6

Advanced scholarship

Interdisciplinary research at the science–policy interface

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How can we more effectively organize and publish meaningful research to help us better understand and respond to the global environment problems we face? This chapter provides suggestions for successful interdisciplinary research on international environmental politics, based on a review of published and unpublished works in the field. Usable science and knowledge are essential for devising effective environmental policies to address major global environmental threats, including climate change (see Chapter 32 and others chapters in Part V of this volume). Most policy analysts believe that better public discourse and elite deliberations require reliable knowledge that is accurate and socially legitimate (Haas 2004a; Mitchell et al. 2006). Accurate knowledge in the environmental domain must be interdisciplinary in order to capture the complex array of interactions between social and physical drivers that give rise to global environmental threats. Legitimate knowledge must enjoy a social pedigree, which in practice is often the peer-review process. For example, the Intergovernmental Panel on Climate Change (IPCC), the United Nations Environment Program's Global Environmental Outlook and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services require that all information that it presents be published or accepted in peer-reviewed journals and books.

While this requirement leads to a lag in the dissemination of scientific knowledge to policy making, it does enforce the legitimacy of the knowledge that is being presented. Consequently, despite efforts by the well-known "climate denialists" (see Chapter 32) and ultimately to science denialists to delegitimize science over the last several years in any country, the integrity of the science was upheld by the courts and high-level oversight panels in each country.

Many scientists are frustrated that their work is not readily recognized in the policy community (Hulme 2009; Schneider 2009; Bradley 2011). One recent approach to science communication focuses on the rhetorical presentation of science and the psychological factors that influence its reception (Boykoff and Boykoff 2004; Leiserowitz et al. 2006; Boykoff 2011). Others look at the political constraints operating on governments that impede the reception of new information, which may require costly new measures (Hulme 2009), or from entrenched domestic interests in the United States (Oreskes 2007; Schneider 2009; Oreskes and Conway 2010; Bradley 2011). In this chapter we focus on the instrumental means by which

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usable knowledge is generated and circulated (see also Chapter 18). Elsewhere, Haas has argued that credible science is provided by epistemic communities (Haas 2001, 2004a, 2004b, 2007, 2016). We focus on the published medium by which epistemic communities may better make their voices heard in the public discourse. We draw largely on experiences from 21 published manuscripts from the MIT Press series on Science, Politics and the Environment.

Although the causes and effects of global environmental problems tend to be multidisciplinary and interdisciplinary, modern scholars too often are disciplinary. The complexity of environmental issues – in terms of the number of interactions among variables, the length of causal chains, and the extent of interactions across time, space and scale – requires insights from multiple disciplines to capture accurately the extensive and multiple understandings of their causes, causal mechanisms and effects (Jacobson and Price 1990; Wiman 1991; Consortium for International Earth Science Information Network (CIESIN) 1992; Price 1992; National Research Council 1999a; Brewer and Stern 2005; Biermann 2007). The international community is starting to recognize that a complex global policy environment requires more sophisticated interdisciplinary insights. The 2030 Agenda and the 17 Sustainable Development Goals (SDGs) recently articulated under the auspices of the United Nations highlight the interdependent challenges for global society (Kanie and Bierman 2017; Sachs et al. 2019; Van wees et al. 2019).

Despite this, most scholars are trained – and often continue to think – in ways that are strongly disciplinary (Snow 1962). As Gary Brewer cleverly quipped, "the world has problems, but universities have departments" (Brewer 1999: 328). Addressing this disconnect between the problems we face and the solutions we offer is akin to reconciling different "epistemic cultures," i.e., the habits and beliefs associated with different academic disciplines (Knorr-Cetina 1999). Given this, how can we better organize and publish meaningful research to help us better understand and respond to the global environmental problems we face? (For more on research strategies, see Chapter 5.)

Interdisciplinarity and Sustainability Science

Since environmental problems emerged on the scholarly agenda in the 1970s, academics have debated the proper way to analyze their causes and effects. Views about the proper training of environmental scholars have changed significantly over time, with corresponding changes in terminology from "generalists" to "multidisciplinary," "interdisciplinary," "transdisciplinary" and "sustainability" scientists.

Alvin Weinberg called for "transdisciplinary" work that went beyond single discipline studies of environmental issues (Weinberg 1972). Others promoted the virtues of multidisciplinary work that drew on various disciplines. Tribe and colleagues noted that variation in analyses of a given environmental problem was likely to reflect, in large measure, the disciplinary values and perspectives of the analysts rather than real variation in the problem unless an interdisciplinary approach was used to help those from different disciplines converge on common values and methods (Tribe et al. 1976). Integrated assessment modelers, particularly in Europe in the 1990s, frustrated by their lack of influence on policymakers, argued for interdisciplinary work that included policymakers and stakeholders at the outset. Indeed, some have argued that environmental complexity exceeds the limits of traditional policy analysis and can only be meaningfully addressed through dialogs among such diverse groups (Ravetz 1986; Funtowicz and Ravetz 1991, 2001; Kasemir et al. 2003).

Training generalists was difficult in a disciplinary-based world. Universities lacked tenure track jobs for such individuals, either failing to hire them or placing them in programs (rather than departments) in which they trained few if any graduate students who could reproduce,

develop and refine their ideas. It soon became clear that few individuals could master the array of tools and scope of knowledge to conduct environmental research.

By the 1980s, multidisciplinary had become the professional mantra, largely in response to the institutional incentive and individual capacity problems mentioned above. This approach saw the answer as building teams of scholars from diverse social science disciplines who individually could receive tenure and promotions within existing university structures but who collectively could shed better light on the complex environmental problems in question (Keohane and Ostrom 1995; Young 1997, 1999; Miles et al. 2002; Young et al. 2008; Young 2017). It was hoped that teams composed of individuals well versed in their own disciplines but interested in working with those from other disciplines could generate better insights by creating analytic synergies and identifying and removing disciplinary blind spots.

During the 1990s, this multidisciplinary perspective transitioned into an interdisciplinary one that sought to bridge the disciplinarian chasm that traditionally divides the social sciences from the natural sciences and engineering (Social Learning Group 2001a, 2001b; Miller and Edwards 2001; Schellnhuber et al. 2003; Jasanoff and Martello 2004). This shift urged greater collaboration across this chasm in an effort to progressively remedy the problem that social scientists often got the natural science wrong and natural scientists and engineers often got the social science wrong, with either error posing the risk that the science would be wrong and/or irrelevant to policymakers.

Policymakers have increasingly expressed their desire for "usable" science that was not only ecologically sound but was also politically, economically and sociologically informed, while scholars demonstrated an increasing desire to contribute to policy debates and a frustration that their work so rarely did so. Increasing attention was paid to those who were calling for transdisciplinary work. Such work sought to generate new theoretical frameworks for understanding social–ecological relationships rather than, as earlier work was accused of doing, simply trying to better understand the causes and effects of particular social–ecological problems (Jasanoff 2003, 2004; Kasemir et al. 2003; Brewer and Stern 2005). Such an approach aspires to forging a new theoretical framework for understanding environmental complexity that is drawn from a hands-on dialog between practitioners, civil society advocates and active scientists across the full spectrum of natural and social sciences and humanities. It also cautions against the hubris of a physics-based nomothetic approach to knowledge cumulation, rather focusing on deeper understandings of specific important problems through participatory learning.

More recently, scholars have called for interdisciplinary, international research teams that encompass not only academic researchers but also policymakers under an umbrella of Sustainability Science (Kates et al. 2001; Gallopin 2006; Clark and Harley 2020; see Chapter 16). It offers an interdisciplinary focus on the interactions between natural and social systems, and on how those interactions affect the challenge of sustainability (Kates et al. 2001). It is also a problem-driven field, that seeks to contribute with practical solutions that span from global to local scales, and it includes different perspectives from the global south and north. A review article of the evolution of Sustainability Science summarizes its purpose as "A science of sustainability necessarily requires collaboration between perspectives in developed and developing human societies, among theoretical and applied scientific disciplines, and must bridge the gap between theory, practice and policy" (Bettencourt & Kaure 2011: 19540). Sustainability Science does not just study the interactions between natural and social systems, but also aspires to govern them sustainably. It focuses on the salient spatial and temporal scales of the interplay, as well as imbuing decision-makers with the skills to govern such features by putting sustainability scientists in positions of authority.

Sustainability Science has been refined and promoted by the Harvard Kennedy School of Government, and the US National Academy of Sciences, with opportunities for publication in *PNAS*. It has been actively adopted by Future Earth and the International Council of Scientific Unions (ICSU), and the Earth System Governance project (https://www.earthsystemgovernance.org) (see Chapter 21). The Belmont Forum (https://www.belmontforum.org) has become a funding source for such activities. The 2019 Global Sustainable Development Report devoted a chapter to science for sustainable development, trumpeting the virtues of Sustainability Science for governing global issues, as well as the UN Sustainable Development Goals in particular (United Nations 2019). Sustainability Science also undergirds some major international policy documents, including the World Conservation Strategy, the Brundtland Report and Agenda 21. Still, it remains far more popular in the global north than south, as fewer scholars have been trained or taken jobs in the developing world.

For interdisciplinary research to be successful, it must involve individuals from a range of disciplines, each of whom is well trained in their own discipline; has some familiarity with the core concepts of other relevant disciplines; and is skilled in making the core concepts of their discipline accessible to other scholars, policymakers and stakeholders. Assembling teams of such scholars is thought to promote progressive research that generates new knowledge and new frameworks of understanding that could not, or would be unlikely to, emerge from a single discipline's perspective.

The US National Academy of Sciences proposed a division of labor for social–ecological research. In the National Academy's rubric, the social sciences can help explain the causes (or driving forces) of human behaviors that lead to global environmental change. The social sciences can also help explain the processes by which societies and decision-makers respond to identified threats and thus help better understand the likelihood, means and conditions that foster or inhibit alternative collective responses. The natural sciences can help explain how problems unfold and identify goals for sustainable responses. In turn, different disciplines can contribute in ways that relate to their core concepts: power and institutions from political science, markets and price signals from economics, public opinion and social attitudes from sociology and political science, local knowledge and organization from anthropology, issues of law and enforcement from legal scholars, and the like. Similarly, distinct fields of natural science can contribute insights into the behavior of different types of ecosystems (Rayner and Malone 1998; National Research Council 1999b; Biermann 2007). Including Indigenous and local community knowledge appears key for the better governance of biodiversity, deforestation and desertification (Xavier et al. 2018; Turnhout, Tuinstra, and Halffman 2019).

Such calls for interdisciplinarity and transdisciplinarity, of whatever sort, complement rather than replace more traditional disciplinary efforts. A full understanding of social–ecological systems will always require the deep disciplinary research that stays within more traditional disciplinary boundaries. For instance, in political science, Institutions for the Earth (Haas et al. 1993), a team-based project undertaken by political scientists, looked at the question of how international institutional design can improve the management of shared ecosystems, as well as international public goods (see Chapters 8 and 9). It found that institutions that enhance cooperation, concern and capacity were more likely to yield beneficial results than those without. Other groups of political scientists have confirmed that regimes with organized scientific involvement (epistemic communities) yield more comprehensive regulatory commitments and also better environmental outcomes than those without (Andresen et al. 2000; Miles et al. 2002; Haas 2007; Biermann and Pattberg 2012; see Chapter 18).

Conducting effective environmental policy research

How can effective research on global environmental issues be conducted? A key conclusion from this review of the philosophy of science for social–ecological research suggests at the very least that meaningful work is best performed by teams of scholars. Several recent books have also tried to develop heuristics for effective environmental policy research (Benda et al. 2002; Bergmann et al. 2005; Morin et al. 2020). Our judgments are based on our experiences as authors, as participants in interdisciplinary research projects, as editors of journals and book series, and as peer-reviewers for journals, publishers and foundations. For present purposes, we consider research as effective when it provides new insights into the causes or consequences of global environmental problems in ways that foster, in the short or long term, human society's ability to mitigate or adapt to those problems. Achievements in this realm can be observed (if not measured) by reference to the degree that research is published in peer-reviewed journals or with university presses, trains new scholars, and leads policymakers and stakeholders to accept new understandings of a problem and respond in more effective ways to mitigate or adapt to those problems.

The results of most past collective research projects in the global environmental politics arena, usually published as edited volumes, have tended to involve multiple chapters written by different, often multiple, scholars from various disciplines and countries. Such volumes often include authors at different career stages, from graduate students to senior professors. Building on our distinctions above, we distinguish two classes of research: interdisciplinary projects involving scholars from distinctly different disciplines including both social and natural scientists; and multidisciplinary projects involving scholars from a single discipline or a narrow range of cognate disciplines within the social (or natural sciences), such as political science, sociology, law and economics (Choucri 1993; Winter 2006).

To date, most published work has been multidisciplinary. Interdisciplinary work is more difficult to achieve, as discussed below, because of the difficulties in spanning disciplinary cultures and vocabularies. In general, while these efforts highlight insights from individual disciplines about a problem, they fail more generally to integrate them into a more coherent picture or even clearly to articulate the compatibility or tensions between different approaches (Cebon et al. 1998; Social Learning Group 2001a, 2001b). In short, truly interdisciplinary work remains in its infancy with considerable room for improvement.

To foster progress in that venture, the following section reflects our thoughts for improving, and publishing, both multidisciplinary and interdisciplinary work on global environmental problems. While successful multidisciplinary and interdisciplinary work may generate new integrated wisdom, it may also reveal uncertainties and fundamental differences in understanding between actors and disciplines.

Applications of interdisciplinarity

Here we provide three exemplars of interdisciplinary books whose findings exceed the conventional views of single disciplines. *Changing the Atmosphere* (Miller and Edwards 2001) has ten chapters written by nine authors, ranging from PhD candidates to full professors. The authors come from information sciences, philosophy, social studies of science, biology and climate science. The research was well supported by a variety of grants. This collection was one of the earlier social science investigations of the production and use of climate science for policy. Thus, it had a comprehensive introduction, providing an overview of the critical social studies of science literature, but lacked a concluding chapter. The

empirical chapters demonstrate the greater role of interpretation and uncertainty associated with scientific advice and the IPCC than was generally recognized by hard scientists and policy analysts (see Chapters 18 and 19). It developed the finding that science and science–policy does not directly mirror the natural world, but rather that it interprets the world for policy and political consumers in ways that are socially and politically shaped. The effective provision of scientific information requires political and social inquiry about the frames and context within which policymakers solicit and understand scientific advice. Policy studies need to better understand the degree of distortion involved in the knowledge being delivered, and to focus on the political processes by which choices about knowledge claims are made and the knowledge is itself interpreted by less technically trained policymakers.

The Reflexive Governance for Global Public Goods (Brousseau et al. 2012) provides an interdisciplinary investigation of global public goods; an analytic category that includes climate change. *Reflexive Governance* has 15 chapters as well as an introduction and conclusion, written by 21 international contributors, drawn from research fellows, assistant professors to full professors, and one government official. Substantively, they include economics, ecological economics, philosophy, politics, and interdisciplinary training in environment change. The interdisciplinary approach to global public goods complements conventional studies of international public goods that seek to internalize the costs of environmental degradation through hierarchical controls, market arrangements to internalize costs, or institutional arrangements to concentrate the environmental consequences. By studying a number of public goods occurring at different scales and with different participants, the authors find that the provision of organized scientific knowledge is capable of educating political actors to change their behavior and take account of environmental externalities, which remain economically low cost. In this regard the volume is "reflexive" in documenting knowledge about how knowledge may be usefully integrated by national-level decision-makers to learn about climate change, and to embark on new policies that are more sustainable. Such collective reflection requires democratic participation, scientific information and a lengthy social process of deliberation (Dedeurwaerdere et al. 2012: 316–317).

Governance and Environmental Planning: adaptation and public policies in the Macrometrópole Paulista (Torres et al. 2020) is a collective effort to discuss climate change adaptation from an interdisciplinary point of view. The authors include economists, engineers, biologists, social scientists, lawyers, urban planners and oceanographers and all chapters aiming to discuss how a climate change adaptation policy should be carried to promote environmental governance within different perspectives. The book presented various conceptualization approaches, methods and critical thinking in an attempt to integrate epistemologies.

Improving interdisciplinary and multidisciplinary research

What are the factors that support (or not) publishing interdisciplinary research in peer-reviewed journals? In our view, conducting and publishing effective research requires that the scholars design the research in ways that meet the three criteria delineated. This conclusion is confirmed by an analysis that additionally mentioned six factors that would ideally foster an interdisciplinary publication, such as "(1) a strong, interdisciplinary coordinator, (2) a clear shared vision of integration and a common framework, (3) flexibility in terms of money and time, (4) a certain sense of timing regarding when and how to exchange results and knowledge, (5) subject editors who are familiar with the specific project and its interdisciplinary merits, and (6) reviewers who are open minded about interdisciplinary efforts" (Pohl et al. 2015).

Yet, where peer-reviewed articles may raise challenges to publication, books, introduce a great opportunity to assemble a team of experts to approach a subject within an interdisciplinary perspective.

Selecting participants

The first step in developing successful interdisciplinary research is the selection of the research team. Individuals should be chosen on the basis of their depth of disciplinary expertise and their ability to communicate clearly about their discipline with those from other disciplines. Individuals also should be chosen to create an "expert team" rather than a "team of experts." An expert team consists of a set of scholars who have individual skills but also, collectively, represent the range of disciplines necessary to accurately evaluate and analyze the environmental problem in question and who also have the interpersonal skills that help a team run well. These include the ability and willingness to provide honest yet constructive feedback to others, to listen and respond quickly and well to such feedback from others, and to contribute to the project's overall goals, especially when that means altering individual research approaches and processes to foster those goals.

In addition, several benefits arise from having multiple ranks represented within a team. Junior scholars benefit from the explicit and implicit training and mentoring from more senior scholars with more extensive and varied experience who can demonstrate various solutions to the inevitable problems that arise in collective research. Senior scholars benefit from the intense exposure to and interaction with those trained in the most current research and methodological developments and by being challenged to respond to, rather than merely read about, alternative perspectives on various issues. Such interactions may help overcome the theoretical myopia that can develop in senior researchers who have worked within their own traditionally defined boundaries for most of their careers.

Additionally, beyond generational balance within a team, it is also valuable to consider gender balance as well as a regional balance among the north and south countries. This will support a wider view of the problem, and it will bring a range of experiences to contribute to the team.

There are several obstacles to building such a team. One is that most networks of scholars are built within rather than across disciplines. Most scholars' networks include those who went to graduate school together and those who meet by going to the annual conventions of their own discipline. Institutional incentives reinforce the need to write papers that will be published in one's own discipline's journals and to "build a reputation" in that discipline and discourage the time "wasted" going to conferences, engaging in collaborations, and networking with those from other disciplines. The challenge is to identify and recruit people who either have found ways to achieve traditional measures of disciplinary success while retaining both the time and inclination to engage in interdisciplinary work or have found less traditional research trajectories in places such as the Santa Fe Institute. Few graduate or undergraduate programs yet provide meaningful training.

We believe that policymakers and stakeholders can make significant contributions to interdisciplinary research teams. One useful model involves having policymakers and stakeholders involved in initial research project meetings to ensure that the research questions are framed in ways that promote salient research results that stand some chance of contributing to upcoming policy decisions in ways that are sensitive to existing political, financial, and social constraints and perspectives (Mitchell et al. 2006). Briefing these policymakers and stakeholders at regular intervals during the research process also allows for "course corrections" that can improve the "uptake" of the ultimate conclusions without making them

susceptible to the influence of these groups. An obstacle that may need to be overcome exists in the relatively brief job tenure and demanding time schedule of individual policymakers and civil society members. Thus, involving individuals in such an enterprise runs the risk of discontinuities as members drop off and replacements bring in new agendas. Having briefing sessions with a broader community at the beginning and end of the research process, rather than relying directly on a cadre of individuals, offers an alternative solution (see Chapter 14).

Finally, we believe there is a "Goldilocks" problem in terms of team size. Interdisciplinary teams, to be successful, must contain sufficient expertise to address the array of perspectives and disciplines that can contribute to analyzing the problem in truly interdisciplinary ways. At the same time, teams that exceed 10 to 15 individuals can present a range of cost and logistical problems that can prove challenging for the organizers and can undermine team members' sense that their contributions are crucial to the team goals.

Building a team

Once participants have been selected, the next step in effective interdisciplinary research is building a team. Perhaps most important to doing so is the need to develop effective communication among team members, taking time to understand both the terminology and perspectives of the other scholars involved. Different disciplines can use the same word or phrase to mean completely different things and, at times, can use different words or phrases to mean the same thing (consider the difference in what a "climate regime" means to an atmospheric scientist and a political scientist). Equally important, but often harder to get at, are the more subterranean assumptions, methodologies and "ways of thinking" that are deeply embedded in each discipline. Without intending to stereotype, economists may be more comfortable monetizing certain human values, physicists may see the world in more mechanistic terms, anthropologists may be less comfortable generalizing across different cultures, etc. Mutual understanding of and, equally important, respect for, these "cultural differences" requires an ongoing process that tends to require considerable in-person interaction and may take a year or more. Open and explicit discussions of disciplinary semantics and methodologies can help identify often broad and deep divergences in outlooks and approaches. Such efforts are crucial to development of a common but integrated understanding of the environmental problem that the scholars seek to understand.

The success of "team-building" also requires explicitly and directly addressing the task of designing an internally consistent framework that accurately and usefully integrates the different disciplines and perspectives of the scholars involved. When such efforts are undertaken and succeed, truly interdisciplinary work can emerge that creates synergies from the contributing scholars. When such efforts fail, edited volumes whose chapters nominally address the same problem may prove quite non-cumulative, with insights from many chapters being ignored, misunderstood, or not taken advantage of with the result that meaningful communication across disciplines fails to emerge.

Overcoming these problems often benefits from strong editorial leadership that develops support for, and if necessary, imposes, a common framework for analyzing the problem, either with all contributing scholars applying the same framework or each scholar accurately using their own disciplinary tools to contribute to the overall framework. Procedurally, this often requires frequent face-to-face meetings throughout the course of the research project – and often more meetings than seem necessary – to develop a coherent common framework, to ensure collective understanding of that framework, to foster consistent application of that framework within individual chapters, and to develop careful cross-chapter insights as the project moves toward conclusion.

Sources of knowledge

One great challenge to promote interdisciplinarity is to build knowledge including different sources, from academic peers as well as diverse actors, such as Indigenous and local communities with knowledge from practice. A more recent example of this effort is The Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services. Although they have accumulated some lessons learned, still there are challenges to promoting inclusion and to working with Indigenous, local and scientific knowledge (Pascual et al. 2017; Díaz-Reviriego, Turnhout, and Beck 2019; Hill et al. 2020).

Yet improving participation and inclusiveness has been highlighted as important to the co-production of knowledge and influence the decision-making process (Fischhoff 2019), which involves the collaborative creation of knowledge that may be recognized as usable knowledge. Still, there are challenges and barriers to involve and incorporate different sources of knowledge, such as collating and validating local knowledge, and ensuring the appropriate and fair participation of various stakeholder groups (Sutherland et al. 2014).

Developing coherent and collective findings

To ensure a project generates strong interdisciplinary insights and presents them in a coherent manuscript requires iterative interactions among those contributors analyzing the individual cases and the editors developing the collective conclusions. Reinforcing the need for "strong leadership" noted above, the need for a strong leader or team of leaders becomes particularly important as a project moves to completion. These individuals must, from the outset, clarify both the standards and deadlines they will use for including or excluding chapters in any final published manuscript. Projects are too often delayed by one or two scholars who deliver their manuscripts late or provide manuscripts of demonstrably lower quality than others planned for inclusion. Although telling a team member that their contribution will not be included is unlikely to be pleasant for either party, they are easier when the criteria for such a decision have been delineated and understood at the outset.

Beyond these logistical points, the editors of collective volumes owe an obligation to their contributors to engage in the careful cross-case comparisons that are necessary to identifying common patterns and themes and to deriving both backward-looking conclusions and forward-looking conjectures. Editors should plan on blocking out the requisite three to six months of time needed to carefully read the contributed analyses, identify and write up interesting patterns, analyze the comparisons carefully, have their findings reviewed by all contributing authors, and revise the conclusions and introduction so that they simultaneously meet the goals of abstracting from the individual cases without doing injustices to the empirical evidence from those cases.

Training scholars

Beyond their intellectual benefits, interdisciplinary research projects that contain both senior and junior scholars provide excellent opportunities for mentoring. In-person interactions as well as those by phone or email, provide excellent opportunities for senior scholars to advise junior scholars on "threading the needle" of conducting research that is publishable in disciplinary journals and fosters professional advancement, that contributes to interdisciplinary understanding of important environmental problems, and that helps stakeholders and policymakers improve human responses to the environmental problems being studied.

Equally important, relationships that develop over the two- to ten-year timelines common to such projects provide the basis for respected senior scholars to write compelling letters of recommendation for interdisciplinary junior scholars seeking jobs or promotion in a world that remains, unfortunately, highly disciplinary.

These training and mentoring benefits can be fostered, especially for junior scholars, by developing a common team identity. This can be promoted by having a central institutional home for the research team, with a critical mass of PhD candidates, post-docs, and faculty that can interact regularly over the course of two or three years. Where such intensive interactions are not possible, ensuring that dedicated research team meetings are combined with more ad hoc meetings involving those team members that happen to be at annual conventions, particularly when team findings are presented at those meetings, can help considerably. Annual "retreats" at relatively isolated locations can also improve team esprit de corps and promote possibilities for following up themes more carefully than can occur in briefer more structured settings and can also facilitate more serendipitous interactions with benefits in terms of concept formation, analytic insights and development of future collaborations.

Crossing the academic–policy divide

A crucial aspiration of many scholars involved in studying social–ecological systems is to have their scholarship contribute to the mitigation and resolution of specific environmental problems and, more generally, to the improvement of the relationship humans have with the natural world. Yet understanding the conditions under which and processes by which good scholarship becomes usable and used knowledge remains a poorly understood element of social–ecological work (Mitchell et al. 2006). Indeed, the current popularity of Sustainability Science reflects, at least in part, an effort to improve the ways social–ecological scholarship is produced and presented to make it more usable and thereby overcome existing political disinterest and resistance that fail to lead to usable knowledge actually being used.

In the short term and at an initial level, scholars can increase the contribution they make to policy by self-consciously attempting to understand, and conduct their research in ways that reflect and respond to, the political and policy opportunities and constraints that often are the cause of scholarly irrelevance. Research often fails to be "salient," in the sense of being relevant to current policy decisions – it comes in before the policy recommendations being offered have any chance of success or after the policy "window of opportunity" has closed (Kingdon 2003; Mitchell et al. 2006). Equally important, scholars often confuse what "should be" the constraints and opportunities with what are those constraints and opportunities. In this vein of "small changes," it certainly also makes sense for scholars to carefully develop "summaries for policymakers," to provide policy briefings to those working on the issue, and to entertain the wide range of other opportunities to communicate with and provide inputs to policymakers and decision-makers. Dual conclusions, aimed at academic researchers and policymakers, are another an imaginative technique (Miles et al. 2002).

Conclusion

The ability for scholars to have a larger and more long-lasting influence with policymakers and stakeholders requires a deeper change in how research is conducted and how scholars are being trained. Notions of "co-production" of knowledge and of "adaptive management" involve ongoing interactions among scholars (both natural and social scientists), policymakers, diverse stakeholders (e.g., Indigenous and local communities) and resource managers

(Jasanoff 2004). In this model, the sequestered generation of knowledge by scholars that is published and handed off to policymakers and others in policy briefings is replaced by efforts to build social institutions that involve relatively frequent interactions over several years in which trust and understanding can develop in ways that are designed to avoid political pressures influencing scientific findings while, at the same time, ensuring that political constraints are recognized as creating important boundaries within which policy recommendations must fall (even if, over the longer term, those boundaries themselves may be subject to change). Such co-production institutions and bridging organizations allow policymakers and stakeholders to realize the value of, and better understand natural and social science insights; provide managers with better insights into novel techniques for addressing their day-to-day problems; and help scholars have a better sense of existing policy constraints and opportunities and why they exist.

These approaches are likely to be more challenging, more time-consuming and slower to "bear fruit" than more traditional strategies of publishing scholarship and hoping it has influence. But they offer the promise of allowing scholars to have significantly more influence than they would otherwise. Such strategies also require scholars to think carefully about how they maintain their scientific impartiality and credibility while improving their policy-relevance, what Stephen Schneider has called the "double ethical bind" of being politically effective while being scientifically accurate and honest (Russill 2010).

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