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Ocean Acidification in the Arctic

Scientific and Governance Responses

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07

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SUMMARY

1. Noting the early response of Arctic environments to global environmental change, this Fact Sheet outlines high rates of ocean acidification experienced in Arctic waters and resulting threats posed to Arctic communities and ecosystems.

2. The Arctic remains at the forefront of ocean acidification research and governance. In addition to national actions, the Arctic Council and its working groups engage in ongoing scientific research and governance initiatives addressing ocean acidification throughout the region. The Arctic Council additionally promotes the integration of Indigenous knowledge in research and governance, which may further advance understandings of ocean acidification and other marine stressors.

3. While scientific and governance attention towards ocean acidification has increased in the Arctic, the issue of ocean acidification remains largely peripheral to global discussions of environmental change. It has therefore been argued that more explicit and specific efforts are needed to effectively address ocean acidification, both globally and within the disproportionately vulnerable Arctic environment.

1 Ocean Acidification in the Arctic: What is the problem?

The Arctic serves as a bellwether for global environmental change. Emerging ecological and climate challenges frequently impact the Arctic earlier and more rapidly than in other regions of the world. From this perspective, the Arctic offers an opportunity for the assessment and management of evolving environmental conditions, such as ocean acidification, which threaten local ecosystems and the communities that depend on them (Harada, 2021; Stephens, 2021).

Despite comprising only three percent of total ocean surface, the Arctic Ocean accounts for as much as ten percent of carbon dioxide absorption into global waters. When carbon dioxide (CO_2) from the atmosphere interacts with the absorbing ocean water (H_2O), bicarbonate ions (HCO_3^-) and excess hydrogen ions (H^+) are produced under weak alkaline condition. These outputs cause an overall rise in the concentration of hydrogen ions and a decrease in pH levels of the water, thereby increasing ocean acidity. This is called ocean acidification (Harada, 2021).

Ocean acidification affects Arctic ecosystems and food webs in a variety of ways. Marine calcifiers including crabs, sea urchins, and coral are particularly afflicted due to the impacts of ocean acidification on calcium carbonate saturation in global oceans. Aragonite and calcite, a form of calcium carbonite, are absorbed by the marine calcifiers for the production of shells and sufficient supply is thus required to support calcifier populations. It is projected that the Arctic Ocean will experience severe undersaturation of aragonite by 2100. This undersaturation will inhibit calcifier shell growth, contribute to the corrosion of existing shells, and decrease the overall productivity of Arctic food webs. Such cascading effects of ocean acidification will subsequently impact local livelihoods, regional food security, and subsistence and commercial fisheries throughout Arctic communities that depend on marine ecosystems (Comeau et al., 2009; Elias, 2021; Fabry et al., 2009).

2 Monitoring and Scientific Assessment

Due to its critical implications for marine economies, ecosystems, and broader environments, the scientific community monitors pH levels and aragonite saturation in affected waters. Arctic stakeholders take a leadership role in monitoring ocean acidification in polar regions, where communities face economic and social threats from changing marine environments (Heinrich & Krause, 2017; Stephens, 2021).

(1) Regional responses and programmes

Scientific monitoring efforts in the Arctic are led by the Arctic Monitoring and Assessment Program (AMAP), one of the six working groups of the Arctic Council. The mandate of AMAP is to conduct ongoing monitoring and assessment of the overall Arctic environment. As part of this monitoring and assessment mandate, AMAP has produced two detailed scientific assessments of ocean acidification in the region.

AMAP Assessment 2013: Ocean Acidification offers a comprehensive review of the impacts of ocean acidification in the Arctic. It notes that the current acidification rate in the Arctic Ocean is unsurpassed over the past 55 million years. The report further cites the strengthening of cooperative regional marine management, including greater scientific collaboration, the establishment of marine protected areas (MPAs), and the development of sustainable tourism practices, as key strategies for managing the effects of global environmental change at the regional level. Integration of traditional knowledge is also recommended for the mitigation of acidification and other environmental stressors in the Arctic Ocean (AMAP, 2013).

AMAP Assessment 2018: Arctic Ocean Acidification provides an update to the 2013 Report and further evaluates biological responses to ocean acidification in the Arctic. It notes observed aragonite saturation and shifts in species distribution due to ocean acidification, with progressive effects on food webs and subsistence and commercial fisheries anticipated both within and beyond the Arctic region. Further meta-analysis finds a multi-stressor impact on marine ecosystems due to enhanced or enlarged sensitivity to ocean acidification in areas of increased warming. The report additionally highlights geographic variability of ocean acidification across the Arctic, with socio-economic conditions strongly influencing community-based effects (AMAP, 2018).

(2) National responses and programmes

In addition to regional scientific initiatives undertaken by international institutions such as the Arctic Council, individual nations and their scientific bodies carry out monitoring and assessment of ocean acidification in the Arctic. National responses are particularly valuable in addressing localized threats related to ocean acidification and establishing comprehensive action plans across multiple government sectors such as economic and environmental agencies (USGAO, 2014; Stephens, 2021).

Canada and the United States engage in scientific research on ocean acidification via federal government institutions. In the *Arctic Report Card: Update for 2021*, jointly authored by researchers from Fisheries and Oceans Canada and the National Oceanic and Atmospheric Administration (NOAA) of the United States, ocean acidification is highlighted as a critical threat to Arctic ecosystems. The report notes emerging technologies, such as simulation models, being deployed to advance research on ocean acidification and its diverse effects on the Arctic (Cross et al., 2021).

Ocean acidification is additionally a growing focus of research among other Arctic nations, institutions, and stakeholders. Researchers from Lund University of Sweden found that northern Norwegian fisheries, as well as those surrounding the Oslo fjord in southern Norway, are at high risk of collapse due to

ocean acidification. This study was later reported on by the European Commission (European Commission, 2017). The Nordic Council of Ministers likewise published a 2018 policy brief on trends of acidification in Nordic waters, which notes significant vulnerabilities to marine ecosystems and commercial fisheries throughout the region (Cartensen et al., 2018).

One example of similar efforts by non-Arctic nations is provided in a 2015 report published by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) Institute of Arctic Climate and Environment Research. The report provides current trends in Arctic environmental change and associated scientific research and highlights ongoing JAMSTEC studies on ocean acidification in the Arctic, including measuring the response of marine calcifiers to aragonite undersaturation (JAMSTEC, 2015).

Ocean acidification represents an emerging field of scientific research. For this reason, methodological guidelines and best practices for ocean acidification research continue to be developed. Although regional and national research focusing on ocean acidification has increased over the past several years, significant uncertainty remains surrounding the scientific understanding of ocean acidification and its potential impacts on marine environments. It has therefore been argued that, to improve this understanding, effort must be undertaken within the scientific community to strengthen methodological practices and within governments to increase focus on ocean acidification research (Cornwall and Hurd, 2016; Harada, 2021; Stephens, 2021).

3 Governance Response

Policy may be used to mitigate causes of ocean acidification (i.e., carbon emissions) and to facilitate adaptation to its effects. Due to the transboundary nature of carbon emissions, policy discussions occur at the global level and sometimes as part of broader climate negotiations. However, regional and national governance initiatives are also introduced to address localized threats posed by ocean acidification (Stephens, 2020; 2021).

(1) Global level

Ocean acidification is a global issue stemming from transborder carbon emissions. High levels of emissions from all global regions are disproportionately absorbed by cold waters, such as those in polar regions, affecting ocean acidity and marine ecosystems in the area. For this reason, it has been argued that effective and comprehensive mitigation of ocean acidification requires governance response at the global level (AMAP, 2013; Stephens, 2020).

Opportunities for such widespread and international governance response may be found through established global institutions. The United Nations, in particular, highlights ocean acidification as part of Sustainable Development Goal (SDG) 14, *Life Below Water*.

SDG target 14.3 aims specifically to "minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels". The Intergovernmental Oceanographic Commission (IOC) of UNESCO was identified as the guardian of SDG 14 and associated targets and indicators. This includes SDG indicator 14.3.1, which outlines objectives for acidity levels in global waters and methodological guidelines for the monitoring and measurement of ocean acidification. Through its guardianship role, the IOC additionally collects, maintains, and publishes data associated with the measurement of ocean acidity levels (IOC, 2022).

An additional effort towards global mitigation of ocean acidification may be found in the 2008 Monaco Declaration on the Ocean and the subsequent 2015 Monaco Ocean Acidification Plan. These documents were elaborated by scientists from around the world, highlighting mandates for scientific research and governance response surrounding ocean acidification. Such mandates include the shifting of scientific research from individual species to regional ecosystems, investment in adaptive marine management strategies, and the development and sustaining of collaborative international governance efforts (Monaco Declaration, 2008; Monaco Ocean Acidification Plan, 2015).

While SDG 14, the Monaco Declaration on the Ocean, and the Monaco Ocean Acidification Plan represent specific initiatives aimed at the mitigation of ocean acidification, the United Nations Framework Convention on Climate Change (UNFCCC) offers a broad, treaty-based environmental governance for potential application to the issue of ocean acidification. The 1992 UNFCCC is an initial agreement which established a legal foundation for subsequent series of treaties that endeavor to reduce global carbon emissions. Although such emissions are the leading cause of ocean acidification, this international agreement fell short of addressing the issue explicitly (Stephens, 2020).

Ocean acidification has likewise not been explicitly included in later international climate agreements such as the 1997 Kyoto Protocol and the 2015 Paris Agreement on Climate Change. Due to this omission, global governance efforts for the reduction of carbon emissions focus on broad targets and measures rather than those specific to ocean acidification (Stephens, 2021). For example, it has been stated that ocean acidification was treated as a peripheral issue within broader climate change negotiations during the COP26 in 2021 (Scott, 2021). There are some who further argue that binding international agreements specifically targeting ocean acidification are needed to implement successful mitigation policy (Stephens, 2020).

(2) Regional level

Despite the need for improved global governance and mitigation efforts, there remains significant opportunity to address ocean acidification via regional regimes such as the Arctic Council (Stephens, 2020). The *AMAP Assessment 2013: Ocean Acidification* and *AMAP Assessment 2018: Ocean Acidification* have effectively influenced Arctic Council governance response to address acidity levels in local waters (Stephens, 2021). Most notably, ocean acidification has been directly referenced in several declarations agreed upon by Arctic Council member states, such as the 2013 Kiruna Declaration (Arctic Council, 2013).

The Arctic Council' s 2021 Reykjavík Declaration made more specific reference to ocean acidification. The Reykjavík Declaration affirms that the people and communities of the Arctic acknowledge ocean acidification as a threat to regional marine and coastal environments. Further, the Declaration renews the commitment of signatories to monitor and assess in a cooperative manner regional impacts of ocean acidification and associated environmental stressors (Arctic Council, 2021).

Issues related to ocean acidification have also been addressed by Arctic Council bodies outside of AMAP. Examples of such efforts include the 2015 Framework for a Pan-Arctic Network of Marine-Protected Areas introduced by the Protection of the Arctic Marine Environment (PAME), another working group of the Arctic Council. Within this framework, MPAs are referred to as critical tools for strengthening "marine ecosystem resilience that underpins human wellbeing, including traditional and current livelihoods and ways of life" in the Arctic. Ocean acidification is identified as one of several Arctic Ocean stressors that can be mitigated via the establishment of pan-Arctic MPAs (PAME, 2015).

In addition to assessing and addressing ocean acidification at the regional level, the Arctic Council additionally engages in external global advocacy. For example, the Arctic Council organized a side event – outside of the formal negotiation forum – at the COP25 in 2019 specifically addressing ocean acidification. The event convened a panel of experts who presented on the chemical, biological, and socio-environmental impacts of ocean acidification in the Arctic. Special attention was paid to the role of global activities in contributing to acidification in the Arctic Ocean, as well as implications of severe and progressive ocean acidification expanding beyond the Arctic into global waters (Arctic Council, 2019).

While regional governance responses have increased local and global attention toward ocean acidification, the potential for such regional response remains finite (Stephens, 2021). Localized adaptation strategies have proven particularly limited, with capacity for only short-term alleviation of ocean acidification and its effects (Harada, 2021). The global nature of carbon emissions contributing to ocean acidification necessitates mitigation efforts beyond regional regimes. For this reason, it has been argued that ocean acidification must advance beyond a peripheral issue within global climate discussions such as the COP26 (Stephens, 2020; 2021).

(3) National level

Some nations have implemented policies specifically addressing the causes and effects of ocean acidification. Norway, which is projected to face significant environmental and socio-economic threats associated with ocean acidification, makes a specific policy commitment with regard to acidity levels in regional waters. In tackling ocean acidification and broader climate change, the Norwegian government has pledged to emphasize "climate-resilient management of living marine resources and marine biodiversity work, to maintain natural carbon sinks (blue forests), and facilitate the development of new ocean industries such as environmentally friendly cultivation of seaweed and kelp as a measure for boosting carbon uptake" (Norway, 2021).

Canada and Iceland have likewise taken special interest in the effects of ocean acidification. Fisheries and Oceans Canada publishes comprehensive reporting on the status of acidification throughout Canada' s three oceans: The Pacific Ocean, Atlantic Ocean, and Arctic Ocean (Canada, 2012). Meanwhile, the third report on impacts of climate change in Iceland notes that "[c]ompared with the global rate of ocean acidification, the acidification of Icelandic waters is observed to be progressing rapidly" (Iceland, 2018). The Government of Iceland has indicated a "special interest" in regional ocean acidification and has pledged to achieve federal carbon neutrality before 2040.

(4) Integrating Indigenous knowledge

It has been argued that there is a growing potential for integration of Indigenous knowledge into scientific research of marine environments, including Arctic marine environments. Studies find that marine research is often constrained by limited data availability and dysfunctional spatial scales. These constraints are particularly inhibiting for research on community-level or otherwise geographically variable effects on environmental conditions (Ban et al., 2017; Steiner at al., 2019).

It has been reported that Indigenous knowledge may be used in conjunction with scientific findings to bolster overall understandings of marine environments. These reports are supported by governance responses to ocean acidification of the Arctic. For example, *AMAP Assessment 2013: Arctic Ocean Acidification* notes that "[i]t would be beneficial to apply traditional knowledge in marine management systems to tackle ocean acidification" (AMAP, 2013). Meanwhile, the Reykjavík Declaration states that "scientific data together with traditional knowledge and local knowledge will continue to provide the basis for informed decision making in the Arctic and in the work of the Arctic Council" (Arctic Council, 2021).

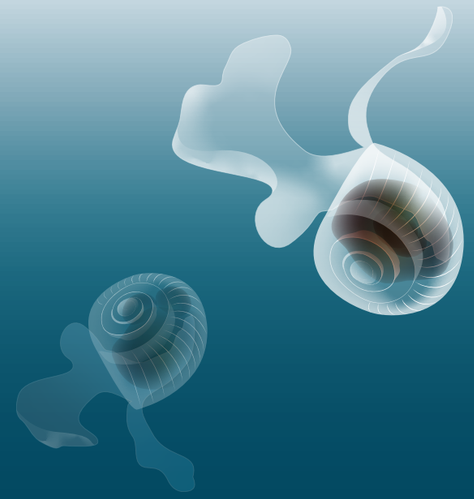
4 Conclusion

Ocean acidification poses a critical threat to Arctic ecosystems and the communities that depend on them. The Arctic Council, Arctic states, and other Arctic stakeholders have taken on leadership roles with regard to scientific and governance response to ocean acidification. Such response has included global advocacy initiatives, regional marine management, and widespread scientific assessment of acidification in the Arctic Ocean. However, because ocean acidification remains an emerging issue, significant uncertainty persists surrounding both scientific understanding and appropriate governance response.

Despite such uncertainty, the Arctic remains at the forefront of ocean acidification research and governance. Arctic nations such as Canada, Iceland and Norway identify and monitor threats posed by ocean acidification at the national level, while the Arctic Council and its working groups engage in ongoing scientific research

and governance initiatives addressing ocean acidification throughout the region. The Arctic Council additionally promotes the integration of Indigenous knowledge in research and governance, which may further advance understandings of ocean acidification and other marine stressors.

While scientific and governance attention towards ocean acidification has increased in the Arctic, the issue of ocean acidification remains largely peripheral to global discussions of environmental change. This indirect or incidental approach persists even as scientific research suggests a growing multi-stressor impact on Arctic marine ecosystems. It has therefore been argued that more explicit and specific efforts are needed to effectively address ocean acidification, both globally and within the disproportionately vulnerable Arctic environment.



■ Relevant Information

Tim Stephens, "Ocean acidification and the polar oceans: The case of polar leadership to address a global challenge", 14th Polar Law Symposium, 21 November 2021
Naomi Harada, "Ocean acidification in the Arctic Ocean: What is the problem?", 14th Polar Law Symposium, 21 November 2021
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