6

Community-Driven Research in the Anthropocene

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6.1. INTRODUCTION

The Anthropocene, as outlined in the introduction to this volume, is defined by the unprecedented global impact human society has made, and will continue to make, on the Earth system. Never before have human actions directly and indirectly impacted the lives and livelihood of ecosystems and people who were far away and yet to be born.

Our ways of doing and applying science grew up before the Anthropocene and are still adapting to this new reality. Science has already undergone two paradigm shifts in the Anthropocene: a shift away from determinism driven by the insights of quantum mechanics and chaos theory and a shift from reductionism toward systems thinking. Geoscience played a major role in both of these shifts. It will also play a major role in a third shift, as we adapt scientific methods and ideas to the challenge of doing science in an increasingly interconnected world and recognize humans as part of the Earth system.

The gap between science and society will motivate this next change. You can see evidence of this gap throughout the geosciences, in the growing socioeconomic impact of natural disasters, the politicized debates about human-induced climate change, and the difficulty in recognizing and planning for diminishing supplies of fossil fuels. It is also visible across the sciences, in low levels of public understanding of science [*National Science Board (NSB)*, 2012], students' disinterest and poor-performance in science and engineering [*NSB*, 2012], and the conflict between science and other ways of knowing, as epitomized by the longstanding controversy in the United States over teaching evolution in public schools [e.g., *Berkman and Plutzer*, 2011]. The low rates of minority participation in science [*National Science Foundation (NSF)*, 2013] in the United States suggest this science–society gap is biggest for communities that have been, and continue to be, underrepresented in science.

In the Anthropocene, the gulf between scientific understanding and civic decision-making simultaneously increases the likelihood of disaster, our vulnerability to natural hazards, and the inequity of their impact. Hurricane Katrina provides a vivid illustration. Scientists long warned about the combination of fragile physical environment and declining socioeconomic infrastructure [*Travis*, 2005; *Comfort*, 2006] that exacerbated New Orleans' risk. Nonetheless, decision-making designed to minimize the impact of frequent small events increased the vulnerability to less frequent, stronger events—a common and well-documented pattern [*Kates et al.*, 2006]. For example, landfill development of the wetlands reduced the occurrence of seasonal flooding and also eliminated a natural buffer from strong winds and storm surges [*Farber*, 1987]. Similarly, the levees were only designed to withstand a "standard project hurricane," (about a Category 3) but could be overtopped by stronger hurricanes [*Sills et al.*, 2008]. Meanwhile, anthropogenic climate change increased both the likelihood of a stronger hurricane and the strength of the associated storm surge [*McInnes et al.*, 2003]. Finally, the strong racial and class differences in the impact of the storm [*Elliott and Pias*, 2006] raises difficult questions about inequitable application of scientific research and underscores the urgency of applying science for *all* of society.

Hurricane Katrina also illustrates a fundamental point: disasters result from the combination of physical events—environmental phenomena such as drought or

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earthquakes—and the social, economic, political, and cultural environments that structure how people live and make them more or less vulnerable to those events [*Wisner*, 2004]. Anticipating, mitigating, and recovering from disasters, therefore, requires the integration of multiple kinds of scientific knowledge into the broader social context used to support decisions [*Alexander*, 1997]. In other words, living in the Anthropocene requires we bring science and society closer together.

Our continuing descent into the Anthropocene argues for a new approach. The large difference between the scientific consensus and public opinion about anthropogenic climate change—97 percent publishing climate scientists agree that humans' activities are contributing to a changing climate [*Anderegg*, 2010] versus only 40 percent of Americans [*Leiserowitz*, 2011]—points to a basic communication gap. The polarized nature of belief in climate change suggests that scientific evidence alone is not sufficient to affect change or impact behavior [*Moser and Dilling*, 2006] and challenges us to better integrate scientific knowledge into cultural, ethical, and aesthetic frameworks. Indeed, the notion that political opinions can influence belief in empirical phenomena is frustrating to many scientists and highlights some of the challenges of expecting scientific findings to influence actions and policy.

6.2. MIND THE GAP

Because this book is aimed at scientists and science educators, this chapter focuses on what scientists and science educators can do to bridge the science–society gap. To do this, the chapter begins by exploring how scientist and science educators contribute to the gap. This is not meant to blame scientists, paint them all with a broad brush, or excuse the unhelpful approaches of some non-scientists; instead it is meant to identify things scientists and science-educators could do differently that would have a positive impact.

The cultural norms, or set of expectations and rules for behavior and interaction, associated with science contribute to the gap between scientists and non-scientists. For example, the competitive norm in science shows up in introductory science classes and the focus on "weeding out" students; this in turn contributes to college students' decision to leave or avoid science majors [*Tobias and Fehrs*, 1991; *Seymour and Hewitt*, 1994, *Strenta et al.*, 1994; *Luppino and Sander*, 2012]. A corresponding devaluing of collaborative processes shows up in the tendency to value single-authored publications above multi-authored publications in tenure and promotion [*Macfarlane and Luzzadder-Beach*, 1998], despite the fact that the number of co-authored papers has grown over the last forty years in nearly every field of science [*O'Brien*, 2012], including geosciences [*Engelder*, 2007].

As another example, from personal experience, I have seen the scientific norm of skepticism (i.e., the critical scrutiny of ideas before acceptance) create tension when overused in social contexts that call for support for students or respect for elders. Communalism, or the norm that makes scientific results the common property of the entire scientific community [*Merton*, 1973], can conflict with the notion that some kinds of indigenous knowledge are privileged and only appropriate for a specific time, place, or community [*Thornburgh*, personal communication, 2009].

Even the norm of universalism [*Merton*, 1973] or the belief that anyone can make a contribution to science regardless of race, gender, or ethnicity can interfere with the connection between scientists and non-scientists. Some scientists conflate the intent of science with the practice and assume that biases and preconceptions are not active in the conduct and evaluation of science. Research, not to mention the readily apparent dearth of minorities in many sciences, demonstrates that biases do influence decisions such as hiring and mentoring [*Moss-Racusina et al.*, 2009]. This visible difference between the aspirational norm and the actual practice can undermine the overall credibility of scientists. Insidiously, the presence of the aspirational norm may exacerbate the problem by discouraging people from acknowledging and addressing bias [*Valian*, 1999].

Communication norms also contribute to the science–society gap. At the most basic level, communication to the public is often valued less than communication to other scientists. Excellent public communication may even be penalized: Carl Sagan's denial of membership in the National Academies of Science was partially attributed to his success connecting with general audiences [*Poundstone*, 1999]. More practically, the strategies scientists learn to communicate with each other may not work as well in communicating with the public. Whereas scientists focus on the content of the presentation and their argument, many non-scientists, or scientists operating outside of their own discipline, look to noncontent-related cues (such as style of dress, manner of speech, clarity of graphics) to judge the credibility of a scientific messenger and her or his message [*Olson*, 2007]. Critical questioning, common in scientific discussion, can alienate the general public [*Olson*, 2007]. The careful qualification of uncertainty can be confusing [*Bubela et al.*, 2000] or frustrating to non-scientists seeking actionable information [*Moser and Dilling*, 2006]. Worse yet, uncertainty may be deliberately exaggerated in an effort to influence public policy, as in the case of climate change [*Oreskes*, 2010].

For me, the most disturbing way in which scientists and science-educators contribute to the science– society gap is through the inclination of some of us to put science on top of the hierarchy of ways of knowing about the world. The increasingly specialized and high-tech nature of research, which raises barriers to doing science, may exacerbate this. Even within the sciences there is the oft-joked about hierarchy that places physics at the top and categorizes everything else as "mere stamp-collecting." Although that example is nearly comical, I have known geoscientists who complain about the lack of rigor in the social sciences. Misguided attempts to validate other ways of knowing scientifically, for example by "verifying" traditional ecological knowledge, are also evidence of this perceived hierarchy.

Even well-meaning attempts to place science alongside other ways of knowing may not bridge the science–society gap. Although this idea has been offered to mitigate the conflict between religion and science [*Gould*, 2004], it implies that knowledge can be pulled apart and compartmentalized, an idea that is inherently at odds with many indigenous worldviews. Albert Whitehat, a Lakota Elder, often said, "we didn't have a religion, we had a way of being," to underscore the integration and inseparability of practical, spiritual, ecological, and scientific ideas in Lakota culture. Indeed, many indigenous thinkers argue that traditional ecological knowledge is part of an integrated and complete belief system that has its own standards and practices for discovery and verification [*Deloria*, 1995; *Ford and Martinez*, 2000; *Piertti and Wildcat*, 2002]. Science has also been associated with a worldview that places humans as separate observers of natural systems [*Mayr*, 1977] and this stands in sharp contrast with many indigenous worldviews that places humans as part of the natural systems [*Deloria*, 1992; *Pierotti and Wildcat*, 1997].

All of these norms, attitudes, and practices are aspects and outgrowths of the "loading dock" model of science [*Cash et al.*, 2006]. This model was introduced in the book *Science the Endless Frontier*, which served as the blueprint for the organization and funding of academic and government research in the US after World War II [*Kelves*, 1977, p. 12]. In it, the author asserts, "the centers of basic research are the wellsprings of knowledge and understanding … [and] there will be a flow of new scientific knowledge to those that can apply it to practical problems in government, industry, or elsewhere."

By asserting that research excellence alone is sufficient to produce societal benefit, this model set the stage for the science–society gap we see today. It freed scientists from the responsibility of connecting research to practical problems and allowed decisions about science priorities to be made with minimal input from non-scientists [Sarewitz and Pielke, 2007]. Indeed, some have argued that the input of non-scientists would even be detrimental to the advancement of science because it would constrain free inquiry [e.g., *Polyani*, 1962].

A mild modification of the loading dock is the "science push" model of science–policy interaction, in which scientists are the primary decision makers about which projects to pursue, pursuit of knowledge is the leading criterion for setting research directions, and application to policy comes from scientists mining their findings [*Stokes*, 1977]. Even this modified loading dock does not bridge the gap between science and society. For example, much of the gap between climate science policy and climate research has been attributed to the overuse of the "scientist-push" model [*Dilling and Lemos*, 2011].

A common feature of both scientist-push model and loading-dock model is that they both begin with scientists defining the questions to pursue, as shown in the left-hand side of Figure 6.1. When the public is not included in any part of the resulting process (the left-most path in Fig. 6.1) the isolation of scientists can breed an insular culture with norms and values that diverge from the larger culture. Even if nonscientists are invited into the process later (either to contribute data or to collaborate on the analysis, as shown in Fig. 6.1) scientists remain the intellectual leaders, and this hierarchy can reinforce the tendency to elevate scientific approaches ahead of local knowledge and prioritize scientific goals over societal benefit. All the scientist-driven approaches on the left-side of Figure 6.1 ultimately lead to "push" education and application where scientists mine their results to share the results they think society might be, or should be, interested in.

6.3. CLOSING THE GAP

Closing the gap between science and society does not require entirely abandoning the scientist-driven approach to research. Even if the goal of research is to produce societal benefit, scientist-directed research—even research that is motivated only by curiosity—can lead to unforeseen societal benefits and should therefore stay part of the portfolio of approaches [*Leshner*, 2005]. Even outside of societal benefit, curiosity-driven scientist-led research is important simply for the value many attach to advancing human understanding of the world.

It is also worth pointing out that the simple division based on who asks the question in Figure 6.1 is overly clear-cut. Even in the last half-century while the loading-dock model has been prominent and scientists have taken the lead in asking research questions, decisions about funding research programs have long been influenced by desired societal outcomes [*Sarewitz and Pielke*, 2007].

Nevertheless, understanding and especially responding to the challenges posed by the Anthropocene requires additional approaches to science that move beyond scientists asking the questions. These approaches place more

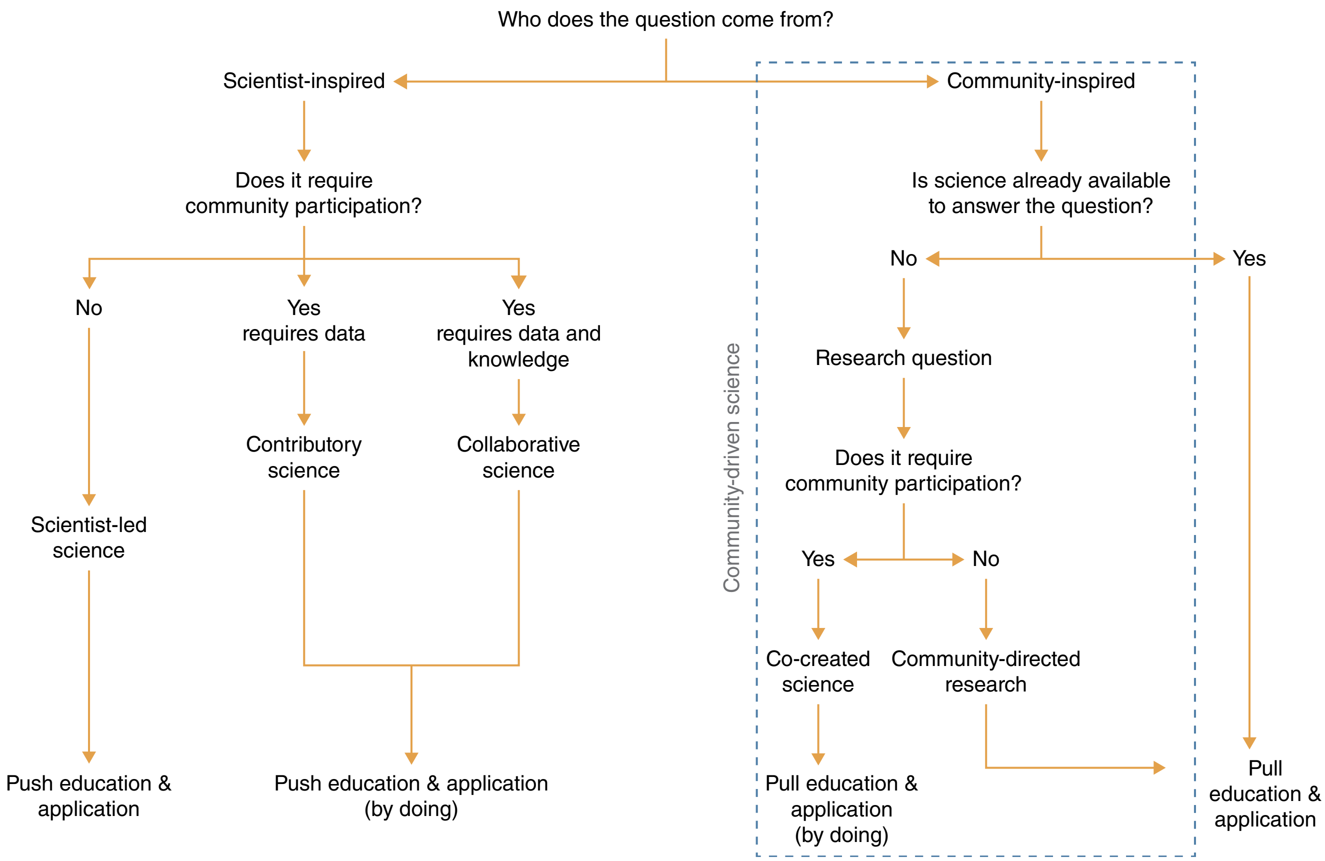

Figure 6.1 A schematic tracing the different paths for connecting science and society. A key distinction is who participates in defining the scientific question, and this distinction flows into whether science results are pushed out from scientists or pulled into community priorities. For color detail, please see color plate section.

emphasis on the application of science, the participation of non-scientists, and the willingness to include science as one of many tools for learning about the world. At their core, all the approaches on the right side of Figure 6.1 share a commitment to inviting non-scientists to guide research priorities and define socially relevant research questions. These additional approaches will supplement the scientist-driven model and, by enhancing public benefit from science, may even increase the willingness to fund all modes of science, including the scientist-led curiosity-driven research on the extreme left side of Figure 6.1.

These new approaches expand the desired outcomes of research to include both scientific insight and usability of results. This move has been variously referred to as Jeffersonian Science [*Holton and Sonnert*, 1999], use-inspired basic research [*Stokes*, 1977], post-normal science [*Funtowicz and Ravetz*, 1993], mode 2 science [*Gibbons et al.*, 1994] and solutions-oriented science [*Crow*, 2010]. Jeffersonian and use-inspired science attempt to find a middle ground between societal and scientific priorities, by suggesting, for example, that specific projects might be situated in an area "of basic scientific ignorance that seems to lie at the heart of a social problem" [*Holton and Sonnert*, 1999]. Solutions-oriented science, mode 2 science, and post-normal science go a step farther and suggest that research can actually be initiated to address societal priorities, particularly in the context of environmental systems and sustainability. As such, these models seem particularly appropriate to the challenges of the Anthropocene.

Post-normal, mode2, and solutions-oriented science rest on a series of insights about how scientific information or insight becomes used by nonscientists. They emphasize the multidisciplinary nature of many of the questions [*Crow*, 2010]; the tight coupling of research, communication, and use [*Sarewitz and Pielke*, 2007]; iterative interaction between users and producers of scientific knowledge [*Dilling and Lemos*, 2011]; and the need for individuals or institutions to mediate between scientists and decision makers [*Gibbons et al.*, 1994].

The shared practical feature of all these models is their emphasis on including non-scientists in the process of science, and especially in decisions about which science to pursue. All these approaches, therefore, are community driven and fall on the right hand side of Figure 6.1. In all cases except the right-most path in Figure 6.1, these approaches to science also emphasize close and continual interaction between scientists and non-scientists [*Cash et al.*, 2006; *Sarewitz and Pielke*, 2007; *Dilling and Lemos*, 2011].

In examining the factors that make scientific information likely to be used in decision making, *Gibbons et al.* [1994] found that scientific findings were less likely to be contested when non-scientists were part of the scientific process. Further, interaction with a diverse collection of non-scientists—especially in setting research priorities—is necessary as a way to ensure that science is responsive to the needs of *all* who have a stake in the research outcome [*Kitcher*, 2001] and that new knowledge is not preferentially available to members of certain groups [*Bozeman and Sarewitz*, 2005]. In the words of one colleague from an underrepresented community, "if you aren't at the table, you're on the menu."

There are several related frameworks for community-driven research that span a number of fields: community-based participatory research in public health [*Israel et al.*, 1998], participatory action research in disaster management [*Park*, 1993], community-based natural resource management [*Berkes*, 2004], co-created citizen science [*Bonney et al.*, 2009], and the coproduction mode for science-policy interaction [*Dilling and Lemos*, 2011].

In public health, community-driven approaches have been motivated by the gap between research and application, the lack of research that attends to marginalized communities, and increased sensitivity to working across cultures [*Israel et al.*, 1998]. The advantages of community-driven approaches are well documented and include: better use of research results, refined research questions, enhanced research and management skills for scientists and non-scientists who participate, new employment opportunities for community members, new funding opportunities for researchers, strengthened social networks in the community, and improved relations between research institutions and their partnering communities [*Israel et al.*, 1998].

Conservation practices, especially in emerging economies, moved toward community-based resource management as a reaction to the failures of exclusionary conservation, where natural resources were thought to be best protected by isolation from humans [*Berkes*, 2004]. They have also been connected to a move toward systems-thinking in ecology [*Berkes*, 2004]. The shift to participatory conservation is linked to a better appreciation of the specific strategies indigenous people use to live sustainably [*Fabricus*, 2004] and builds on traditional ecological knowledge that includes people as active parts of the natural world [*Pierotti and Wildcat*, 2000]. Participatory approaches are shown to enhance a community's adaptive capacity or resilience [*Armitage*, 2005].

As in public health, community-driven approaches to disaster risk management were motivated by concerns about equitable benefit from disaster research especially across class and ethnicity [*Galliard et al.*, 2007]; frustration over the slow implementation of new strategies relative to the pace of research [*Glantz*, 2001]; the ever-increasing impact of disasters [*Wisner*, 2004]; and a growing recognition that social systems play as much of a role in disaster as physical systems [*Mercer et al.*, 2008]. In the context of climate change, community-driven approaches have also been motivated by a desire to ensure that poorer communities are not burdened by having the risks caused by climate change shift in their direction [*Yamin et al.*, 2005].

Citizen-science (which is being renamed as Public Participation in Scientific Research (PPSR) because the word *citizen* has become polarized by the ongoing US debate about immigration) also engages non-scientists in scientific research. Not all PPSR approaches are community driven—in contributory and collaborative models, the public is engaged in data collection or analysis but the research goals are defined by scientists (see Fig. 6.1). Co-created PPSR projects, however, involve communities in every stage of the scientific process, especially defining a scientific question, as on the right side of Figure 6.1. As in contributory and collaborative PPSR projects, nonscientists who participate gain scientific knowledge and become more comfortable with science [*Bonney et al.*, 2009], but co-created projects also enhance participants' social capital and economic opportunity and enhance the community's overall technical capacity [*Ballard and Huntsinger*, 2006; *Shirk et al.*, 2012]. In co-created projects, scientists have access to data that would otherwise go unnoticed and uncollected and learn from local insight and community knowledge. An example of a co-created PPSR project is the work of tribal college students on the White-Earth Indian Reservation to include remote sensing data in the process used to allocate permits for wild rice harvesting discussed later in this chapter [*Bennett*, personal communication, 2013].

6.4. COMMON ELEMENTS OF COMMUNITY-DRIVEN SCIENCE

Regardless of the field, community-driven science projects share a number of common elements and premises:

6.4.1. Begin with a Community-Question

Collaborative definition of a research question is the critical first step in all community-driven projects (see Fig. 6.1). This is often an exploratory and iterative process in which scientists and community members work together to identify the overlaps of community priorities and scientific capabilities. Techniques such as concept mapping, facilitated dialogues, and town-hall meetings can help refine the problem.

As the problems are defined, they may be answerable with available scientific knowledge. This is the rightmost path in Figure 6.1, and it encompasses participatory approaches to education [e.g., *Friere*, 2000]. Community-driven research, however, requires community questions that push at the boundaries of what is known scientifically. Some of these questions might be answered by scientists working in isolation from communities (community-directed science in Fig. 6.1), but many of these questions will require community participation to access local knowledge and theory based on the lived experience of the people involved. This is the right-most and most participatory path under community-driven science, co-created science.

6.4.2. Embrace Multiple Priorities

Community-driven participatory research is built on the idea of mutual benefit to all parties, including communities [*Israal et al.*, 1998]. Because community goals go beyond simply contributing to scientific knowledge, participatory research must address a host of goals, including addressing or managing specific environmental challenges [*Hunnington*, 2000; *Probst et al.*, 2003], enhancing economic growth and opportunity, increasing community-members technical skills [*Viswananathan et al.*, 2004], informing and supporting community-led advocacy [*Park*, 1993], and enhancing social ties in the community [*Heany and Israel*, 2002]. For example, one successful strategy that has been used to enhance the diversity of participants in citizen science programs is to attach the citizen-science program to existing programs whose primary goals are youth empowerment or community clean-up [*Porticella et al.*, 2013]. Similarly, the White Earth Nation's investigation of wild rice's future grew out of wild rice's central importance to the cultural education of tribal members, its contribution to family-level food and economic security, the opportunities wild rice provides for tribal economic growth from wild rice export, and the contribution wild rice can make to healthy diets [*Bennett*, personal communication, 2013].

6.4.3. Value Community Knowledge

Successful participatory projects seek expertise from all participants and agree to processes and procedures that validate multiple kinds of expertise [*Israel et al.*, 1998]. Many successful projects value traditional and local knowledge, historical accounts, and participant observations in addition to scientific data [*Huntington*, 2000]. It is worth emphasizing that community knowledge is not limited to indigenous populations [*Huntington*, 2000]. For example, migrant and immigrant harvesters of non-timber forest products in the US Northwest [*Ballard and Huntsinger*, 2006] and people who fish for a living in the Louisiana Bayou [*Button and Peterson*, 2009] have been part of participatory science projects.

It is also important to acknowledge that community knowledge need not be confined to the realm of geosciences. Indeed, part of the point of community-based science is situating the science in a complete context that includes political, social, and ethical considerations. For example, examining the social conditions associated with heat wave mortality led to the realization that rich social networks and strong family connections offer protection from heat [*Harlan et al.*, 2006].

If community knowledge is included, it is important that all participants need to agree on what constitutes data and how those data will be collected, validated, and shared within and even beyond the project [*Huntington*, 2000]. Special care needs to be given to knowledge that is sacred or culturally sensitive. Many communities have guidelines that define the terms and conditions of their participation in research, and these should be part of the discussion between scientists and community. For communities that do not have these guidelines, the creation of such guidelines should be a part of the overall project design [*Minkler and Wallerstein*, 2010].

6.4.4. Iterate

Although all community-driven projects begin with a shared or even community-posed question, participatory or co-created projects engage scientists and non-scientists in all subsequent stages of research including collecting data, analyzing data, sharing results in scientific and non-scientific forums, and applying results. This may encompass extensive training and even employment opportunities [*Fazey et al.*, 2010], and it helps ensure co-ownership of the project and the application of results [*Israel et al.*, 1998]. It also contributes to better research outcomes [*Bang et al.*, 2007].

Successful participatory projects build processes and procedures (such as regular community meetings, advisory boards, frequent informal interaction between researchers and community members, community risk and asset mapping, focus groups) to plan for and encourage interaction between scientists and communities [*Israel et al.*, 1998; *Minkler and Wallerstein*, 2010]. Institutions and actors that "own" the task of creating the conditions and mechanisms for this are essential [*Dilling and Lemos*, 2010].

The most successful projects extend participatory approaches to the dissemination of results not only in the form of scientific publications but in ways that are designed to be relevant to community priorities and allow new knowledge to be easily applied [*Eden*, 2006] for all partners, in appropriate language and venues, and with ownership acknowledged [*Israel et al.*, 1998]. As with all tasks, dissemination of findings should be the shared responsibility of all project participants. In particular, community participation in scientific presentations has a positive impact on the overall relationship between the scientists and the community [*Button and Peterson*, 2009].

6.4.5. Leverage Diversity

Successful participatory approaches ensure equitable participation for all parts of the community and prevent the science process from enhancing or exacerbating social inequity [*Israel et al.*, 1988]. Strategies for including the whole community include broad stakeholder meetings, focused meetings with members of otherwise marginalized groups, and private conversations in neutral settings [*Peterson and Button*, 2009]. For example, some organizations routinely hold women-only meetings in parts of the world where women are discouraged from speaking up in the presence of men [*Guibert*, personal communication, 2009]. Another strategy involves actively helping community members gain political access and visibility. For example, a project in the Solomon Islands invited project participants who did not have leadership positions to take the lead in briefing government officials about the research [*Frazey et al.*, 2000].

The most successful projects also leverage diverse skills from participating scientists. Many community challenges do not map neatly to a single scientific discipline, and so the most successful teams will include expertise from multiple disciplines [*Crow*, 2010]. Participatory approaches require careful trust building between scientists and community members [*Peterson and Button*, 2009], and this opens the door to valuing and rewarding new kinds of skills in the scientific community. For example, scientists who come from diverse or underserved communities may be able to provide insight into the challenges communities face and can help other scientists learn about unfamiliar customs and practices.

6.4.6. Learn Together

If everyone, scientist or non-scientist, is a valued partner with knowledge to contribute, than it stands to reason that everyone must also have something to learn. Some of this learning is preparatory. Because participatory approaches are new to many scientists, formal training may be beneficial [*Button and Peterson*, 2009]. Cultural orientation can help scientists understand history, learn new approaches, and avoid mistakes. More generally, cultural competence [*Lynch and Hanson*, 2004] and cultural humility [*Tervalon and Murray-Garcia*, 1998] can be learned and can enhance the ability to interact effectively with people. The fastest and most critical learning, however, occurs when scientists are supported with mentoring and given time and resources to engage in reflection and analysis in the course of their participatory work with communities [*Button and Peterson*, 2009].

Similarly, non-scientists from the community have ample opportunities to learn from their collaboration with scientists. Indeed, one of the advantages of participatory approaches is their emphasis on the kinds of hands-on, authentic investigation that is consistent with recommendations for both formal [*Brown and Cocking*, 2000] and informal education [*Bell et al.*, 2009]. In the concept of the Anthropocene, where many civic decisions need to be made in the context of evolving scientific understanding and in the face of uncertainty, participatory approaches are important because they allow people to better apprehend these issues through firsthand experiences in the processes of science [*Brown and Cocking*, 2000]. The combination of education, training, and employment also provides a way to engage whole families, which is often a key priority for many communities [*Porticella et al.*, 2013].

6.5. A FEW EXAMPLES

6.5.1. Meningitis in the Sahel

At its broadest level, this research was motivated by the impact meningitis has in the Sahel. An epidemic in 1998, for example, resulted in 250,000 cases with an estimated 25,000 deaths and 50,000 people left permanently disabled [*World Health Organization*, 2003]. The research question at the heart of the project-"how are meningitis epidemics impacted by weather and climate?"-came directly from people in the Sahel, who have long known that meningitis is a disease of the dry, dusty season and ends with the onset of the monsoon. In fact, in some regions, meningitis is referred to colloquially as "sand disease."

Although this insight defined the broad outlines of the research, iterative interaction with public health practitioners helped focus the research question. Until recently, the protection provided by the only available vaccine was so limited and short-lived that the only practical strategy for health officials was reactive: wait until an epidemic occurs in a region, then vaccinate in and around that region to prevent the epidemic's further spread. Even with this conservative strategy, demand outpaces available vaccine. The research, then, focused on improving and tailoring weather forecasts so that public health officials can know where changing meteorological conditions will end the epidemics naturally and deploy their limited vaccines to other regions experiencing epidemics.

There are several points where this project illustrates the characteristics of community-driven research. Although the general project was generated in response to community input and priorities from people throughout the Sahel, the core participating community was the community of public health practitioners who work in the Sahel. We interacted with local as well as international public health officials in line with the emphasis on engaging across the community. To develop an economic, pragmatic, and culturally appropriate solution, the project included epidemiologists, meteorologists, anthropologists, and economists. Data collection and analysis were shared efforts—with public health practitioners bringing epidemiological data and local knowledge and meteorologists contributing environmental data. The analysis and publications were prepared iteratively, through face-to-face meetings and e-mail. Usability of the final decision–relevant product was refined through our participation in weekly phone calls hosted to make actual decisions about vaccine deployment. The project included lots of opportunities for co-learning including frequent trips to the Sahel for the international research team, project-related graduate school opportunities for partners in Africa, and frequent co-presentation at both geophysical and public-health oriented meetings. Finally, an international organization, meningitis and environmental risk information technology (MERIT) owned the overarching goal of fostering regular interaction between public health and geoscience communities and provided the framework for the interactions in this project. In terms of the different strategies for community-driven science shown in Figure 6.1, this project traced the path from a question asked by the community, to education and application that is "pull" rather than push driven; it is the co-created science or leftmost path of the community-driven paths.

6.5.2. Land Loss in the Louisiana Bayou

Southern Louisiana is undergoing rapid land loss [*Britsch and Dunbar*, 1993]. Natural geologic-scale subsidence is no longer offset by deposition from an active river outlet, and logging of cypress, dredging of canals to support oil exploration, the introduction of non-native species that consume local vegetation, and rising sea-levels associated with climate-change all contribute to the enhanced rate of land loss [*Day et al.*, 2000].

In 2012, to learn and practice participatory approaches to science, two undergraduate interns spent the summer in Southern Louisiana to talk with local communities about the area and its challenges and opportunities. One of the deliverables the students and community agreed to create together was an iPhone app, called Vanishing Points™ that would allow community members to locate culturally important places, collect stories and images of those places, link to projections about the places' future, and finally link to organizations or community resources that are actively working on land-loss issues.

Students working at the Southern Louisiana Wetlands Discovery Center are collecting community locations and associated stories, the National Center for Atmospheric Research's (NCAR) education and outreach group is designing the overall app, and scientists are contributing projections for the places' futures. In terms of the participatory pathways in Figure 6.1, this project is community-driven, with a co-defined problem that aligns scientific questions with the local priorities of educational opportunity, community advocacy, and community planning. The high school–student collection of stories traces the path of community-driven education (the rightmost path in Fig 6.1) and the scientists producing future projections are tracing the middle path of community-directed research in Figure 6.1.

Student participation, especially for the summer interns, made co-learning an organizing premise of this project. The two science interns had extensive mentoring on participatory methods before and during the summer, opportunities for reflection and analysis through blogs and structured conversations, and they were paired with a slightly older community member who could provide an introduction to the community.

6.5.3. Wild Rice and White Earth

Manoomin or wild rice is of tremendous cultural and economic importance to the Anishinaabe people of the Great Lakes region, including those who are part of the White Earth Nation. In recent years, many ricing families on White Earth and the White Earth Natural Resources Department have reported decreased rice production as a result of diminished water availability, fluctuating water levels on the rice beds, and the encroachment of invasive species [*Bennett*, personal communication, 2013]. In the future, continued biome shifts related to climate change will also impact wild rice.

White Earth Tribal and Community College is leading a comprehensive approach that exemplifies the co-creation pathway in Figure 6.1. The goals include developing strategies for managing wild rice and planning for climate change while growing tribal capacity to lead and apply scientific research. They are inviting scientists to help define and clarify the research questions, identify and access relevant data, and improve monitoring, all with the goal of increasing the use of research and data in decision making. Consistent with the college's mandate to serve the community in an open and transparent way, they are reaching into the broad tribal community to engage students and elders in the project. They are integrating many kinds of data, including local knowledge, and developing strategies for data collection, validation, and management that respect local traditions and value local knowledge. Because the college is closely connected to tribal leadership, there is a regular and structured way for the community to contribute to project management and be involved in all stages of the research [*Pandya*, 2012].

White Earth is just one of many indigenous communities that have been observing, experiencing, mitigating, and adapting to climate change. Recognizing this, nearly 50 authors have came together to create a special issue edition for the journal *Climatic Change*, "Climate Change and Indigenous Peoples in the United States: Impacts, Experiences and Actions." The appendix to this chapter discusses this special issue. The special issue as a whole reiterates the importance of viewing people's experiences of the Anthropocene in a larger social and historical context and catalogues the positive outcomes that can come from granting traditional ecological knowledges and local tribal observations the same respect as more conventionally-practiced scientific methods.

6.6. CONCLUSION

To address the challenges of the Anthropocene, humans need to integrate scientific knowledge into their ways of thinking about the world and making decisions. An effective way to do that is to add participatory approaches to the portfolio of scientific methods. The most engaging of these approaches is community-driven science: developing and answering questions that are driven by the needs and priorities of specific, local, diverse nonscientific communities. Community-driven science includes both practical strategies and a shift toward a more inclusive worldview that places science alongside, rather than above, other ways of knowing. In short, as scientists and educators, we need to do science *with* people, not *for* them or *at* them.

These ideas are not new; they have a long history in public health, disaster management, and citizen science, and there are models emerging in the geosciences. It is worth offering a few suggestions to the scientific community, borrowed from the long experience in public health [*Israel et al.*, 2001] to facilitate these kinds of participatory approaches.

Funding: participatory methods depend on building relationships between communities and researchers, and this requires more time than is available in a typical grant application—exploratory or planning grants aimed at fostering these relationships would be helpful. For communities to participate in research as equals, it would be helpful to allocate shared fiduciary responsibility for the work, and so create mechanisms that allow scientific funding to flow jointly to community organizations and researchers. Finally, participatory approaches may require a commitment to long-term projects and to supporting infrastructure, both of which may extend beyond the typical three- to four-year lifetimes of many grants.

Review process: The model of peer review is well-suited to judging the scientific merit of a proposed project, but it is difficult to understand how community-driven questions can be adequately scrutinized without the participation of community members and experts in participatory methods. It would be beneficial, therefore, to include non-scientists in the review of participatory proposals.

Education: Although co-learning is an important part of the participatory process, there should be opportunities to learn before engaging in a project. For community members, scientific, technical, and management skills in advance can help them position themselves as equals when working with researchers. Similarly, advance exposure to participatory methods and cross-cultural communication can help scientists be more effective in developing projects with communities. Educational opportunities for members of historically underserved or underrepresented communities contribute to both goals; they can enlarge the pool of researchers interested in addressing community issues and augment the capacity of the communities they come from.

Tenure and promotion: One barrier to participatory methods is the perceived and/or real career risks for researchers. We need to develop standards for evaluating participatory research, ways for journals to include participatory research results, and incentives that recognize and reward contributions to community goals.

6.7. EPILOGUE

It is easy to see the Anthropocene in terms of unprecedented, largely destructive, and abstract human impacts on the natural system. A series of artworks by Chris Jordan explored ways of making this impact visceral: expansive panoramas that look like natural systems from afar but, as you zoom in, reveal themselves to be built from lots of little pieces of human garbage. A bamboo forest, for example, turns out to be stacks and stacks of the 1.4 million paper bags used every hour in supermarkets in the United States.

Jordan's art also explores something more optimistic. A giant mandala titled "E Pluribus Unum" resolves, on closer inspection, into the names of one million organizations devoted to peace, environmental stewardship, social justice, and the preservation of diverse and indigenous culture. Like "E Pluribus Unum" and the indigenous view that makes humans part of nature, the scientific notion of the Anthropocene offers a way to see all humans as partners in building a sustainable future. Participatory community-driven science offers a strategy to engage them.

APPENDIX

Climate Change and Indigenous Peoples in the United States: Impacts, Experiences and Actions: Highlights from a Special Issue of *Climatic Change*

Julie Koppel Maldonado, Benedict Colombi, Rajul Pandya, Kathy Lynn, and Dan Wildcat

INTRODUCTION

Indigenous ecological knowledge systems present a context for understanding ecological change and adaptive strategies for coping with such change that could provide crucial insight for indigenous communities and all people around the world [*Hardison and Williams*]. However, as the impacts of climate and other human-induced changes they are experiencing everyday become more rapid and severe, this significant knowledge among indigenous peoples is at risk of being lost. The issues currently experienced by indigenous communities in the United States as a result of climate change include: loss of traditional knowledge; forests and ecosystems; food security and traditional foods; water; Arctic sea ice loss; permafrost thaw; and relocation.

Recognizing this, those involved with the tribal chapter of the Draft Third National Climate Assessment called for a careful and respectful summary of indigenous observations, experiences, and adaptive strategies to climate change by indigenous peoples around the United States. Nearly 50 authors representing tribal communities, academia, government agencies, and nongovernmental organizations came together to create a special issue edition for the journal *Climatic Change*, "Climate Change and Indigenous Peoples in the United States: Impacts, Experiences and Actions."

Indigenous peoples maintain tribally specific, place-based cultures, sustainable livelihoods, and knowledge systems tied to culturally modified, ancestral homelands. Many tribal communities are displaced and relegated to marginal lands without access to basic resources, subject to treaties and reserved rights that designate their territories, and constrained by restrictive reservation boundaries—all of which hinder their ability to migrate or access resources as they once did if resources became scarce [*Lynn et al.*]. As the animal and plant species they interact with for their livelihoods and cultural practices move, they can no longer move with them.

Indigenous peoples continue to confront disparate levels of poverty and vulnerability, as well as political and social marginalization from centuries of oppression resulting from the colonial encounter. Climate change impacts intensify related threats and stressors already increasing within many indigenous communities. Thus, situating contemporary indigenous experiences of human-induced change necessitates a greater understanding of the socio-historical context. For example, the severe impacts experienced from European colonization on the quality and quantity of berries that the Wabanaki people of Maine and Canada rely on for their subsistence, culture, healing, and traditional practices are becoming more intense because of climate and other rapid socioecological changes [*Lynn et al.*]. *Reo and Parker* suggest that the severe impacts on coupled human-natural systems that occurred in New England where European colonization led to drastic social and environmental transformations could provide insight to today's context of rapid change. They depict how integrating colonial history and ecology are useful to help determine current, significant human-environment interactions, and adaptive strategies between tribal nations, policymakers, and the global community.

Tribal communities' vulnerability to climate change and other human-induced impacts are not simple linear problems nor are they solely physical ones; rather, these impacts threaten multigenerational tribal epistemologies and cultural value systems, which shape contemporary indigenous practices and identities. For example, the Pyramid Lake Paiute tribe are faced with significant cultural and environmental risks as the lake they economically and culturally depend on is impacted by a reduction in water from the diversions created by dams and shortages of water from sustained drought and climate change [*Gautum et al.*].

Similarly, migratory salmon in the Pacific Northwest are integral parts of tribal subsistence and cultural and spiritual livelihoods. Salmon-dependent resources are increasingly under threat as a result of climate and human-induced changes to the watershed, and so too are tribal livelihoods and a salmon-based way of life

[*Dittmer*; *Grah and Beaulieu*]. Tribal communities throughout the United States are facing similar water-resource hazards, such as risks to water quality and quantity, as a result of significant human-induced changes, including climate change [*Cozzetto et al*.].

To respectfully and effectively address these issues, tribal nations implement policies encouraging federal and state agencies and western scientists to include traditional ecological knowledge in developing adaptation plans for water resource-related impacts [*Cozzetto et al*.; *Grah and Beaulieu*]. For example, Columbia Basin tribes are engaged in intergovernmental and intertribal cooperation, resulting in the Columbia River Inter-Tribal Fish Commission and other collaborations with federal agencies such as the National Oceanographic and Atmospheric Administration and the National Fish and Wildlife Service. In salmon restoration these partnerships are effective in co-managing hatchery programs and in developing long-range management strategies [*Dittmer*].

These partnerships should be based on a just system of responsibilities [*Whyte*]. Creating a governance framework guided by the principles of justice and human rights establishes equitable support to communities facing severe consequences of climate and other human-induced changes, such as forced displacement [*Maldonado et al*.; *Whyte*]. Such a framework would support communities in places such as Alaska and coastal Louisiana leading their own relocation efforts to decrease the social, cultural, and economic impoverishment risks associated with forced displacement [*Maldonado et al*.].

In establishing greater self-governance mechanisms and partnerships, it is particularly important to pay attention to what is happening at the local level [*Doyle et al*.]. For example, based on local observations of climate-related health and water issues by elders of the Crow Tribe in Montana, the tribe and its tribal college partnered with state academic institutions to examine data from National Oceanic and Atmospheric Administration's (NOAA) local weather station. The data and local observations were brought together to develop mitigation strategies to reduce waterborne microbial health risks [*Doyle et al*.].

Despite the layers of vulnerability confronting indigenous peoples [*Gautum et al*.], they continue to use traditional knowledge systems, local observations and experiences, skills, and agency to actively adapt to climate and other anthropogenic changes. Pairing traditional ecological knowledge with western science can enhance understanding and offer new adaptation strategies. For example, the North Pacific Landscape Conservation Cooperative has collected tribal input to prioritize tribal responses and adaptation to the climate-related changes within their forests and ecosystems [*Voggesser et al*.].

The active collaborations taking place between tribes and academic institutions, as well as governmental agencies and nongovernmental organizations give the Crow tribe and Columbia River Inter-Tribal Fish Commission, for example, a base to demonstrate the value of including traditional ecological knowledge and indigenous science in climate change research and adaptation strategies. More of these multipronged approaches need to be implemented to include and mutually respect both traditional ecological knowledge and western science, bringing together data collection, local observations, experiences, and human-environmental relationships and interactions [*Cochran et al*.]. These approaches must also consider culturally sensitive tribal information and protect tribal traditional ecological knowledge [*Hardison and Williams*].

The collaborative effort between both tribal nations and nontribal representatives to create the special issue and the case studies highlighted in the enclosed articles show that indigenous peoples are shaping actions that address the many challenges they face and emphasize the importance of people coming together in strategic and respectful partnerships. Equitable and meaningful results are achieved when traditional ecological knowledge and local tribal observations are held up with the same respect as western science and when indigenous peoples who are experiencing these impacts guide the research, mitigation, and adaptation plans through what Daniel Wildcat calls indigenous ingenuity or "indigenuity." The case studies provide an inclusive view of how indigenous peoples throughout the United States are observing, experiencing, mitigating, and adapting to climate change, which have relevancy for indigenous peoples and communities facing parallel circumstances worldwide.

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