Chapter 9
(Research): Combining Knowledge for a Sustainable Arctic – AMAP Cases as Knowledge Driven Science-Policy Interactions

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Abstract While the Arctic is often perceived as a pristine environment, it is exposed to local as well as globally transported contaminants and is undergoing severe changes in environmental conditions. Major oceanic currents and wind systems transport contaminants from distant sources, with the Arctic acting as a ecosystems and ways of life «sink» for harmful substances. Likewise, climate warming in the Arctic is happening more than twice as fast as at lower latitudes, causing changes in ecosystems as well as ways of life for many Indigenous people living in the Arctic.

A prerequisite for managing and mitigating the impacts of both pollution and climate change in the Arctic is the acquisition of knowledge of conditions, with adequate geographical coverage and sufficiently high spatial resolution, as well as mechanisms for communicating such knowledge for policymaking. The Arctic Monitoring and Assessment Programme (AMAP) was initiated to fulfill such a role in 1991, later becoming a working group of the Arctic Council at its establishment in 1996. AMAP focuses its work on the interface between science and policy. Due to the nature of the origins of pollution in the Arctic, such work requires a focus on both contributing with a knowledge base for policy making among the Arctic states, as well as to international bodies outside the Arctic. The contribution made by AMAP to the establishment of the Stockholm and Minamata Conventions are examples of science and policy development in the Arctic successfully feeding into global international processes.

While long-term research facilities in the vast Arctic region are scarce, Indigenous groups represent a source of knowledge which may contribute significantly to understanding the changing environmental conditions in the Arctic. Therefore, from the start, AMAP has included Indigenous groups – Permanent Participants to the Arctic Council – both in its decisionmaking structures as well its expert groups.

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Co-development of knowledge has informed understanding of climate change and ensured relevance in efforts addressing adaptation and resilience, as discussed in the Adaptation Actions for a Changing Arctic (AACA) reports.

Still, combining Indigenous, traditional and local knowledge and conventional science remains a challenge, both due to their different origin and nature, the diverse spatial diversity across the Arctic, and also due to the speed of change which challenges the predictive power of all knowledge-based systems. Methods to address these challenges need to be discussed.

9.1 The Misperception of the Arctic as a Pristine Area

While for a long time the Arctic was considered to be a remote and pristine area, relatively undisturbed by human activities, research has shown that major ocean and air currents as well as large river inflows bring long-range transported pollutants such as persistent organic pollutants (POPs) and heavy metals including lead and mercury to the Arctic from industrial source areas at lower latitudes (AMAP, 1998), where they are deposited on sea ice and snow and accumulate in waters, soils and glaciers (AMAP, 2010, 2011, 2017c). Local sources also exists for some contaminants, including chemicals of emerging Arctic concern (AMAP, 2017c).

Physiological characteristics of Arctic biota, such as the significant seasonal storage and mobilization of fat in their tissues make Arctic animals susceptible to fat-soluble pollutants that accumulate and biomagnify in food chains, to levels which may affect their health significantly (AMAP, 1998, 2018b) This in turn leads to exposure and associated health risks to humans, in particular for certain Indigenous groups that consume these animals as part of their traditional diet. Because some contaminants can be passed from mothers to their foetus and infants, they are particularly susceptible (AMAP, 1998, 2015b).

Regarding climate change, the Arctic is warming at three times the rate of more temperate regions (AMAP, 2021), due to northward heat transfer and increased absorption of solar radiation as snow and ice melt exposing bare ground or sea water - contributing to a process known as Arctic Amplification (ACIA, 2005; AMAP, 2017d). Maximum Arctic winter sea ice aereal extent in 2015, 2016, 2017, and 2018 were at record low levels, and the volume of Arctic sea ice present in the month of September declined by 75% from 1979 to 2018 (AMAP, 2019b). Arctic glaciers, with the Greenland Ice Sheet, are the largest land-ice contributors to global sea level rise. Even if the Paris Agreement is successful, they will continue to lose mass over the course of this century. (AMAP, 2017d, 2019b). Hence, while anthropogenic drivers for climate change mainly take place outside the Arctic region, the Arctic warming impacts are profoundly affecting the Arctic region, but also have global consequences through sea level rise and global climate teleconnections (AMAP, 2017d, 2019b).

9.2 The Arctic Environmental Initiative and the Establishment of AMAP

Prior to the 1990s, Arctic environmental threats were addressed primarily through national actions by some Arctic states, combined with some international agreements, such as the Svalbard Treaty. The knowledge gained through scientific research during the 1970s and 1980s revealed the idea of a pristine Arctic to be an illusion, raising an urgent need to assess the circumpolar environmental state of the Arctic. At the same time, the Cold War, which had been a major obstacle to cooperation in the region was ending with the break-up of the Soviet Union. Together, these two factors provided the background for the Arctic Environmental Protection Strategy (AEPS, 1991), an agreement between the eight Arctic States that led to the establishment of the Arctic Monitoring and Assessment Programme (AMAP) in 1991. The AEPS was also ground-breaking in the way that Indigenous Peoples Organizations were given a key role in the process (Stone, 2015).

AMAP was established as a pan-arctic monitoring program with a mandate *"to monitor the levels of, and assess the effects of, anthropogenic pollutants in all components of the Arctic environment."*. The AEPS specified that actions should be undertaken in a step-by-step fashion:

- *"Distinguishing human-induced changes from changes caused by natural phenomena in the Arctic will require estimates and regular reporting by the Arctic countries of contaminant emissions and discharges, including accidental discharges, as well as transport and deposition. In addition, monitoring of deposition and selected key indicators of the Arctic biological environment.*
- *As far as possible build upon existing programs. [...] one of the important tasks [...] will be to review and coordinate existing national programs, establish a data directory, and to develop these programs when appropriate in an international framework.*
- *As an initial priority [..] focus on persistent organic contaminants and on selected heavy metals and radionuclides, and ultimately to monitor ecological indicators to provide a basis for assessments of the status of Arctic ecosystems.*
- *[summarize AMAP results in] regular State of the Arctic Environment Reports."*

And as a result of these actions, AMAP should

> *"provide information for: i) integrated assessment reports on status and trends in the condition of Arctic ecosystem;*
> *ii) identifying possible causes for changing conditions;*
> *iii) detecting emerging problems, their possible causes, and the potential risk to Arctic ecosystems including Indigenous peoples and other Arctic residents; and*
> *iv) recommending actions required to reduce risks to Arctic ecosystem."*

(Rovaniemi declaration, 1991)

In subsequent directions from Ministers, the AMAP mandate was extended in several areas, notably:

> *"... assessment of the effects of [...] climate change on Arctic ecosystems."*

". . . human health impacts and the effects of multiple stressors."

(Alta Declaration, 1997)

As a result of the establishment of the Arctic Council in 1996, the AEPS was subsumed into the work of the Arctic Council and AMAP became a working group of the Arctic Council together with five other working groups; Conservation of Arctic Flora and Fauna (CAFF, established 1991), Emergency Prevention, Preparedness and Response (EPPR, established 1991), Protection of Arctic Marine Environment (PAME, established 1991), Sustainable Development Working Group (SDWG, established 1998) and the Arctic Contaminants Action Programme (ACAP, established 2006).

9.3 Organization and Deliverables of the Arctic Monitoring and Assessment Programme

AMAP was organized, with a permanent Secretariat in Oslo, in August 1992, and relocated to Tromsø, Norway in 2018. The decisive strategic level lies with the AMAP Heads of Delegations, consisting of representatives from all the eight arctic states; Canada, Kingdom of Denmark, Finland, Iceland, Norway, the Russian Federation, Saami Council, Sweden and United States of America, as well as representatives from the six Permanent Participants of the Arctic Council, that is Indigenous organizations; Arctic Athabaskan Council (AAC), Aleutian International Association (AIA), Gwich'in Council International (GCI), Inuit Circumpolar Council (ICC), and the Russian Association of Indigenous Peoples of the North (RAIPON) and the Saami Council. Observers, both observer states and observer organizations are invited to participate in AMAP working groups meetings as well as contribute to AMAP work, for example by nominating experts to join AMAP Expert Groups (AMAP, 2019a) and as such contribute as authors to the AMAP assessments.

AMAP's main deliverable are thematic peer reviewed scientific assessments. Since its first report on Arctic Pollution Issues in 1998 (AMAP, 1998), AMAP has published more than 30 such assessment reports, with five new reports being published in 2021. These comprehensive reports are condensed into summaries for policymakers, that include a scientific summary of key findings and recommendations for consideration by policy-makers. Hence, these assessments provide the scientific basis for recommendations on Arctic environmental issues that are addressed to the Arctic Council Ministers and Senior Arctic Officials. In addition, the assessment process is coordinated with international processes, feeding data and information to international bodies such as the IPCC (e.g. the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (IPCC, 2019)), UN Environment Programme, Stockholm Convention on Persistent Organic Pollutants (2001), Minamata Convention on Mercury (2013) and the Convention on Long-Range Transboundary Air Pollution, (CLRTAP, 1979) (Rottem et al., 2020).

9.4 Does it Work – The Black Carbon Case

While AMAP's mandate focuses on monitoring and assessment, the Black Carbon case may be used to illustrate how different Arctic Council bodies interact to monitor, develop and implement actions, execute mitigation projects, and evaluate effects of these actions. Black carbon, or soot, is a short-lived climate forcer that, through both heating the atmosphere by absorbing solar radiation and decreasing the albedo of snow in the Arctic, causes climate warming. Black carbon is also a constituent of particulate matter and an air pollutant that causes health effects through respiratory illnesses that can affect Arctic communities, including those reliant on diesel generators and wood burning for heat and energy (AMAP, 2015a, 2015c). Although Arctic States are responsible for only about 10% of global black carbon emissions, emissions located within and close to the Arctic have a disproportionately high impact on Arctic climate warming (AMAP, 2015a; Arctic Council, 2019). A major reason for this is the pronounced effect black carbon has a climate driver when deposited on snow (AMAP, 2015a). Within the Arctic, the main sources of black carbon are domestic heating, transportation, and flaring in the petroleum industry (AMAP, 2015a).

AMAP's 2015 report on black carbon informed policy makers that significant reduction in black carbon emissions could be achieved using existing technologies and good practices, including reducing emissions from residential and commercial use of fossil fuels, reducing emissions from wood-burning in residential heating, agricultural burning, and changing flaring practices at oil and gas fields (AMAP, 2015c). The scientific background was translated into the Arctic Council's Framework for Action on Black Carbon and Methane, including, e.g. national implementation plans delivered through the Arctic Council's Expert Group on Black Carbon and Methane (EGBCM), and demonstration projects for black carbon emissions reduction organized through the Arctic Councils ACAP working group. The Framework includes an aspirational goal to collectively reduce black carbon emissions from AC member countries by at least 25–33% below 2013 levels by 2025. In 2019, the EGBCM reported a 16% decrease in black carbon emissions by 2016 relative to 2013 (Arctic Council, 2019). As a follow up to this, new inventory-based estimates of black carbon emissions has been made available in the updated AMAP report for 2021.

9.5 Does it Work – The Mercury Case

Mercury is a highly toxic heavy metal that poses serious risks for detrimental health effects on both wildlife and humans. This was brought to international attention when mecury released from an industrial plant caused severe effects on the nervous systems of inhabitants in the Japanese city of Minamata who were exposed by eating fish. The extractation, use and emissions of mercury are now being regulated internationally through the Minamata Convention. As described by Platjouw et al. (2018), the information on trends and levels of mercury in the Arctic reported through AMAP assessments played an important role in the process of establishing the Minamata Convention. Mercury was one of the priority contaminant addressed in the first AMAP assessments (AMAP, 1998, 2002), reports heavily cited in UNEP's first Global Mercury Assessment (UNEP, 2002). The AMAP reports documented spatio-temporal trends and levels of mercury througout the Arctic, as well as its consequences on ecosystems and human health. Data showed that despite the long distance from major sources, mercury levels in Arctic air can on occasions be five to fifty times higher than levels measured in Europe and North America (UNEP Chemicals Branch, 2008), emphasizing the importance of long-range transport of contaminants in to the Arctic, as well as the need to global mechanims for regulating mercury. The data and information compiled in the 2011 AMAP mercury assessment (AMAP, 2011) fed into the process leading up to the UN Environment 2013 Global Mercury Assessment (UNEP Chemicals Branch, 2013), where the scientific technical background report (AMAP/UNEP, 2013) was prepared as a cooperation between AMAP and UNEP (Platjouw et al., 2018). This collaborative effort was repeated in preparing the 2018 Global Mercury Assessment (UN-Environment, 2019). The assessment work done by AMAP therefore played a key role in both documenting effects as well as facilitating the process leading up to the Minamata Convention that was adopted in 2013 and entered into force in 2017 (Platjouw et al., 2018).

9.6 Why Did It Work?

Both the black carbon and the mercury case are examples of an active policy-oriented approach where AMAP has taken the role as a science-broker. Similar examples are given for AMAPs role in the establishment of the Stockholm Convention (Steindal et al., 2021). In the case of mercury, AMAP's comprehensive assessments increased the awareness of the trends and levels at a circumarctic spatial scale, emphasizing the need for emissions to be treated on a global rather than just national scale (Platjouw et al., 2018). Documenting high levels of mercury in what was perceived as a pristine Arctic environment (AMAP, 2002; UNEP Chemicals Branch, 2008), the report stated the urgent need for action to mitigate on the threat to Arctic ecosystems, as well as human health (Platjouw et al., 2018). According to Platjouw et al., (2018), the timing of the mercury assessment was essential for its successful contribution in the Minamata process. The report prepared the ground for the negotiations, by feeding in data in time for a scientific consensus to be achieved. Hence negotiations could focus on legal aspects of the regulation process, rather on scientific disputes (Platjouw et al., 2018; Selin et al., 2018). Also long-term, sustainable funding gave AMAP the possibility to strategically feed in science-based knowledge to the process over a longer time, and through several steps in the negotiation process. AMAPs work allowed the Arctic Council members to have an active policy-oriented approach as a science broker, which, according to (Platjouw et al., 2018) played an essential role in the development and ratification of the Minamata Convention.

9.7 Future Aspects – Increased Understanding of the Arctic Environmental State by Combining Knowledges

In order to produce comprehensive reports, data are needed that reflect both the large spatial variation in environmental parameters due to abiotic factors (such as climate and weather systems, oceanic and atmospheric currents relative to emission sources, etc.) and biotic factors (such as food webs and species trophic level). In addition, anthropogenic factors including local sources of contaminants need to be considered in supporting both Indigenous Knowledge, Traditional and Local Knowledge that can provide resilience to abrupt changes. Hence an important aspect of AMAPs ability to deliver comprehensive assessments is maintaining its coordinated monitoring program. However, infrastructure is limited in the Arctic, including infrastructure for conducting scientific observations of such factors.

Still, the Arctic is not deserted, but has been inhabited since historical times by Indigenous groups and local people for whom the nature of the Arctic has required awareness of the elements as well as an evolving knowledge transition to allow societies to survive and thrive over time. Indigenous Peoples have, through their long-term presence in the Arctic, adapted to their living conditions, and developed knowledge systems and language to describe the environment they live in. Figure 9.1 shows the diversity of Indigenous languages spoken throughout the Arctic, reflecting the diversity of societies; it also illustrates a diverse source of knowledge that to a certain degree has been neglected in scientific work.

Indigenous Knowledge (IK) and Traditional and Local Knowledge (TLK) may provide an essential additional source of information and environmental knowledge of the Arctic by providing access to otherwise inaccessible data, especially where systematic observation and measurement infrastructure are scarce. While the development of satellite observations and autonomous sampling (for example for meteorological data or air measurements, as well as buoys or gliders providing oceanic data) have increased tremendously, environmental data in the Arctic are limited; the area is too vast for such instruments to able to provide complex data at high spatial resolution. Likewise, understanding of trends is dependent on historical records of environmental data. Often gaps due to lacking data need to be filled by extrapolation or methods which introduce variation and uncertainty into models. Combining research and Indigenous Knowledge has been proposed as an approach to increase the understanding of a changing Arctic environment due to climate change or other stressors (e.g. Eira et al., 2013; Krupnik & Jolly, 2002; Lennert, 2017; Lennert,

Fig. 9.1 Map of languages of Indigenous Peoples in the Arctic (CAFF, 2013). (Image retrieved at: http://geo.abds.is/geonetwork/srv/eng/catalog.search#/metadata/9c47173b-4774-436f-ae3f-1925f1173ec6)

2016). For instance, it has been advocated that combining Traditional Knowledge and scientific observations may identify important factors acting as additional stressors on marine mammals exposed to climate change and contaminants (Lennert, 2016). In AMAPs assessment on *Biological effects of contaminants on Arctic wildlife and Fish* (AMAP, 2018b), the decreasing trend in persistent organic pollution (POPs) concentration in polar bear (*Ursus maritimus*) tissue in the eastern Canadian Arctic were observed to be levelling off (AMAP, 2018b; Mckinney et al., 2013). This may be due to changes in feeding behavior of the bears, shifting from ice-associated seal species to open-water seal species, where the latter have higher tissue concentrations of POPs. This feeding change corresponds with a climate driven change of reducing sea-ice extent in the area (AMAP, 2018b; Mckinney et al., 2013).

Terminology developed by Indigenous people over many years to describe their living conditions is a further source of Indigenous Knowledge and Traditional and Local Knowledge that could be used to provide better resolution of data or improved understanding of ecosystem impacts in a changing Arctic. One such example is the description of snow and its impacts on Saami reindeer herding. The Saami language contains at least 318 different descriptions of snow and their relation to reindeer feeding conditions and behavior and hence reindeer herding (Eira, 2012; Eira et al., 2013). Such linguistic richness may be an important tool both for understanding the relation between meteorological data, the historical record, and abiotic impacts on snow, dependent on landscape characteristics, as well as increased understanding on how large scale climate variation may have societal impacts for reindeer herders (Eira et al., 2013; Maynard et al., 2011).

In addition, Indigenous Knowledge and Traditional and Local Knowledge may provide information about the societal relevance and importance of data. For instance, the three regional AMAP reports on *Adaptation Actions for a Changing Arctic* (AMAP, 2017a, b, 2018a) initially focused on adaptations to environmental impacts of climate change. However, local inhabitants emphasized that change in societal factors like infrastructure, development, and education was also important to them. While these societal factors may seem less critical than changes in climate per se, the structure and diversity of such factors may influence societal resilience, and hence the ability of local communities to adapt and meet the challenges associated with climate change (Mathis et al., 2015).

9.7.1 Future Perspectives – Common Challenges and Opportunities for Arctic Knowledge

As described above, combining knowledges from different sources and knowledge systems has potential to give a more diverse input to AMAP assessments and thereby make them more relevant as well as robust in meeting new challenges for predicting Arctic change. Co-production of knowledge feeding into co-management processes in the Arctic may also facilitate conditions that allow for adaptation in a rapidly changing environment (Ådnøy et al., 2003; Armitage et al., 2011; Eira et al., 2018; Frainer et al., 2020). While co-production may imply a need for transformative changes in translation between knowledge systems (Norström et al., 2020; Robards et al., 2018; Wheeler et al., 2020), in this case between natural sciences and Indigenous Knowledge and Traditional and Local Knowledge, data from different systems may be combined and compared for instance by using a mixed method framework (Maxwell, 2016; Teddlie & Tashakkori, 2009), or by semi-quantitative methods such as fuzzy cognitive mapping (e.g. Giles et al., 2007), similar to pathway analyses used in ecology (e.g. Focardi & Tinelli, 1996; Johnson et al., 2001).

For instance, mixed methods have been used to investigate community-based management of pastures among reindeer herders in Finnmark, using quantitative analysis of structural variable and qualitative methods for investigating explanatory mechanisms (Hausner et al., 2012).

Co-produced knowledge based on natural sciences and Indigenous Knowledge and Traditional and Local Knowledge, may face challenges in assessing environmental conditions in a changing Arctic. For conclusions to be made that are relevant on a circum-arctic scale, this knowledge needs to be generalized spatially as well as over time, which, if based on interviews, would be very resource demanding. However, community-based monitoring has a potential of capturing large amounts of data if organized in a structural framework (Johnson et al., 2016). Implementing information technology and mobile platforms into the monitoring or dissemination of knowledge may facilitate a better spatial resolution and over time temporal resolution as well. Such platforms have been initiated, with examples including the Inuit Siku Atlas on Inuit sea ice knowledge and use (https://sikuatlas.ca) and the Local Environmental Observer Network (https://www.leonetwork.org), developed by the Alaska Native Tribal Health Consortium (ANTHC) in 2009, now being expanded under the Arctic Council working group ACAP to create a foundation for a Circumpolar Local Environmental Observer (CLEO) Network.

However, both Indigenous Knowledge, Traditional and Local Knowledge, and science are based on empirical evidence, by definition seen in retrospect. As the Arctic is changing to conditions not known in modern times, and as Artic ecosystems may be susceptible to non-linear changes or abrupt tipping points, interpreting ecosystem responses by extrapolation at the margins of normal range of variation may be challenging (e.g. Heinze et al., 2021). Hence, both knowledge systems are facing similar challenges when it comes to using empirical data for predictions and projections of future conditions. Such challenges for weather predictions based upon Indigenous Knowledge has been described for the Canadian Arctic (ACIA, 2005; Krupnik & Jolly, 2002). Similar findings have been experienced by the first author of this article:

Growing up during at the very northern end of Europe, where the continent meets the Arctic Ocean and its seas the first part of the 1900's, my grandfather from he was 9-10 years old were, together with his brothers sent up in the highlands in winter to trap ptarmigan. And every summer they spent fishing salmon, to contribute to the family's income.

The long life in the mountains provided him with experience on weather patterns. Ever since I was a kid, we used to discuss every spring when the ice was leaving the river so we could start the salmon fishing. My grandfather's predictions were fairly accurate, some years we started the fishing early and some late.

However, I remember clearly a day in late spring in the end of the eighties, when I, as every year; asked: "So grandfather, when will the ice leave the river this year, and we can start fishing salmon?". My grandfather sat silent for some minutes. Then he looked at me and said: "I don't know. The signs in nature I have learnt throughout my life do not tell anymore. Something has changed"

The speed of current Arctic change challenges our ability to understand its dynamics. According to the Bayesian framework, however, science progress can be achieved by continuously adjusting prior expectations and models to current data (Chalmers, 1999). Hence, understanding a rapidly changing Arctic may be better facilitated by combining our knowledge on the Arctic Environment, from both scientific, Indigenous, Traditional and Local Knowledge systems.

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