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Science and Policy Interactions in Assessing and Managing Marine Ecosystems in the Southern Ocean

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Good policy can only be built and implemented using sound advice, and a clear understanding of risk. Scientific advice will often be qualified by the extent of research and knowledge, and uncertainties about the current and future state of the environment. Bodies tasked with protecting the Antarctic environment are required to make decisions based on the best available advice. To not take decisions in the absence of certainty is contrary to clear obligations to protect the Antarctic environment contained in the instruments of the Antarctic Treaty System. The risk of foreclosing future options to protect the environment by indecision is as great, if not greater, than making decisions with incomplete advice, and then actively managing that decision into the future. This "Perspective" explores the relationship between science and policy in the context of the Conference on Marine Ecosystem Assessment for the Southern Ocean held in 2018—it is a perspective from the view of a policy-maker and end user of scientific assessment and advice.

Keywords: climate change, Antarctica, CCAMLR, CEP, Antarctic Treaty

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INTRODUCTION

Understanding what policy-makers want from researchers, and translating science into policy are not straightforward tasks. Good policy requires clear objectives and well-designed pathways to implementation and outcome. Good policy also requires objective measures of success, failure and need for adjustment.

While "good policy," "clear objectives," and "sound advice" are rather general terms, from the point of view of this "Perspective" my intention is that "good policy" is policy that is well defined and understood, and that is assessed *a priori* to not deliver perverse outcomes from its implementation. These terms were deliberately used to connote generic goals of policy-makers.

Often, decisions to create and implement a particular policy are made because something needs to be "fixed"—a previous practice or governance arrangement has failed, or something unforeseen (for example COVID-19) has appeared in the physical and geopolitical environment.

Scientific research on the other hand is almost always a long-term process, often requiring detailed preparation, field work, experimentation, modeling, analysis, and testing. Scientific knowledge is also changing in that new research leads to better or different understanding about the conclusions that have been drawn from previous bodies of work.

For a policy-maker scientific advice that contains "uncertain" conclusions can create doubt about effective policy implementation or, worse, decision paralysis. For the scientist, policy insistence on clear and concise advice is often regarded as shallow and intellectually corrupt.

But the clear facts are that effective policy-making requires the best available information provided in a way that demonstrates the strength of the advice and the limits of its conclusions. It should be then up to policy-makers to design effective and timely policies based on this information. Commonly, policy-makers are required to make decisions in the absence of complete or 'perfect' information. Designing good policy requires not only an understanding of the scientific advice given, and the uncertainties inherent in it, it also requires evaluation of the implications, or costs, of implementing available policy options. In conservation, for example, a "business as usual" policy response to uncertain scientific knowledge may result in adverse consequences, such as species decline and extinction, environmental damage, or ecosystem shift and/or collapse.

In the absence of complete or "perfect" scientific information, it is incumbent on policy-makers and scientists to understand the gaps in scientific information, to set research priorities to fill these gaps, and to adapt management approaches as new information is received.

This article provides a perspective on the discussions held during the Policy Forum that was held at the Conference on Marine Ecosystem Assessment for the Southern Ocean (MEASO) in Hobart in 2018. It looks at some of the ways that science and policy can be integrated to inform policy development and decision making for the conservation of the Antarctic marine environment given the current state of scientific understanding. It is written from the perspective of a long-time end user of scientific research and information used to develop and pursue policies for the conservation of the Antarctic environment. The context of this "Perspective" is the research and decision-making structures of the Antarctic Treaty System, rather than a perspective on national or other international frameworks.

PERSPECTIVES ON ANTARCTIC ECOSYSTEMS AND THEIR MANAGEMENT

In 2018 the journal Nature published, an editorial calling for "reform" of the Antarctic Treaty System (ATS) (Anon, 2018). The Nature editorial, and other recent work, highlight the challenges faced by scientists and policy-makers in responding effectively to existing and emerging environmental management challenges, especially those that relate directly to, or are exacerbated by climate change:

> "Pressure on the Antarctic Treaty from geopolitics can only increase, as demand for the continent's stocks of fish and expected reserves of minerals rises with the depletion of resources elsewhere. . .," and

> "Scientists can strengthen and harness . . . support by relentlessly telling the public and policymakers about the seriousness of the threat to Antarctica and the need to protect the region" (Anon, 2018).

Rather than deal in any practical way with how science can be better used by policy-makers, or how policy and science can better interact, Nature concluded with the unrealistic proposal that the fundamental decision-making principle of the Antarctic Treaty System, consensus, be abandoned—an impossible step that would unravel the governance of the entire Antarctic region.

Nonetheless, the Nature editorial, and other recent work, highlight the challenges faced by scientists and policy-makers in responding effectively to existing and emerging environmental management challenges, especially those that relate directly to, or are exacerbated by climate change.

Chown and Brooks (2019), for example, in their broad-ranging review of the "state of Antarctic environments" concluded that,

> "Information on key species, such as Antarctic krill, seabirds, and seals, and on key ecosystems, such as those of the West Antarctic Peninsula, remains inadequate to fully understand their dynamics. Additional long-term monitoring is essential for effective management. . .

> "Accelerating climate change, if mitigation of greenhouse gas emissions is ineffective, will pose considerable challenges to environmental management across the region. . .

> "Environmental degradation elsewhere will increase pressure for use of Antarctica and the Southern Ocean's resources". [Author's emphasis].

Given the importance of Antarctic marine ecosystems, historical exploitation of its marine living resources (particularly whales, seals, and fish), and the disruption to ecosystems that climate change brings, science must play a central role in establishing policy and governance mechanisms for the protection of the Antarctic.

THE SCIENCE-POLICY INTERFACE

One of the most difficult aspects of policy development is how relevant science is sought and received. Science is a contested space by its very nature: hypotheses are developed and tested; conclusions on cause and effect are often qualified by the current extent of knowledge; and new knowledge will alter understanding of processes and outcomes. That does not mean that 'science-into-policy' is not achievable, but it does mean that policy-makers need to understand the state of scientific knowledge and the practical limits of scientific understanding. A clear understanding of these factors can then be used to make precautionary decisions—decisions that take into account uncertainty in such a way that future options are not inadvertently foreclosed by bad (or, no) decisions.

The Intergovernmental Panel on Climate Change (IPCC), for example, has well-established and coherent practices for using the best available science to provide information and advice to policy makers[1]. The important elements relevant to this paper are that the IPCC processes involve:

- Assessment of all available relevant scientific and technical information[2];
- Expert assessment of draft IPCC reports for their accuracy, completeness and balance; and
- The distillation of scientific and technical reports into a "Summary for Policy Makers" that has agreed and transparent language about "uncertainty"[3].

The process ensures differences of view are opened for discussion and resolution, and that IPCC reports contain verifiable information and advice that clearly establishes the state of knowledge about conclusions and advice to policy-makers. This process also enables the prioritizing of scientific research: the "uncertainties" in scientific understanding of the Earth System revealed through the IPCC process have resulted in increased research in these "uncertain" areas, for example Antarctic ice sheet mass balance.

Comparable processes are being used in other global assessments, such as the Intergovernmental Panel in Biodiversity and Ecosystem Services (Díaz et al., 2019), and the First Global Assessment of the World's Oceans[4].

THE ANTARCTIC

In the Antarctic context the Committee for Environmental Protection (CEP) established under the Protocol on Environmental Protection to the Antarctic Treaty (Madrid Protocol)[5], and the Scientific Committee (SC-CAMLR) established under the Convention on the Conservation of Antarctic Marine Living Resources (CAMLR Convention)[6], are bodies tasked with taking expert advice, including scientific evaluation and advice, and making recommendations for adoption by their respective decision-making bodies. Both bodies have established processes for review and assessment of scientific and technical information, and can call on external organizations such as the Scientific Committee on Antarctic Research (SCAR) for expert advice.

In relatively data-poor regions, such as Antarctic marine ecosystems, it is important to clearly understand the limits of currently available scientific knowledge and the context and requirements of information by policy-makers. This is especially important in managing risk (that is, failure of policy resulting in adverse outcomes). The fact that scientific information may be sparse or uncertain should not inhibit decision-making. Quite the opposite, it should provide, first, the incentive for precautionary decision making that reduces environmental risk to future conservation and, thereby, sustainable use options, and, second, the context for and needs of future long- and short-term research and assessment.

THE MEASO POLICY FORUM

The Policy Forum held during the MEASO 18 Conference was designed to bring together scientists, fishers, NGOs, and marine policy-makers to develop priorities for marine biological and ecological research "over the next two to three decades." The policy forum sought to "target research that will deliver science-based advice to support stakeholders and policy-makers." Presentations to the Policy Forum were given in four themes:

1. Future of the Southern Ocean.
2. Needs and capabilities for biological research in the Southern Ocean.
3. Filling the gaps.
4. Priorities to meet the needs.

The presentations and subsequent discussions at the Policy forum were concluded with a plenary discussion that attempted to synthezise the major outcomes and conclusions of the Policy Forum. The full program for the Policy Forum is provided as **Supplementary Material**. The presentations at the Policy Forum (**Table 1**) ranged widely over science knowledge (e.g., physical, chemical, and biological changes in the Southern Ocean); critical questions for future scientific research; timescales for understanding change and conducting research; the history of, and requirements for, scientific advice to inform policy and the scientific requirements of fishers and policy-makers; technology, modeling, collaborations and relationships; and importantly desirable futures for the Southern Ocean and pathways to delivery of research into policy.

General Conclusion

It was evident from the plenary discussion held at the end of the Policy Forum that the participants saw benefit in policy-makers and researchers working together to frame research programs and translate science into policy. Acknowledging that policy decisions often needed to be made with limited available data, the Forum concluded:

- Decision making could be aided by using the best available, even if imperfect, science which includes a combination of field studies, new technologies, and modeling.

One strong theme in the discussion was the need for scientists, policy-makers and stakeholders to understand each other's requirements for research inputs and policy outcomes, and the constraints on both decision-making and research effort. The forum concluded:

[1]IPCC Procedures. At https://www.ipcc.ch/documentation/procedures/; in particular the IPCC "Principles' at https://www.ipcc.ch/site/assets/uploads/2018/09/ipcc-principles.pdf. As accessed 21 May 2020

[2]IPCC Procedures. While preference is given to peer reviewed literature, other kinds of technical reports are assessed for review, but subject to scrutiny for veracity and relevance.

[3]The IPCC has developed defined and "calibrated" language to convey to the reader the confidence that is given to each of its assessments. See for example, Special Report on Oceans and Cryosphere, Technical Summary. At https://www.ipcc.ch/srocc/chapter/technical-summary/

[4]Summary of the first global integrated marine assessment (2015) United Nations, at https://undocs.org/A/70/112; and the ongoing oceans assessments at https://www.un.org/Depts/los/global_reporting/WOA_RegProcess.htm

[5]Protocol on Environmental Protection to the Antarctic Treaty, Madrid, 1991.

[6]Convention on the Conservation of Antarctic Marine Living Resources, Canberra, 1980.

TABLE 1 | Sections and topics presented and discussion at the Policy Forum in the conference Marine Ecosystem Assessment for the Southern Ocean, held in Hobart Australia on 11 April 2018.

Topic	Speaker
1. Future of Southern Ocean ecosystems	
Changing ecosystem forces on Southern Ocean biota	Jess Melbourne-Thomas and Nathan Bindoff (AAD, IMAS, CSIRO, ACE CRC)
Impacts of global geopolitics, economics and policies impacting on the Southern Ocean	Ray Arnaudo (United States)
Desirable futures for Southern Ocean ecosystems	Tony Press (ACE CRC) Discussion
2. Needs and capabilities for biological research in the Southern Ocean	
Critical questions for understanding Southern Ocean ecosystems: how to 'do the science' and timescales for research	Eileen Hofmann (Past Chair, IMBeR SSC)
What do policy-makers need from science?	Gill Slocum (Australian Commissioner to CCAMLR)
Fisheries needs from science	Martin Exel (Austral Fisheries)
Conservation needs from science	Andrea Kavanagh (Pew Charitable Trusts)
3. Filling the gaps	
Technology for future priority research	Oscar Schofield (recent Co-Chair, SCAR/SCOR Southern Ocean Observing System)
Models and modeling	Eugene Murphy (Chair, SCAR/IMBER program—Integrating Climate and Ecosystem Dynamics Program)
Partnerships	Katherine Woodthorpe (Chair, ACE CRC)
Public participation	Chris Johnson (WWF Australia)
4. Science priorities to meet the needs	
Global perspectives on the importance of science in the Southern Ocean	Anthony Bergin (National Security College, ANU; Australian Strategic Policy Institute)
The future of research capabilities—a global perspective	Tim Moltmann (Director, IMOS, Australia; Chair, Australian National Marine Science Committee)

- Policy makers rely on scientists to provide concise, compelling explanations of their research to inform policy. Scientists need clear guidance to respond to policy needs.
- Strengthening the link between science and policy priorities will require conversations among scientists, policy makers, industry, and diverse stakeholders.

Access to, and limitations on, data availability for the Southern Ocean were seen as a major constraint to both research and decision-making. The Forum concluded that:

- Making Antarctic and Southern Ocean data easily and publicly accessible will aid the advancement of science and the development of science-informed policy.
- A MEASO could help the scientific community communicate policy relevant findings in a collective voice that is accessible and understandable to policy makers.

Scientists and policy-makers should frequently explore how their interactions can be more productive, and how science can be used to better achieve the goals of conserving and protecting the Antarctic environment. In this context it is not only important to be clear on the modes of interaction between scientists and policy-makers, but also whether the goals sought are being achieved[7].

DISCUSSION

In essence, the conclusions from the Policy Forum could be applicable to many environments and decision-making bodies. But the context of Antarctica and the Southern Ocean makes the Forum's discussion both unique and compelling. After all, the context is 10% of the planet; Antarctica's role in the global climate system; the impending consequences of global warming; and the responsibilities of the Antarctic Treaty System (ATS)[8].

The Antarctic Treaty System has developed into a regional management system responsible for the environmental protection of the Antarctic region and the surrounding Southern Ocean since the negotiation of the Treaty itself in the late 1950s. Many of the significant developments in the ATS, for example the Agreed Measures for the Protection of Flora and Fauna (1964), the negotiation of the of the CAMLR Convention, and subsequently the Madrid Protocol, grew from concerns about the Antarctic environment, human pressure, and the need to base management decision-making on best available science.

The Need for Science

Antarctic research over the past three decades has shown that the Antarctic marine environment is changing: the ocean and atmosphere are warming with significant regional impacts; atmospheric and oceanographic changes are occurring, affecting sea-ice, ice sheet stability, and impacting the global overturning circulation of the ocean; and the chemistry of the ocean is changing with increased acidity and changes in oxygen saturation.

Biological changes are also occurring with shifts in predator distributions, pelagic species ranges, and potential changes to food-chains and ecosystems. While some marine species will be resilient to physical and chemical changes in the Southern Ocean, there is great potential for ecological disruption, and consequences for productivity. Southward shifts in global

[7] See, for example, Cvitanovic et al. (2015); Lacey et al. (2018), and Norström et al. (2020).

[8] The Antarctic Treaty System is the combination of international agreements, bodies established under these agreements, and the corpus of decisions made under them, since and including the 1959 Antarctic Treaty.

fisheries productivity as a result of climate change are also projected[9]. Understanding these changes and their impacts is critical information for policy development, management, and decision-making.

The IPCC's 2019 Special Report on Oceans and Cryosphere in a Changing Climate (SROCC) report highlighted the importance of understanding spatial and temporal scale in responding to climate change, acknowledging that established governance arrangements are often unsuited to dealing with changes over large geographical regions and long timeframes[10]. The report also emphasized the importance of precautionary and science-based management in the context of climate change.

Given that both precaution and science-based policy-making are embedded in the Antarctic Treaty System, it is imperative that clear pathways for the delivery of science into policy, and research responses to policy needs, are identified and strengthened.

The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) established under the CAMLR Convention, is often cited as a "best practice" regional marine management body. It has been praised for its precautionary approach to setting catch limits for exploited fish stocks; its exemplary measures to reduce Illegal, Unreported and Unregulated (IUU) fishing; and its success in almost eliminating the by-catch of sea birds, particularly albatrosses and petrels. It is worth noting here, that the precautionary approach should be both incremental and iterative. Precautionary decisions, based on the best available science, should minimize the risk of failure and maximize chances for recovery from potential failure. CCAMLR's decision rules for krill and toothfish catch, and for exploratory fisheries are such examples.

In recent years, CCAMLR has been subject to criticism for failing to agree, through consensus, to the expansion of marine protected areas in Antarctica.

The CAMLR Convention, includes the mandate to conserve Antarctic marine living resources, including:

> "maintenance of the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources and the restoration of depleted populations. . .; and
>
> "prevention of changes or minimisation of the risk of changes in the marine ecosystem which are not potentially reversible over two or three decades, taking into account the state of available knowledge of the direct and indirect impact of harvesting, the effect of the introduction of alien species, the effects of associated activities on the marine ecosystem and of the effects of environmental changes, with the aim of making possible the sustained conservation of Antarctic marine living resources"[11]. [Author's emphasis].

It follows that in order to achieve the goals of the CAMLR Convention, there must be a strong link between science and policy-making. While the absence of 'complete' scientific information is not an inhibition on developing law and Measures[12] by CCAMLR (see the extract from the Convention above) there is a need to gather scientific information that allows CCAMLR to fulfill its obligations under international law. These obligations span not only the setting of catch limits and regulation of fisheries, but they preferentially extend to the protection of the Antarctic ecosystem[13], species conservation, the management of human impacts such as fishing, and responding to the impacts of climate change.

The duty to protect the Antarctic environment contained in Antarctic law[14] requires a dynamic relationship between science and policy. Policy-makers cannot wait for perfect scientific information—to do so would foreclose options for future decision making, and restrict the ability to effectively manage environmental change. Scientific "evidence" will never be perfect, therefore effective decision making requires assessment of available knowledge, risk, and the consequences of non-action.

The Antarctic region is undergoing change, both human and climate-related, and "waiting", in the opinion of this author, is not rational. Both policy-makers and scientists should recognize that the future will be shaped by today's decisions (or non-decisions). Change is far more likely to produce more obstacles to protecting the Antarctic environment, than it will opportunities.

Given this, it follows that policy-makers require a range of scientific information for both short and long term decisions: information, for example, to establish precautionary catch limits; evaluations such as the status of species or the impacts of fishing or other environmental disturbances; and the status and trends of climate change impacts on the marine environment. Much of this information is directly relevant to the work of the CEP and decision-making in the Antarctic Treaty Consultative Meeting.

It is important to note in this context that effective science-policy dialogue requires an iterative approach that involves assessments now of trends and risks, clear articulation of policy needs, and the modes and ability of scientists and policy-makers to set tasks and programs of research.

The effective management of risk, of course, requires a willingness to make decisions.

CONCLUSION

Antarctic science is expensive, logistically difficult, requires detailed planning, and often takes considerable time to complete. Science that is directed to the conservation and management of the Antarctic environment will benefit from open and ongoing dialogue between policy-makers and scientists. Understanding

[9]IPCC (2019) Special Report on the Ocean and Cryosphere in a Changing Climate, Summary for Policy Makers, Figure SP3 pp 23–24, at https://www.ipcc.ch/site/assets/uploads/sites/3/2019/11/03_SROCC_SPM_FINAL.pdf

[10]IPCC, "Challenges" C.1.2., p29.

[11]Convention on the Conservation of Antarctic Marine Living Resources, Canberra. 1980, Article 2.

[12]Conservation Measures are legally binding decisions made under the CAMLR Convention by the Commission for the Conservation of Antarctic Marine Living Resources.

[13]Article 1 of the CAMLR Convention, including "The Antarctic marine ecosystem means the complex of relationships of Antarctic marine living resources with each other and with their physical environment."

[14]The requirements from the Antarctic Treaty and the ATCMs; the CAMLR Convention; and the Madrid Protocol.

what policy-makers need in order to make decisions, and policy-makers understanding the context and limits of the scientific endeavor, will lead to better outcomes for both "sides" of the dialogue. Planning both short term and long term scientific research programs to inform decision making should be integrated in policy development, research planning and the workplans of Antarctic organizations.

This process must incorporate dialogue that understands risk. Decision-rules, for example, can use metrics derived from science or expert advice that is provided to inform policy in order to keep risks to a satisfactory level (for example precautionary catch limits). The dialogue should involve scientists, stakeholders and policy makers in discussion of desired outcomes and risk, and the limits of policy. The desired outcome in this context is the conservation of the Antarctic marine environment, and the tolerance of the risk that decisions leading to adverse consequences will be very low.

The 2017 CCAMLR Performance review addressed these issued directly[15]. Among its recommendations were that:

> "The Scientific Committee evaluate options for ecosystem-based management of all CCAMLR fisheries, taking into account ecosystem and climate change and the types of data that can be reliably obtained. . .
>
> "CCAMLR implements practical mechanisms to coordinate and deliver research activities among Members to deliver the long-term research required by the Commission to achieve its objective, including better targeted fish stock research to ascertain productivity and yield of stocks across their ranges, and analyses of status and trends of those stocks and Antarctic marine living resources more generally. . . and,
>
> "A management-science forum across the Commission and the Scientific Committee be established to facilitate open communication and dialogue between scientists and policy makers involved in CCAMLR on key topics and issues and their respective expectations for science and policy."

These recommendations are hardly controversial. On the contrary, their implementation broadly would considerably enhance the protection of the Antarctic environment.

Policy making and scientific endeavor are two different pursuits, but the delivery of the goal of protecting the Antarctic environment requires both. While the politicization of science should be fought vigorously, dialogue between the "politicians" and the scientists is vital to Antarctica's future.

[15] See https://www.ccamlr.org/en/system/files/e-cc-xxxvi-01-w-cp.pdf, accessed 21 May 2020.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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