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Editorial

Towards an Arctic Sustainability Monitoring Framework

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It is becoming more evident that in the twenty-first century we are living in the new era of Anthropocene, where humans attained the ability to alter planetary processes, bringing new urgency to the systematic understanding of current and future social and environmental changes. The Arctic is among the world's regions most affected by rapid socioeconomic, cultural, and environmental transformations, with uncertain and unpredictable consequences. In this context, the sustainability of Arctic social–ecological systems (SES) is of key interest to scholars, Artic stakeholders, rightsholders, and policymakers. Sustainability in the Arctic is becoming a pluralistic, multifaceted, and polycentric concept that is open to multiple framings, which involve both planetary-scale and place-based conceptualizations. These complementary approaches to understanding sustainability reflect diverse ways of knowing and living in the Arctic. Western science and Indigenous knowledge are increasingly brought together to co-produce sustainability knowledge and co-design community-determined pathways to sustainable development. With growing polycentricism and complexity of sustainability and sustainable development in the changing Arctic, observations and monitoring gain the utmost importance and value.

Sustainability monitoring in the Arctic aims to assess the vulnerability, resilience, adaptive capacity, and overall sustainability of SES. The contributions for this special issue focus on conceptual and practical approaches, methodologies, and experiences in defining, measuring, and monitoring sustainability in the Arctic regions and communities. The papers deal with qualitative and quantitative measurement systems, indicators, observing networks, and other monitoring options devoted to tracing sustainability as both a process and an outcome. Although the contributions are diverse in terms of topics, methods, geographies, and messages, we believe that we begin to see the contours of an emerging sustainability monitoring framework. Below we discuss key 'take home' messages from the papers in the Special Issue "Monitoring Arctic Sustainability: Methods, Indicators, Monitoring Systems and Experiences" as they contribute to developing such framework.

The diverse set of papers lays out the foundations for the Arctic sustainability monitoring by advancing our knowledge in respect to the following major elements: conceptual approaches, definitions, and methods of Arctic sustainability and its measurement; scales and units of analysis for sustainability monitoring; Arctic sustainability monitoring domains; key sustainability issues, challenges, processes and solutions to be observed; key drivers and factors of change to be monitored; and sustainability indicators.

Among the main conceptual approaches, definitions and methods advanced by the authors in this issue we would like to highlight the definition of sustainability utilized by Blair et al. [1]. This definition refers to the "long-term maintenance of desirable and meaningful life support systems which are biophysically, culturally and socially determined". Its dynamic and practical nature may be a good fit for sustainability monitoring platforms. Using the example of sea ice services, the paper provides an insight into navigating complex decision-making contexts in when contradictory solutions may be required to address uncertainties across different spatial and temporal scales. It identifies tactics,

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such as co-production and responsible innovation, along with socio-economic scenarios as an implementation tool to deal with these decision-making complexities.

Vlasova et al. [2] draw attention to long-term sustainability monitoring through the implementation of socially-oriented observations (SOO). They discuss the principles for designing a suitable Arctic sustainability monitoring framework based on the convergence between the resilience thinking and sustainable development paradigms and elucidate potential approaches and methods to define sustainability indicators. This interaction could occur as a part of transdisciplinary sustainability monitoring activities, as designed by socially-oriented observations, which couple together sustainable development goals (SDG) and resilience assessment in defining and observing sustainability indicators [2].

Since the global Sustainable Development Goals (SDGs) were adopted in 2015, the efforts to identify indicators for SDG monitoring progress in the Arctic are analyzed by Nilsson and Larsen [3]. The authors highlight the need for initiatives that can support bottom–up processes for identifying locally relevant sustainable development indicators that could serve as a way to engage Arctic residents and other regional and local actors in shaping the future of Arctic communities, within a global sustainability context. The value and the role of participatory sustainability monitoring are also emphasized by other authors of this issue [1,2].

Several papers underline the importance of the Arctic's unique geographic, environmental and social characteristics for developing key indicators of sustainability monitoring. Nilsson and Larsen [3] argue that perceptions of sustainability are scale- and place-specific, and they call for developing SDGs and indicators that are more relevant for the Arctic. Based on earlier developed Arctic Social Indicators, new insights from scenario workshops and interviews at various locations in the Barents region and Greenland Nilsson and Larsen [3] provide an exploratory assessment of how global SDGs can be applied in the Arctic. They highlight the need for additional attention to demography, migration, Indigenous rights, Arctic-relevant measures of economic development, and indicators describing social capital and institutions that can support adaptation and transformation in this rapidly changing region.

Berman and Orttung [4] investigate whether and how remote location, cold and changing climate, and resource-based economies may create different sustainability challenges for Arctic cities. They remind us that more than two-thirds of the Arctic population live in larger settlements, but relatively little is known about urban sustainability in the Arctic. The paper offers an analysis of the applicability of the globally-envisaged ISO 37120 indicators to assess sustainability in Arctic cities. The findings show that only half of ISO 37120's indicators actually measure future-oriented concerns and the ISO 37120 framework should only be used as a foundation for a more in-depth analysis. The authors suggest that to better represent Arctic cities, the ISO 37120 needs to include indicators that situate cities within their regional contexts, addressing both remoteness and the resource nature of the economy, as well as the important role of the Indigenous Peoples. These conclusions are well-aligned with [3] in respect to developing Arctic-specific indicators of sustainability.

The papers in this Special Issue examine several types of socio-ecological systems from the sustainability monitoring perspective. Arctic cities are covered in [4], while sparsely populated areas are analyzed by Stepanova et.al. [5]. The latter article suggests a conceptual model for linking sustainability to the unique characteristics of the sparsely populated regions of the Russian Arctic and the Far East. It provides an empirical illustration that is based on region-level data. The authors suggest indicators that could be best suited to promoting sustainable regional development that accounts for the environment, economy, and social needs of sparsely populated territories.

Blair et al. [1] point out that the same changes, their impacts, and solutions, benefit some, while disadvantage others creating decision-making paradoxes. The authors bring our attention to the fact that in the Arctic, the tensions that are emerging from risks, opportunities, and adaptations for diverse groups of stakeholders increasingly pose irresolvable dilemmas without easy policy solutions. As a result, groups of stakeholders compete and

advocate for different solutions. These are tensions of a paradox state, which no policy choice can resolve because contradictory or opposing solutions are needed. The interplay between synergies and tradeoffs in paradox, in which tradeoffs can become synergies, however, enables the actors to claim a win from loss.

Orang Young [6] focuses on monitoring of geopolitical "regime complexes". Such complexes may deal with identifiable challenges that have direct and indirect impacts on sustainability (e.g., regime complexes for plant genetic resources and for climate). Research on regime complexes has produced two major findings of interest to Arctic governance. One is that interactions between or among the individual elements of a regime complex need not give rise to conflicts. The second is that it is possible under some conditions to manage interactions among the elements of a regime in ways that enhance the capacity of these complexes to meet governance needs. Young suggests the need to develop more innovative approaches to the issue of membership in the Arctic Council as a forum for discussing Arctic issues, including sustainability. For example, he points out that there may be a useful distinction between terrestrial issues of interest mainly to the eight Arctic states and marine and atmospheric issues of interest to a larger membership. The paper also stresses the need to devise creative ways to handle interactions between the Arctic and the global system.

Sustainability can not be either a fixed goal or a preconceived outcome in a rapidly changing Arctic. Sustainability challenges and solutions are changing over time as nature and society also transform. That is why it is crucially important to monitor these complex changes by involving data and knowledge from different groups of Arctic stake-, rights- and knowledge holders (such as the Indigenous Peoples, scientists, educators, business, decision-makers, etc.) at diverse and cross-cutting scales (global, national, regional, and local) and though time. Achieving sustainability in the Arctic means the implementation of the Arctic-tailored SDGs and ultimately building resilient social-ecological systems. A clear understanding of sustainability and its measurement and monitoring methodologies becomes even more important given that sustainability is becoming a top policy and action priority for many Arctic countries, institutions, and societal groups.

As argued in this special issue [2], one possible way forward to implementing these approaches is to develop the Arctic Sustainability Monitoring Network (ASMON). It can capitalize on the experiences of the socially-oriented observations (SOO), Arctic Social Indicators, and other initiatives, described in the issue. ASMON could be developed and operationalized under the auspice of the international organizations, such as the Arctic Council and its working groups, in close collaboration with Indigenous communities and science coordinating bodies, and become a part of the Sustaining Arctic Observing Networks (SAON) and other monitoring and knowledge engagement initiatives deployed in the Arctic now and in the future.

Such observations may constitute the core of a future "H-MOSAIC" (i.e., Human MOSAIC) initiative that will entail an extended period of coordinated observations of human systems and their sustainability using compatible, co-productive methodologies, where approaches discussed in this issue could play a key role. This work may also lay the foundation for planning integrated sustainability-oriented activities to be a part of the possible large-scale knowledge production programs in the Arctic, such as the next International Polar Year. Furthermore, the Arctic, where sustainable development is complicated by rapid climate change and dramatic socioeconomic transformations, could serve as a testbed for designing and implementing sustainability monitoring principles and methodologies that could be later transferred to other regions of the world.

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