Informed Decisionmaking for Sustainability

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Editors

Governing Arctic Seas: Regional Lessons from the Bering Strait and Barents Sea

Volume 1

Science Diplomacy Center
The Fletcher School • Tufts University

Springer

Informed Decisionmaking for Sustainability

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This Springer book series – Informed Decisionmaking for Sustainability – offers a roadmap for humankind to address issues, impacts and resources within, across and beyond the boundaries of nations. Informed decisions operate across a 'continuum of urgencies,' extending from security time scales (mitigating risks of political, economic or cultural instabilities that are immediate) to sustainability time scales (balancing economic prosperity, societal well-being and environmental protection across generations) for nations, peoples and our world. Moreover, informed decisions involve governance mechanisms (laws, agreements and policies as well as regulatory strategies, including insurance, at diverse jurisdictional levels) and built infrastructure (fixed, mobile and other assets, including communication, research, observing, information and other systems that entail technology plus investment), which further require close coupling to achieve progress with sustainability. International, interdisciplinary and inclusive (holistic) engagement in this book series involves decisionmakers and thought leaders from government, business, academia and society at large to reveal lessons about common-interest building that promote cooperation and prevent conflict. The three initial volumes utilize the high north as a case study, recognizing that we are entering a globally significant period of trillion-dollar investment in the new Arctic Ocean. Additional case studies are welcome and will be included in the book series subsequently. Throughout, to be holistic, science is characterized as 'the study of change' to include natural sciences, social sciences and Indigenous knowledge, all of which reveal trends, patterns and processes (albeit with different methods) that become the bases for decisions. The goal of this book series is to apply, train and refine science diplomacy as an holistic process, involving informed decisionmaking to balance national interests and common interests for the benefit of all on Earth across generations.

More information about this series at http://www.springer.com/series/16420

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Cover map illustration: Oldest and longest continuous satellite record of ship traffic in the Arctic Ocean from 1 September 2009 through 31 December 2016, produced by the Arctic Options and Pan-Arctic Options projects to facilitate "Holistic Integration for Arctic Coastal-Marine Sustainability" with international, interdisciplinary and inclusive (holistic) collaboration from Canada, China, France, Norway, Russia and the United States. As introduced with the NASA Earth Observatory image of the day on 12 April 2018 (*Shipping Responds to Arctic Ice Decline*), the centroid of ship traffic north of the Arctic Circle has *"moved 300 kilometers north and east—closer to the North Pole—over the 7-year span."* The satellite Automatic Identification System (AIS) data was provided by SpaceQuest Ltd. with big-data analyses and map production by Greg Fiske at the Woods Hole Research Center (for additional details, see *Chapter 11: Next-Generation Arctic Marine Shipping Assessments* in this book).

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Book Series Preface: Informed Decisionmaking for Sustainability

Abstract This is the opening preface for a new book series – *Informed Decisionmaking for Sustainability* – published by Springer. Utilizing the Arctic Ocean as an initial case study with its diverse dimensions – within, across, and beyond national jurisdictions – this book series will reveal insights, lessons and precedents to apply, train, and refine with science diplomacy, considering local-global relevance with synergies of education, research, and leadership. The initial three volumes are:

Volume 1 – Governing Arctic Seas: Regional Lessons from the Bering Strait and Barents Sea
Volume 2 – Building Common Interests in the Arctic Ocean with Global Inclusion
Volume 3 – Pan-Arctic Implementation of Sustainable Infrastructure

The first volume involves the Russian Federation as a common denominator with either Norway (oldest multilateral region in the Arctic) or the United States (sharing with Russia the longest maritime boundary in the world) to interpret changes with connected biophysical and socio-economic systems that underscore decisions across a "continuum of urgencies" from security to sustainability time scales. The second and third volumes will emerge from presentations during the annual Arctic Frontiers Conferences in Tromsø, Norway, starting in January 2020. Volume 2 will consider circumstances associated with areas beyond sovereign jurisdictions from Arctic and non-Arctic perspectives, recognizing the international community has unambiguous rights and responsibilities in the Arctic High Seas under the law of the sea. Volume 3 is intended to synthesize insights on a pan-Arctic scale, analogous to the world ocean across all sea zones, involving decisions to achieve ongoing progress with sustainability, coupling governance mechanisms and built infrastructure. Throughout this book series, which we expect to expand beyond the Arctic, science diplomacy will be applied as an international, interdisciplinary, and inclusive (holistic) process, facilitating informed decisionmaking to balance national interests and common interests for the benefit of all on Earth across generations. With holistic integration, this book series will reveal skills, methods, and theory of informed decisionmaking that will continue to evolve, contributing to balance, resilience, and stability that underlie progress with sustainability across our home planet.

Introduction to the Book Series

This is the opening preface for a new book series – Informed Decisionmaking for Sustainability – published by Springer. This book series emerges from fruitful collaborations between the editors, who convened the first formal dialogue between the North Atlantic Treaty Organization (NATO) and Russian Federation (Berkman and Vylegzhanin 2012), demonstrating the capacity of observers to contribute as participants by convening dialogues with allies and adversaries alike to build common interests. The enduring outcome of that historic dialogue in 2010 at the University of Cambridge, co-convened with MGIMO University (Moscow State University of International Relations), is a precedent of science diplomacy that can be applied to the sustainable, stable, and peaceful development of our world.

Utilizing the Arctic Ocean as an initial case study with its diverse dimensions – within, across, and beyond national jurisdictions – this book series will reveal insights, lessons and precedents to apply, train, and refine with science diplomacy, considering local-global as well as global-local relevance with synergies of education, research, and leadership. The initial three volumes are:

Volume 1 – Governing Arctic Seas: Regional Lessons from the Bering Strait and Barents Sea
Volume 2 – Building Common Interests in the Arctic Ocean with Global Inclusion
Volume 3 – Pan-Arctic Implementation of Sustainable Infrastructure

These three volumes will build on each other, addressing shared challenges and solutions that operate across contrasting Arctic marine regions with Pan-Arctic interconnections of associated and dependent biophysical and socioeconomic systems. This volume (Volume 1) involves the Russian Federation in shared marine regions with either Norway or the United States, respectively, in the Barents Sea (oldest regional multilateral governance complex in the Arctic) and Bering Strait (longest maritime boundary between two nations in the world), recognizing Russian coastlines surround nearly half of the Arctic Ocean.

Volume 2 will consider circumstances associated with areas beyond sovereign jurisdictions from Arctic and non-Arctic perspectives, recognizing the international community has unambiguous rights and responsibilities in the Arctic High Seas under the law of the sea, to which the eight Arctic states and six Indigenous peoples organizations "remain committed." Volume 3 is intended to synthesize insights on a pan-Arctic scale, analogous to the world ocean across all sea zones, involving decisionmaking with governance mechanisms and built infrastructure as well as their coupling to achieve ongoing progress with sustainability. Herein with Volume 1, starts this journey to reveal, define, integrate and apply the puzzle pieces (**highlighted**) of informed decisionmaking as the engine of science diplomacy, helping to achieve sustainability with Arctic and global relevance onward.

This three-volume series is inspired by two intertwined projects with scope across Arctic regions in a global context, sharing the subtext of *Holistic Integration*

for Arctic Coastal-Marine Sustainability (Table 1). **HOLISTIC** is the unifying puzzle of science diplomacy with the shape of **international, interdisciplinary, and inclusive** that facilitates convergence (Roco et al. 2013), which is further revealed by accelerating knowledge co-production. For example, the *Arctic Options* and *Pan-Arctic Options* projects enabled synergies to produce the Baseline of Russian Arctic Laws (Berkman et al. 2019), introducing transparency to promote cooperation and prevent conflict with the authentic English translation of all Russian laws since the early nineteenth century. Similarly, considering options (without advocacy), holistic engagement was introduced to support implementation of the 2017 *Agreement on Enhancing International Arctic Scientific Cooperation* (Arctic Science Agreement 2017; Berkman et al. 2017; Arctic Science Agreement Dialogue Panel 2019). An outcome of these two projects also is the Science Diplomacy Center through the Fletcher School of Law and Diplomacy at Tufts University.

The central goal of *Arctic Options* and *Pan-Arctic Options* involves development of a holistic process, revealing informed decisionmaking as the engine of **science diplomacy**, characterized as an holistic process, involving informed decisionmaking to balance national interests and common interests for the benefit of all on Earth across generations.

Table 1 Intertwined projects involving *Holistic Integration for Arctic Coastal-Marine Sustainability*[a]

	Project name	
Aspects	Arctic options	Pan-Arctic options
Duration	2013–2019	2015–2020
Conceptual scope	Decision-support process to integrate stakeholder perspectives, evidence and governance mechanisms to reveal options that contribute to informed decision-making for sustainable infrastructure development in the Arctic Ocean	
Geographic scope	Arctic High Seas, Barents Sea Region (BaSR), Bering Strait Region (BeSR)	Pan-Arctic (defined as north of the Arctic Circle + Bering Strait Region)
Options	Governance Mechanisms	Governance Mechanisms and Built Infrastructure
Funding nations	United States, France	United States, Russian Federation, Norway, France, China and Canada
Funding program	**ArcSEES**	**Belmont Forum**
	(*Arctic Science, Engineering, and Education for Sustainability*)	(*Arctic Observing and Research for Sustainability*)
	www.nsf.gov/pubs/2012/nsf12553/nsf12553.htm	https://www.belmontforum.org/cras/#arctic2014
Funding	$2,000,000+	€1,000,000

[a]**Goal** Design, develop, and demonstrate a holistic process to enhance the effectiveness of governance with built infrastructure for sustainable development in Arctic coastal-marine systems. **Objective 1** Aggregate Arctic coastal-marine data from the natural and social sciences in an efficient and flexible manner for diverse decisionmaking purposes. **Objective 2** Apply analytical tools and strategic planning concepts to reveal plausible scenarios about Arctic coastal-marine development over diverse spatial and temporal scales. **Objective 3** Generate infrastructure and policy options through international, interdisciplinary, and inclusive dialogues responding to Arctic coastal-marine opportunities and risks. **Objective 4** Share the options resulting from Objectives 1–3 with members of the policy community in view of current Arctic governance issues

- How does science diplomacy balance national interests and common interests?
- What is informed decisionmaking and how does it operate?
- How do we facilitate inclusion in a world filled with exclusion?

This book series is designed to address these questions with examples and lessons, insights and inspiration, contributing to progress with local-global as well as global-local sustainability.

Globally-Interconnected Civilization

The reality of human civilization is that we are now globally interconnected (Fig. 1). This fact is revealed simply by the concept of "world wars," which happened for the first time in the history of humankind only in the last century. For perspective, the oldest continuous annual calendars still in use record nearly 6000 years – with the past few centuries like years in a life-span of sixty centuries – demonstrating that we are still in our infancy as a globally-interconnected civilization. Moreover, timing of the past few centuries coincides with ACCELERATING **increase in global human population size**, which is orders of magnitude larger than at the dawn of the nation-state with the *Treaty of Westphalia* in 1648.

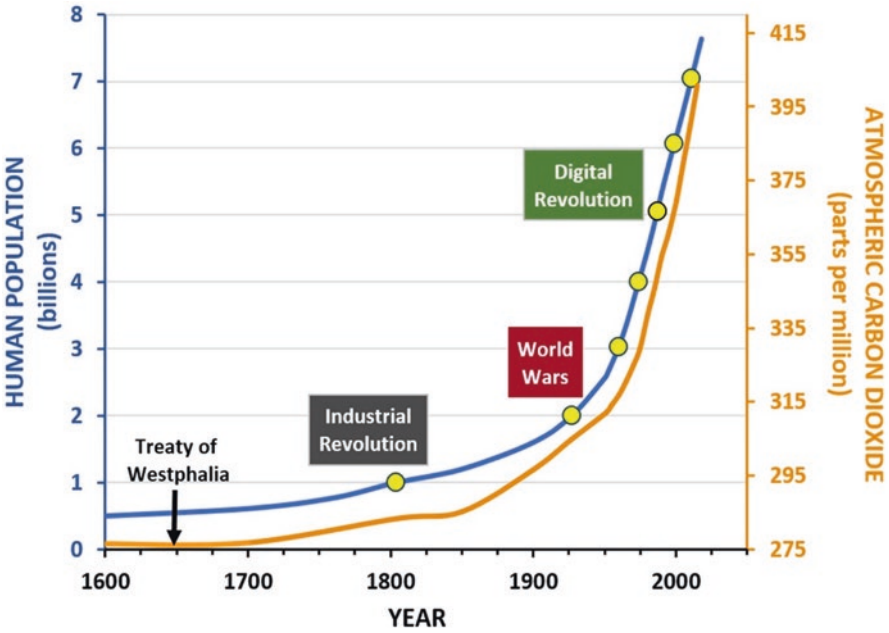

Fig. 1 Globally-Interconnected Civilization, viewed on a planetary scale with our human population (Durand 1977; Worldometer 2019) multiplying by billions (yellow dots) and increasing concentrations of carbon dioxide in the atmosphere (USEPA 2019) – across Science, Technology, and Innovation (STI) eras – recognizing "correlation alone does not mean causation"

At the scale of the Earth, carbon dioxide levels in the global atmosphere also are accelerating (Fig. 1). Without trying to explain this global atmospheric phenomenon or even predict any changes, it is clear that there is a symbiosis between human population and Earth's climate, which is by definition a planetary process (i.e., Jupiter and other planets in our solar system each have their own unique climates). Underlying all such discussions is the fact that human population size on Earth is increasing exponentially, which is the root cause for considering climate change "as a common concern of humankind" since the 1992 *United Nations Framework Convention on Climate Change* (UNFCC 1992). The challenge for humankind is to address solutions on a planetary scale, in a dynamic system that changes over decades to millennia (Roberts and Westad 2013), requiring societal processes that operate in a holistic manner.

Working from first principles – on Earth, there are areas within the boundaries of nations as well as areas beyond national jurisdiction (ABNJ), established under international law as international spaces to promote peace after World War II. These two generalized categories of jurisdiction reveal our fundamental challenge as a globally-interconnected civilization (Figs. 1 and 2) – to balance national interests and common interests for the benefit of all on Earth across generations, recognizing that nations will always first and foremost look after their national interests. With perspective, the law of the sea provides a pedagogical framework to illustrate our fundamental challenge within, across, and beyond national jurisdictions, considering legal zones that apply across the Earth (Fig. 2).

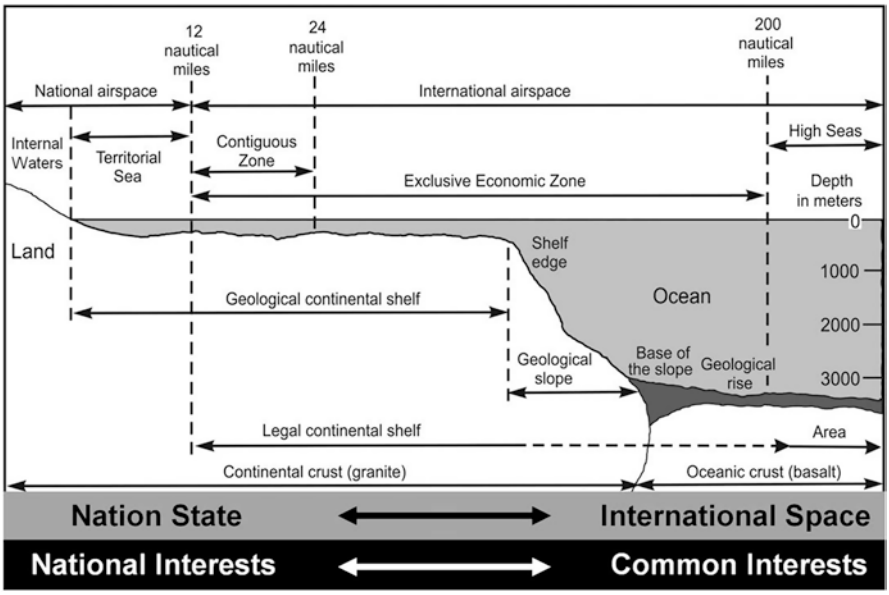

Fig. 2 Law of the Sea Zones, from coastal baselines into areas beyond national jurisdictions (ABNJ), namely, the high seas and area of the deep sea, across a gradient from national interests into common interests (adapted from USGPO 1985). The sea zones are applied under customary international law (as by the United States) and through the *United Nations Convention on the Law of the Sea* (UNCLOS) with nearly 160 signatories. Provisions of UNCLOS are for "strengthening of peace, security, co-operation and friendly relations among all nations" with central applications for *Marine Scientific Research* (UNCLOS 1982)

Negotiated over centuries, at least since 1609 when *Mare Liberum* was crafted by Hugo Grotius (Bull et al. 1992), the zones in the ocean underscore the pull and push (as well as ebb and flow) of nations with TRANSBOUNDARY **issues, impacts, and resources**. Moreover, these transboundary considerations shift over time due to our changing Earth system, but also involving political cycles with government leaders in office over years, even decades, some in nations and regions that have recorded histories extending across centuries and a few with heritages over millennia.

Science as the "Study of Change"

In our transboundary world, applications with science diplomacy originate and operate inside as well as outside of government with connections that exist at all scales on Earth, revealing two cross-cutting questions. How does science enable allies and adversaries alike to build common interests? How can science promote cooperation and prevent conflict? From our industrial and digital revolutions into the future with STI (Fig. 1), these questions underscore the stimulus for science diplomacy as a holistic process to address issues, impacts, and resources across time and space in our globally-interconnected civilization.

With international and interdisciplinary inclusion, **SCIENCE is the "study of change"** (symbolized by the Greek letter delta, Δ, as in mathematics), including the natural sciences and social sciences as well as Indigenous knowledge. Across time and space – all "sciences" involve rigorous training with inquiry skills and strategies to characterize patterns, trends, and processes (albeit with different methodologies) that become the bases for decisionmaking. STI contributes to measurements, assessments, and responses as well as impacts with our civilization across the Earth, as we have seen from the industrial revolution to the digital revolution (Fig. 1).

In relation to current decisionmaking, it is easier to understand security issues because urgencies are here and now. Sustainability, on the other hand, involves urgencies across time into the future, which is uncertain. Nonetheless, the starting point and momentum of humankind are known today, without predictions on a planetary scale (Fig. 1). Moreover – underlying diverse decisions – it is understood that human impacts are related to populations, affluence, and technology (Ehrlich and Holdren 1971; Holdren 2008). But, with all kinds of biophysical and socioeconomic "evidence" for decisions from diverse stakeholders, how do we make informed decisions? How can uninformed decisions be detected and corrected? To avoid jargon, as a proposition, informed decisions operate across a "continuum of urgencies" (Fig. 3), introducing a scalable framework that applies across tactical and strategic time scales as well as diverse regional scales to address issues, impacts, and resources.

As a hypothesis, informed decisionmaking is scalable to the person, institution, system, region, situation, and world, involving the two generalized arenas of decisions that require close coupling to achieve progress with security as well as sustainability (Berkman 2015):

- **GOVERNANCE MECHANISMS** (laws, agreements, and policies as well as regulatory strategies, including insurance, at diverse jurisdictional levels)
- **BUILT INFRASTRUCTURE** (fixed, mobile, and other assets, including communication, research, observing, information, and other systems that require technology plus investment)

We are entering a world with 8 billion people this decade. Human generations now are aligned with change on a planetary scale, recognizing human-population size has skyrocketed over 400% just in the lifetimes of our oldest living relatives (Fig. 1). Crossing thresholds unlike any in human history – considering *Our Common Future* (UNWCED 1987) – there is great responsibility for decisions that operate in the face of change, considering immediate instabilities as well as balance across generations on Earth (Fig. 1).

Pedagogy of the United Nations Sustainable Development Goals

Children and even young adults living today will be alive in the twenty-second century, underscoring the "continuum of urgencies" for humankind (Fig. 3). The context of these urgencies is further revealed in view of human population growth, which began to accelerate on a planetary scale over the past few centuries, introducing the nation-state as the basic administrative unit with sovereignty, sovereign rights, and jurisdiction across geographies (Fig. 1). The metronome is across generations, central to the concept of sustainability, from Maximum Sustainable Yield in fisheries to the Sustainable Development Goals (SDG) of our world (Fig. 4).

Fig. 3 Theory of Informed Decisionmaking (Berkman 2019a, b) that an **INFORMED DECISION operates across a *continuum of urgencies*** (Vienna Dialogue Team 2017) as a scalable proposition for nations and peoples across the Earth (Fig. 1) from **security time scales** (mitigating risks of political, economic, cultural, and environmental instabilities that are immediate) to **sustainability time scales** (balancing economic prosperity, environmental protection, and societal well-being across generations). For each of us as individuals, the *continuum of urgencies* is like driving on any road, constantly adjusting to the surrounding vehicles and circumstances while being alert to the red lights ahead and traffic behind

For humankind, the generalization of Thomas Robert Malthus (1798) at end of the eighteenth century still is correct. Human populations are controlled by war, famine, and disease. Fortunately, as a globally-interconnected civilization, our understanding of these risks has matured with increased granularity into an evolving set of development goals for humanity (Fig. 4). Because they are inclusive, the SDGs can be applied with flexibility by governments and businesses as well as civil society more broadly, where all individuals can contribute to decisionmaking. Moreover, for each of the seventeen SDGs, there is integration with generations across a "continuum of urgencies" (Fig. 3) that involves decisions to achieve stability, balance, and resilience as underlying attributes of sustainability (Table 2).

The pedagogy of the Sustainable Development Goals to build common interests is further revealed with increased granularity, involving the indicators and targets for each SDG that are elaborated by many nations in their *Voluntary National Reviews.* Unlike any time in human history – with necessity as the spice of innovation (Fig. 1) – the clarity of common interests with the SDGs is visionary to address issues, impacts, and resources at local-global as well as global-local scales on Earth across generations.

Fig. 4 The United Nations Sustainable Development Goals (SDG), crafted in a holistic manner for the benefit of all on Earth across generations (UN 2030 Agenda 2015)

Table 2 Attributes and global-local characteristics of sustainability

Attributes	Global-local characteristics
Balance	Environmental Protection + Economic Prosperity + Societal Well-Being
	National Interests + Common Interests
Resilience	Present Generations + Future Generations
	Governance Mechanisms + Built Infrastructure
Stability	Promoting Cooperation + Preventing Conflict
	Peace + Survival

Informed Decisionmaking as the Engine of Science Diplomacy

Informed decisions start with questions (Fig. 5). Questions arise in view of systems, defined by their boundaries, providing frameworks to interpret internal and external dynamics. The interpretations of associated and dependent patterns, trends and process begin with questions for any research project, independent of the scientific focus. For human systems, questions also represent the least-complicated stage to build common interests among diverse actors when investments of time, effort, and resources are minimal. Importantly, for diplomacy, questions introduce a framework to reset dialogues when there is minimal progress with conflict resolution in human systems, involving boundaries with biophysical and socioeconomic components.

Fig. 5 Pyramid of Informed Decisionmaking, as the underlying methodology to apply, train, and refine across a "continuum of urgencies" (Fig. 3) that is self-selected, involving stages of research and action with outcomes of common-interest building and enhanced capacities across levels of holistic integration. (Adapted from Berkman et al. 2017)

Inquiry is a powerful methodology (Berkman 2002) for *turning observations into questions that illuminate answers that become new questions in an ever-growing cascade of insight.* When there are **QUESTIONS OF COMMON CONCERN** (Fig. 5), progress with common-interest building is revealed by application of appropriate methods to generate answers. With biophysical and socioeconomic systems, the ANSWERS INVOLVE DATA generated in an interdisciplinary manner. "Big data" and "open data" (Kitchin 2014) are continuously emerging, increasingly as public goods (ISC 2018), creating opportunities for service industries to help build an economy based on knowledge (Ackoff 1999).

However, to operate across a "continuum of urgencies" with the SDGs (Figs. 3 and 4), there is more than research with questions and data. In addition, actions are required with evidence and options (without advocacy) for decisions, recognizing **DATA IS NOT EVIDENCE** (Fig. 5). Data are for answering questions whereas evidence is for decisionmaking, reflecting their different purposes and origins.

EVIDENCE emerges with integration of data and questions in contexts of the decisionmaking institutions (The Royal Society 2018; Donnelly et al. 2018), involving perspectives and agendas of diverse stakeholders (Fig. 6). Yet, evidence only compels decisionmakers to act, but without specifications of what, when, where, or how to act with governance mechanisms and built infrastructure. In this sense, *evidence-based* decisionmaking is incomplete as well as redundant, in that all decisions involve some form of evidence. Recognizing that competing agendas engender political dynamics, is evidence being considered selectively by decisionmaking institutions? How can decisionmaking institutions be optimized to consider evidence inclusively?

Fig. 6 Decision-support process to integrate options (without advocacy) that contribute to informed decisions (Figs. 3 and 5). (Adapted from Berkman et al. 2017)

Ultimately, the diplomacy comes from **OPTIONS (without advocacy), which can be used or ignored explicitly**, avoiding the political complications that commonly arise when there are different agendas. In this manner, options (without advocacy) are tendered with respect for the roles and responsibilities of the decisionmakers to produce informed decisions as the apex goal (Fig. 5).

Informed decisionmaking is the engine of science diplomacy underscoring a holistic process that starts with questions to "connect the dots" in dynamic biophysical and socioeconomic systems with diverse stakeholders and agendas. The key puzzle piece with informed decisionmaking is "holistic" – international, interdisciplinary, and inclusive – at the center of sustainable development, with common-interest building and knowledge co-production across research-action stages for the benefit of all at global-local scales (Figs. 3, 4, 5, and 6 and Table 3).

Table 3 Categories of questions to apply, train, and refine with science diplomacy and its engine of informed informed decisionmaking (Figs. 3, 5, and 6) to implement the 17 sustainable development goals (Fig. 4) on EARTH across generations (Fig. 1)

Question category for decisionmaking[a,b]	Holistic dimensions to consider		
	International	Interdisciplinary	Inclusive
Science as *an essential gauge of changes over time and space*	X	X	X
Science as an *instrument for Earth system monitoring*	X	X	X
Science as *an early warning system.*	X	X	X
Science as *a determinant of public policy agendas.*	X	X	X
Science as *an element of international legal institutions.*	X	X	X
Science as *a source of invention and commercial enterprise.*	X	X	X
Science as *an element of continuity in our global society.*	X	X	X
Science as *a tool of diplomacy to build common interests.*	X	X	X

[a]Decisions involve governance mechanisms and built infrastructure, coupled for sustainability
[b]Elaborated from Berkman et al. (2011)

Transforming Research and Action

Skills are required within and between levels of the Pyramid of Informed Decisionmaking (Fig. 5) to apply, train, and refine with holistic approaches, delivering informed decisions (Fig. 3). Among the levels, enhancing capacities across the **DATA-EVIDENCE INTERFACE** between research and action with decisionmakers and scientists among other stakeholders (Fig. 6) will be transformative. The primary skill upward and downward across this decisionmaking interface involves

individuals as both observers and participants, facilitated by curiosity and a sense of responsibility to address key questions (Table 3) with science diplomacy and holistic integration for sustainable development (Table 2) at all scales.

Observers are scientists, studying change by recognizing as well as interpreting patterns, trends, and processes of systems at local-global and even galactic and elemental scales. Such observation skills involve curiosity, which is encouraged with the **SOCRATIC METHOD**, asking and answering questions to stimulate critical thinking with dialogue. In this broader sense, an effective education is revealed when individuals can teach themselves with questions and life-long learning.

Observation skills require rigorous training as provided through the natural sciences and social sciences as well as Indigenous knowledge, studying and managing the home ("eco"), as represented by ecology and economics, respectively, as well as ecopolitics (see Volume 1, Chap. 1). Applying insights about trends, patterns, and processes, it is then possible to contribute to informed decisionmaking for sustainable development with actions taken by participants who design and implement governance mechanisms as well as built infrastructure.

The opportunity is to train a next generation of informed decisionmakers, serving as observers and participants who also would be contributing to a **KNOWLEDGE ECONOMY**, where research is transformed with action and vice versa (Fig. 5). Questions provide the foundation for informed decisionmaking and, at its core, science diplomacy stimulates inquiry to identify, answer and refine the questions that apply across all SDGs (Fig. 4 and Table 3). Where do the questions arise for sustainable development at local-global scales? Who is responsible for addressing questions that impact our sustainable development? Thought leadership can come from anywhere, where individuals can be observers and participants with informed decisionmaking (Fig. 3), building from the stage of questions with research and action to informed decisions (Figs. 3 and 5).

Beyond symbolism of science as the "study of change" (Δ), the **TRIANGULATION OF SCIENCE** underlies a skill with holistic integration to accelerate knowledge co-production across the Pyramid of Informed Decisionmaking (Fig. 5). Integration skills also are implied across the learning hierarchy from data and information to knowledge and wisdom, a complementary pyramid that is known widely. In addition, triangulation is involved with diverse pyramids, triads, and trinities, inspiring synergies that are revealed literally by architectural applications with geodesic domes (Fuller and Applewhite 1975). More basically, triangulation reflects indivisible first principles, as with colors and prime numbers to integrate (Fig. 7).

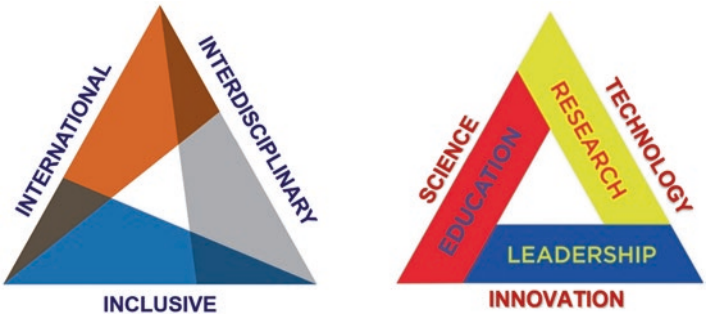

Fig. 7 Co-production of knowledge – with science as the "study of change" symbolized by Δ – illustrating triangulation with: (**left**) holistic integration and (**right**) science-diplomacy features that apply together at each level of the Pyramid of Informed Decisionmaking (Fig. 5)

Triangulation as a skill can come from anywhere, beyond the responsibilities of decisionmakers alone, enabling leadership with research and education (Fig. 7). From research to action with informed decisionmaking (Fig. 5), triangulation comes with the natural sciences and social sciences as well as Indigenous knowledge. The resulting knowledge co-production is reflected literally with the 17 SDGs (Fig. 4), opening doors for a knowledge economy empowered by the capacities of our digital revolution (Fig. 1).

Applying ***SCIENCE AS A PUBLIC GOOD*** (ISC 2018) synergies are evolving with informed decisionmaking, as revealed in a global context with the International Science Council (ISC 2019) that evolved in 2018 from the International Council of Science (ICSU) and International Social Sciences Council (ISSC). Within the ISC, science diplomacy is championed by the International Network on Government Science Advice (INGSA), closely collaborating with the Foreign Ministry Science and Technology Advice Network (FMSTAN 2019) that originated in 2016. On the Pyramid of Informed Decisionmaking (Fig. 9), INGSA represents the action stages with other ISC bodies, such as the Committee on Data (CODATA) or the International Arctic Science Committee (IASC), representing the stages of research. How can research and action stages of informed decisionmaking (Fig. 5) be triangulated (Fig. 7) to produce synergies for our sustainable development (Fig. 4)?

Synergies emerge from holistic dialogues that seek to integrate knowledge. At strategic time scales, syntheses can be integrated to co-produce knowledge with a sense of legacy, as with the *2009 Antarctic Treaty Summit* that resulted in the first book on *Science Diplomacy* (Berkman et al. 2011) as well as the 2009 Wilton Park meeting that resulted in the widely referenced **SCIENCE-DIPLOMACY TAXONOMY: Science in diplomacy, diplomacy for science, and science for diplomacy** (The Royal Society 2010). Lessons and observations from these meetings translated in 2010 into the first formal dialogue between the North Atlantic Treaty Organization (NATO) and Russian Federation regarding security in the Arctic (Berkman and Vylegzhanin 2012), operating across the continuum from security to sustainability time scales (Fig. 3).

At tactical time scales, holistic dialogue also can be the source of knowledge co-production to transform observations into actions that contribute to informed decisionmaking (Vienna Dialogue Team 2017; Talloires Dialogue Team 2018). For example, the 2017 *Agreement on Enhancing International Arctic Scientific Cooperation* mandated a first-year review of its implementation, involving diplomatic as well as scientific communities to make progress, when options (without advocacy) and syntheses would be helpful (Berkman et al. 2017; Arctic Science Agreement Dialogue Panel 2019). In the context of this book series on Informed Decisionmaking for Sustainability, for Volumes 2 and 3 at least, the Arctic Science Agreement will have a central role at the data:evidence interface (Fig. 5) with Pan-Arctic sustainability and associated decisionmaking (Fig. 8).

To illustrate holistic integration, the **ARCTIC OCEAN SYSTEM offers a case study** (Fig. 9) with the inclusive natural boundary of the Arctic Circle, crossing land and sea without being human-imposed, relating to the horizon for sunlight defined by tilt of the Earth's axis at 66.5° North latitude (Fig. 9a). In this pan-Arctic region, the Arctic Ocean extends within, across, and beyond the jurisdictional boundaries of the surrounding states (Fig. 2) with Indigenous peoples who have lived in the high north for millennia among other residents (Larsen and Fondahl 2014).

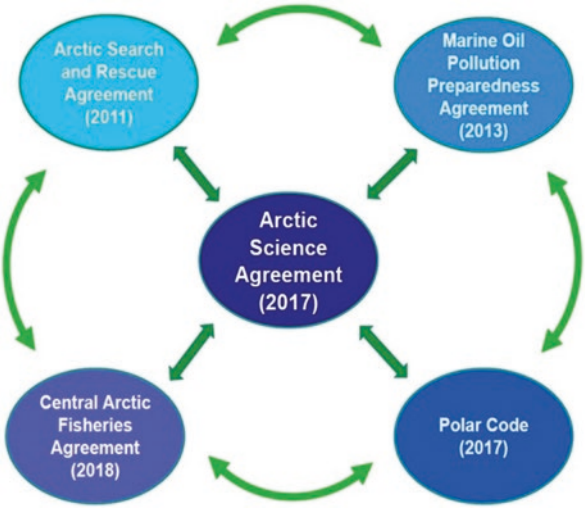

Fig. 8 Institutional Interplay with the Arctic Science Agreement and other circumpolar Arctic governance mechanisms adopted after 2009 (Berkman et al. 2019), closely coupled with the international framework of the Law of the Sea, to which the eight Arctic States and six Indigenous Peoples Organizations "remain committed" (Arctic Council Secretariat 2013)

Open water and diminished sea ice (Fig. 9b) allow more light to penetrate, stimulating algal production (Arrigo and van Dijken 2015) and available biomass to consume at higher trophic levels throughout the food web (Fig. 9c). Similarly, with warmer waters, southern species are beginning to invade the Arctic marine ecosystem (Vermeij and Roopnarine 2008), illustrating internal and external dynamics with the Arctic Ocean (Fig. 9d), which is undergoing an environmental state-change with its sea surface boundary (Berkman and Vylegzhanin 2012).

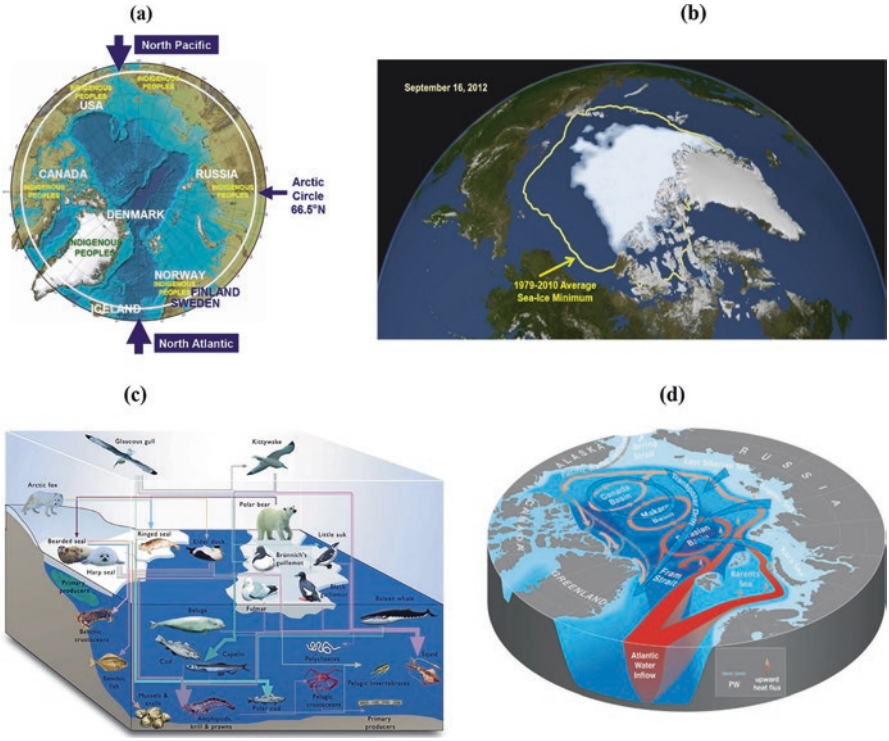

Fig. 9 The Arctic Ocean System with boundaries, inputs and outputs, and internal dynamics. (**a**) Geographic boundaries north of the Arctic Circle in view of surrounding land boundaries with national jurisdictions and Indigenous peoples among other residents, involving connections to the North Atlantic and North Pacific (Berkman 2015). (**b**) Changes in the surface boundary from perpetual multiyear sea ice to seasonally open water, as measured by satellites since 1979 (NASA 2012). (**c**) Illustration of ecosystem interactions among dependent and related species (ACIA 2004) without showing humans and their many connections and (**d**) Water masses and currents, illustrating internal and external dynamics with the North Atlantic and global ocean (Carmack et al. 2015)

Balancing National Interests and Common Interests

In our globally-interconnected civilization (Figs. 1 and 2), international peace and security transcend boundaries beyond the capacities of nation-states alone, recognizing that sustainability on a planetary scale operates across a **SPECTRUM OF JURISDICTIONS**. The central jurisdictional unit on Earth since 1648 is the nation-state, which will always look after its interests first and foremost. The larger jurisdictional unit is international, which emerged with the League of Nations and United Nations after the "world wars" of the twentieth century, leading into an era of building common interests among nations (Fig. 10). The smaller jurisdictional unit is subnational, recognizing the emergence of "megacities" with more than 10 million people (UNESA 2014) and wealth of associated regions (CBS News 2018),

even businesses (Office of Denmark's Tech Ambassador 2019), surpassing the economic capacity of many nations.

With establishment of international spaces (Fig. 10), regions on Earth provide opportunities to develop precedents and learn lessons about balancing national interests and common interests. With the Arctic Ocean System as an initial case study, representing common interests – the High Seas surrounding the North Pole in the waters above the sea floor are unambiguously beyond Exclusive Economic Zones and sovereign jurisdictions (Fig. 2). In contrast, representing national interests – on and in the sea floor – the Continental Shelf and deep-sea Area in the Central Arctic Ocean are seen as extensions of land areas, where there are recognized sovereign jurisdictions with rights that can be extended under UNCLOS (1982). Balancing between national interests and common interests in the Arctic Ocean will be the focus of Volume 2 of the book series on Informed Decisionmaking for Sustainability.

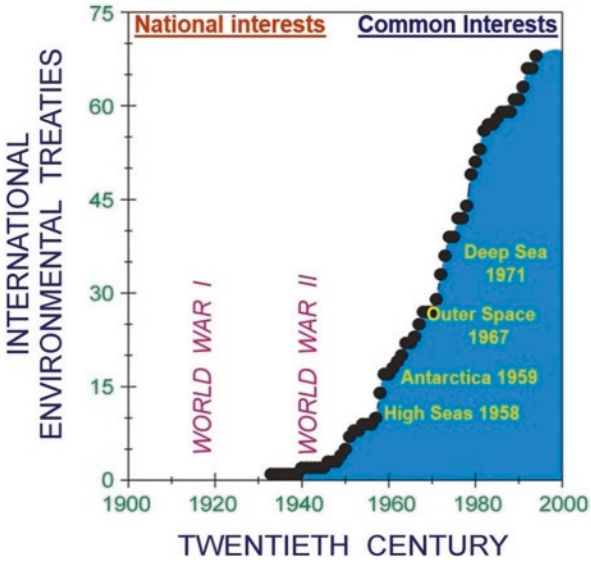

Fig. 10 Balancing national and common interests over time on a planetary scale during the twentieth century, applying international environmental treaties as data (Fig. 5) to address sustainability questions (Table 3) about our globally-interconnected civilization (Fig. 1), with international legal establishment of areas beyond national jurisdictions (ABNJ in yellow) that cover nearly 70% of planet surface (plus outer space) to build common interests and minimize risks of conflicts over jurisdictional boundaries on Earth. (Adapted from Berkman 2002)

The juxtaposition of international legal zones in the Arctic Ocean – on the sea floor and in the superjacent waters (Figs. 2 and 11) – illustrates balancing between national interests and common interests, where questions (Table 3) can be used to stimulate knowledge co-production as the basis for informed decisionmaking (Figs. 3, 4, 5, and 6 and Tables 2 and 3). The questions and progress to build common interests in the Arctic Ocean are reflected by the emergence of binding legal

agreements (Fig. 8), which further involve decisionmaking for built infrastructure and emerging markets in this "$1 trillion ocean" (Roston 2016).

With global relevance, the Arctic Ocean is a special responsibility for humanity with the North Pole as a "pole of peace" and "burning security issues" surrounding the region (Gorbachev 1987). These observations in the 1987 Murmansk speech by Soviet President Mikhail Gorbachev were accompanied with introduction of the "Arctic Research Council," becoming the Arctic Council in 1996 as a high-level forum with its six scientific working groups to address "common Arctic issues" (Ottawa Declaration 1996), that evolved with informed decisionmaking into a suite of binding agreements after 2009 (Fig. 8).

Considering the pan-Arctic agreements that were signed in 2011 and 2013 as examples, while they are important and forward looking, they also are hollow in the absence of effective built infrastructure for their implementation. Who are the decisionmakers to couple governance mechanisms and built infrastructure? How will the investment mature to achieve progress with Arctic sustainability? Such infrastructure questions (Table 3) are an ongoing focus of the Arctic Economic Council that was established through the Arctic Council in 2015, fostering circumpolar business partnerships. Principles for business development in the Arctic also have emerged through the World Economic Forum (2016): "to promote sustainable and equitable economic growth in the region that furthers community well-being and builds resilient societies in a fair, inclusive and environmentally sound manner."

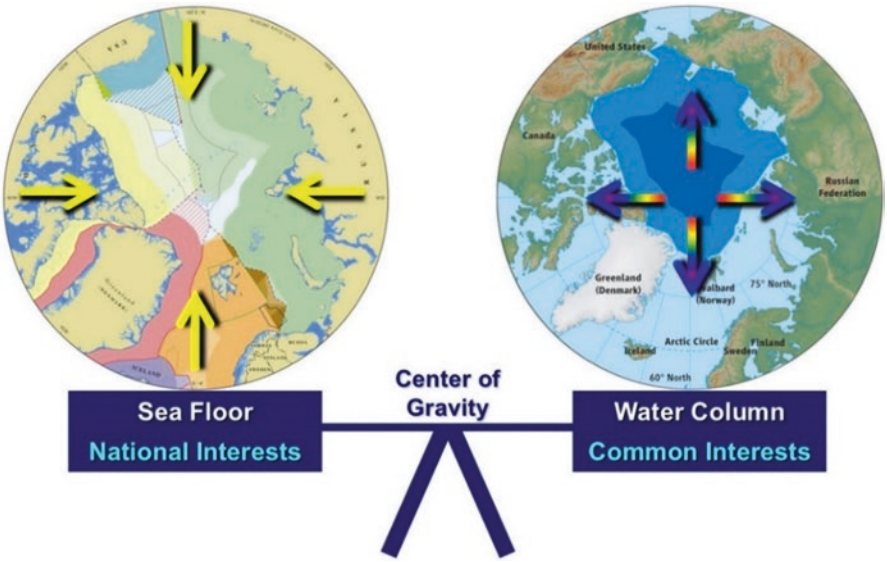

Fig. 11 Balancing national interests and common interests over space with the law of the sea (Fig. 2) in view of the Central Arctic Ocean from the: (**left**) sea floor with sovereign areas and outer Continental Shelf claims into the currently defined Area of the deep sea (different colors) and (**right**) overlying water column with the High Seas (dark blue) as an unambiguous international space surrounded by Exclusive Economic Zones (light blue). National interests are seaward in contrast to common interests landward with perspective from the North Pole. (Adapted from Berkman and Young 2009)

With sustainable development as a "common Arctic issue" (Ottawa Declaration 1996), there is an opportunity for decisionmakers to operate across a "continuum of urgencies" (Figs. 3, 4, 5, and 6). The world well knows discussions at security time scales. There also are holistic dialogues that are emerging in view of sustainability time scales with built infrastructure across the twenty-first century (Peoples Republic of China 2015). Developing toward Volume 3 with INFORMED DECISIONMAKING FOR SUSTAINABILITY, what are the investment phases in the Arctic (Fig. 12) as well as elsewhere on Earth to couple infrastructure with governance (e.g., Fig. 8), achieving progress with sustainability across generations?

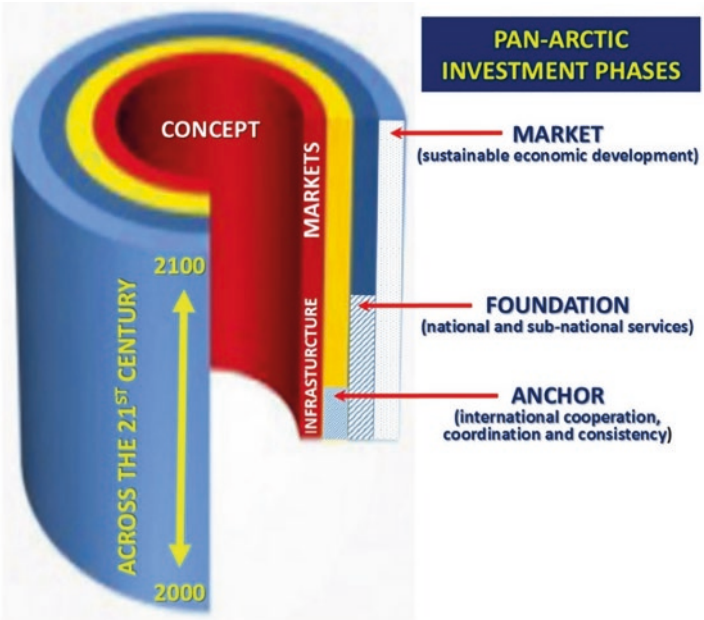

Fig. 12 Concept of Investment Phases that are operating in parallel today to address a "continuum of urgencies" (Fig. 3) in the Arctic Ocean, as a globally-relevant case study with governance mechanisms (Figs. 2, 8, 10 and 11) and built infrastructure (NORDREGIO 2011) to develop as well as integrate for sustainable development across generations (Figs. 1, 3, 4 and 5; Tables 2 and 3).

Public-private partnerships (World Bank 2019) with informed decisionmaking at tactical and strategic time scales (Figs. 1, 3, 4, 5, 10 and 11) are necessary to balance economic, environmental, and societal considerations (Tables 2 and 3). In view of trends, patterns and processes revealed with research and addressed with action (Fig. 5), this book series is intended to empower personal capacities with science diplomacy and its engine of informed decisionmaking as a holistic process for the benefit of all on Earth across generations.

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