in environments that typically experience wide fluctuations in seawater acidity may prove to be more resilient to ocean acidification than organisms accustomed to a more stable environment.

Key finding 7

Ocean acidification impacts must be assessed in the context of other changes happening in Arctic waters

Arctic marine organisms are experiencing not only ocean acidification, but also other large, simultaneous changes. Examples include climate change (which fundamentally changes physical, chemical, and biological conditions), harvesting, habitat degradation, and pollution. Ecological interactions—such as those between predators and prey, or among competitors for space or other limited resources—also play an important role in shaping ocean communities. As different forms of sea life respond to environmental change in different ways, the mix of plants and animals in a community will change, as will their interactions with each other. Understanding the complex, often unpredictable effects of combined environmental changes on Arctic organisms and ecosystems remains a key knowledge gap.

Corey Arnold

Christophe Boisvieux / Corbis

Potential economic and social impacts of ocean acidification on Arctic fisheries

Key finding 8

Ocean acidification is one of several factors that may contribute to alteration of fish species composition in the Arctic Ocean

Ocean acidification is likely to affect the abundance, productivity, and distribution of marine species, but the magnitude and direction of change are uncertain. Other processes driving Arctic change include rising temperatures, diminishing sea ice, and freshening surface waters.

Yukon Council of First Nations

Key finding 9

Ocean acidification may affect Arctic fisheries

Few studies have estimated the socio-economic impacts of ocean acidification on fisheries, and most have focused largely on shellfish and on regions outside the Arctic. The quantity, quality, and predictability of commercially important Arctic fish stocks may be affected by ocean acidification, but the magnitude and direction of change are uncertain. Fish stocks may be more robust to ocean acidification if other stresses—for example, overfishing or habitat degradation—are minimized.

Key finding 10

Ecosystem changes associated with ocean acidification may affect the livelihoods of Arctic peoples

Marine species harvested by northern coastal communities include species likely to be affected by ocean acidification. Most indigenous groups harvest a range of organisms and may be able to shift to a greater reliance on unaffected species. Changing harvests might affect some seasonal or cultural practices. Recreational fish catches could change in composition. Marine mammals, important to the culture, diets and livelihoods of Arctic indigenous peoples and other Arctic residents could also be indirectly affected through changing food availability.

What should be done

What can the Arctic Council States and members do to address this serious issue for our future?

Because more than a quarter of global carbon dioxide emissions from fossil fuels come from the Arctic Council States, the Arctic Council has an opportunity to provide leadership by addressing the global ocean acidification issue. It is increasingly clear from the scientific evidence that immediate cuts in carbon dioxide emissions are essential to slow the acidification of the Arctic Ocean.

The biological, social, and economic effects of ocean acidification are potentially significant for the Arctic nations and their peoples, as well as global society. Effects on the marine ecosystems and northern societies due to ocean acidification are likely to have significant impacts, particularly on future fisheries and potentially on harvesting of marine mammals and marine tourism. There remain large gaps in knowledge that currently prevent reliable projections of these impacts.

Based on the key findings from the Arctic Ocean Acidification scientific assessment, the AMAP Working Group agreed to the following recommendations:

It is recommended that the Arctic Council

1. **Urge its Member States, Observer countries, and the global society to reduce the emission of carbon dioxide as a matter of urgency.**

2. **Call for enhanced research and monitoring efforts that expand understanding of acidification processes and their effects on Arctic marine ecosystems and northern societies that depend on them.**

3. **Urge its Member States to implement adaptation strategies that address all aspects of Arctic change, including ocean acidification, tailored to local and societal needs.**

AOA Executive Summary 2013

This document presents the Executive Summary of the 2013 Arctic Ocean Acidification (AOA) Assessment. More detailed information on the results of the assessment can be found in the AOA Scientific Assessment Report. For more information, contact the AMAP Secretariat.

ARCTIC COUNCIL

This document was prepared by the Arctic Monitoring and Assessment Programme (AMAP) and does not necessarily represent the views of the Arctic Council, its members or its observers.

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