Research and Networks for Decision Support in the NOAA Sectoral Applications Research Program

Panel on Design Issues for the NOAA Sector Applications Research Program, Helen M. Ingram and Paul C. Stern, Editors, National Research Council

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RESEARCH AND NETWORKS FOR DECISION SUPPORT
IN THE NOAA SECTORAL APPLICATIONS RESEARCH PROGRAM

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Committee on the Human Dimensions of Global Change

Division of Behavioral and Social Sciences and Education

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PANEL ON DESIGN ISSUES FOR THE NOAA SECTORAL APPLICATIONS RESEARCH PROGRAM

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Preface

Moving from science to action is a challenge in many policy areas, and it has been difficult in climate science. For instance, until fairly recently the construction of climate forecasts was largely producer driven, and the scientists who worked on them had little knowledge of what potential users needed. For the most part, those forecasts were not used because the intended decision makers were not aware of the significance of a changing climate for their decision domains. Moreover, the forecasts were perceived as coming from "outside" and therefore carried less trust and legitimacy than information from the decision makers' organizations.

The lack of fit between what decision makers thought would be useful and what climate forecasters were producing, along with the reluctance of decision makers to use even relevant outside information, led to new efforts to engage potential users earlier in the production process for climate forecasts. Potential decision makers and user groups were invited to engage at the point at which climate information began to be developed. Rather than a top-down decision process, scientists and users were engaged in a discourse that was aimed at influencing the orientations and actions of both parties. The Regional Integrated Sciences and Assessment (RISA) program in the National Oceanographic and Atmospheric Administration (NOAA) institutionalized this more collaborative and networked style of developing climate information.

In these pioneering collaborative efforts, the meaning of decision support is evolving in ways supported by this report. The idea of decision support is gravitating from the provision of tools or products to the support of practices. Instead of some specific physical science-driven product, decision support is becoming a process of engaging a network of producers and users. This report endorses the progression of decision support away from translating the products of science into useful forms and disseminating them and toward more inclusive and iterative practices. Decision support as used in this report means creating a two-way process of communication between the producers and users of climate information.

The experience of the RISA program, generally viewed as successful, along with the intellectual movements in management and public administration toward more collaborative and inclusive governance, has resulted in new challenges that this report addresses: How can social and physical science insights be integrated into processes and products that provide needed support to decision makers for areas affected by climate change? How can such collaborative efforts that strongly relate to changed processes rather than outcomes be evaluated?

This National Research Council (NRC) panel, whose membership includes social and physical scientists as well as practitioners, adopted an open and collaborative process of developing its report. At a workshop on November 13, 2006, representatives from a range of different sectors and extension-type networks discussed the kinds of climate information needed and how such information could be produced, shared, and evaluated. The panel met the day after the workshop and again on March 1-2, 2007, to develop this report.

In preparing this report, the panel built on a solid foundation of previous NRC studies that addressed similar issues. *Understanding Risk: Informing Decisions in a Democratic Society* (1996b) helpfully raised matters of process and deliberation as important aspects of making science and analysis useful and accepted. In 1999, *Making Climate Forecasts Matter* called attention to the importance of linking science to users. The preface drew attention to improvement in the ability to forecast climatic variability as "one of the premiere advancements in the atmospheric sciences at the close of the 20th century," yet noted that application of this knowledge was problematic. *Decision Making for the Environment: Social and Behavioral Science Research Priorities* (2005a) provided a number of important insights about when science is used by decision makers. Finally, the panel was aided considerably in its discussion of issues of evaluation by the report *Thinking Strategically: The Appropriate Use of Metrics for the Climate Change Science Program (2005c).*

This report could not have been completed without the aid of the NRC staff. Paul Stern served as study director, and full use was made of his skills in planning, organizing, negotiating consensus, and writing. The members of the Committee on the Human Dimensions of Global Climate Change, under whose auspices the panel was constituted, deserve both credit and thanks.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We thank the following individuals for their review of this report: Nancy Dickson, Center for International Development, John F. Kennedy School of Government, Harvard University; Kirstin Dow, Department of Geography, University of South Carolina; Maria C. Lemos, School of Natural Resources and Environment, University of Michigan; Rita P. Maguire, President's Office, Maguire and Pearce, LLC, Phoenix, AZ; Andrew R. Solow, Marine Policy Center, Woods Hole Oceanographic Institution, Woods Hole, MA; Brent Yarnal, Center for Integrated Regional Assessment, Pennsylvania State University.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Roger E. Kasperson, George Perkins Marsh Institute, Clark University, Worcester, MA and Robert A. Frosch, International Affairs, John F. Kennedy School of Government, Harvard University. Appointed by the National Research Council, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Helen Ingram, *Chair*
Panel on Design Issues for the NOAA
Sectoral Applications Research Program

Contents

Executive Summary

The Sectoral Applications Research Program (SARP) is a new, small program in the National Oceanic and Atmospheric Administration (NOAA). It is devoted to research for making science-based climate information more accessible and useful to decision makers responsible for managing resources likely to be affected by climate variability or change in "sectors" defined by resources (such as water) or decision domains (such as emergency management). SARP's responsibility includes consideration of the social, economic, health, and welfare effects of decisions for specified sectors.

NOAA requested this study to obtain strategic advice on three specific questions:

1. What role(s) should SARP play in improving understanding of the human dimensions of climate variability and change in ways that can improve decisions in key sectors?
2. What are the best approaches for organizing research support to meet program goals (e.g., grants, centers of excellence, series of workshops, etc)?
3. How should NOAA monitor and evaluate the effectiveness of the program?

These questions reflect the role of SARP as part of the "decision support" efforts of NOAA and the U.S. Climate Change Science Program (CCSP). This term is given no precise definition in CCSP documents, but two quite distinct implicit definitions are in use in the program. In one, it means translating the products of climate science into forms that are useful for decision makers; in the other, it centrally includes establishing communication between climate information producers and users that ensures that the information produced addresses users' decision needs and gets to them in useful ways. Evidence from multiple fields demonstrates that potentially valuable scientific information often goes unused, largely because of inadequate prior communication between the producers and users of the information. Considering this evidence, we recommend that SARP and NOAA adopt a broad definition of "decision support" that emphasizes communication.

The first question above states a mission goal far too ambitious for any program as small as SARP ($2.6 million in fiscal 2006). That mission is too large even with the combined budgets of SARP and two related programs, Regional Integrated Sciences and Assessment (RISA) and Transition of Research to Applications for Climate Services (TRACS) (about $7 million in fiscal 2006). SARP must therefore focus its efforts to make the best use of the limited resources available.

PROGRAM RECOMMENDATIONS

With SARP's very limited current and likely future budgets, we recommend that the program emphasize a few critical activities over the next several years. We recommend use-inspired science, workshops, and pilot programs, all directed to the basic need to make climate-related information more useful and to get it used appropriately.

> **We recommend that the Sectoral Applications Research Program support research to identify and foster the innovations needed to make information about climate variability and change more usable in specific sectors, including research on the processes that influence success or failure in the creation of knowledge-action networks for making climate information useful for decision making. This should be the major focus of the Sectoral Applications Research Program support over the next 3-5 years. Support should go to research that offers the largest potential benefit to decision making across sectors.**

> **We recommend that the Sectoral Applications Research Program support several workshops each year for the next 3 years to identify, catalyze, and assess the potential of knowledge-action networks in sectors, defined by resource areas (e.g., water, coastal resources) or decision-making domains (e.g., emergency response, insurance,**

planning, and zoning). The Sectoral Applications Research Program should also support selected follow-up activities.

We recommend that the Sectoral Applications Research Program, beginning no earlier than 1 year after funding the first workshop, support one or more pilot projects to create or enhance a knowledge-action network for supporting climate-related decisions in a sector (defined by resource or decision domain).

FINDINGS AND CONCLUSIONS

Our recommendations for a limited focus for SARP are based on several findings and conclusions about the field, as well as the program's limited budget.

- The recently developed ability to offer climate forecasts on a seasonal timescale and beyond is unprecedented in human history. Nevertheless, this ability is limited, and the degree of forecasting skill in relation to practical decisions remains generally unknown.
- Integrating such fundamentally new kinds of information into real-world decisions requires social innovations that are not accomplished easily. Those who might benefit must modify their usual information-gathering and decision-making routines. Climate information producers will also need to make changes in order to meet users' information needs. Increasing the skill of climate forecasts does not necessarily confer credibility with potential users. As important as the scientific validity of information is to the quality of the decisions based on it, other attributes of the information will be more influential in determining whether it is used.
- Achieving the needed innovations will usually require establishing new lines of communication between the producers and users of climate science information, sometimes called knowledge-action networks, to ensure that scientific outputs meet users' needs and that users can inquire about uncertainties and unknowns.
- Achieving SARP's objective of making climate science useful will require investments in improving several kinds of social-scientific and practical knowledge.

RECOMMENDED ACTIVITIES AND PRIORITIES

We recommend specific research, workshop, and pilot project activities as ways to carry out the recommended SARP program. We also recommend priorities for choosing the activities to support.

Research

Use-inspired science is needed to understand how and why decision makers who could benefit from climate-related information use or do not use such information. It is important to understand: (1) factors internal to the decision making of individuals, groups, or organizations; (2) the influences of external forces and organizations on decision makers; (3) the ways climate information is used and transformed within multi-factor decision systems; and (4) how networks that link the producers and consumers of climate information develop, evolve, and function to make climate information more useful to decision makers. Such research would include studies of possible strategies for overcoming barriers to innovation.

This research should include

- studies to understand the conditions under which existing networks incorporate sources of knowledge about climate change and variability;
- studies to understand how individuals or relatively unorganized constituencies can develop ways to become informed about how climate variability and change may affect them; and
- studies to improve understanding of the roles that information from climate science can play in network construction and continuity.

SARP's limited resources dictate this narrow research focus. We urge other sources in NOAA and other agencies that are part of the CCSP to support other important lines of research that we identify, relevant to the program's decision support goals.

Workshops

The recommended workshops would bring together individuals, organizations, or existing networks of potential climate science users to: (1) identify the climate-related issues important to a sector or domain, (2) characterize the kinds of climate-related information that would help inform decisions in the sector or domain, (3) determine whether existing climate science products can provide that information, and (4) identify climate or social science research needed to produce needed information that is not yet available. To accomplish these objectives, we believe that SARP would need to commit up to half of its budget during the first year, and a declining fraction thereafter, to workshops in order to identify sectors and domains that may benefit from targeted efforts.

Pilot Projects

The recommended pilot project(s) would create or enhance knowledge-action network(s) for supporting decisions in a climate-affected sector (defined by a resource or decision domain). SARP should not support long-term maintenance of networks created by pilot projects, and it may not even be able to offer continued support for the delivery of scientific information through them. Existing and emerging networks would need to seek such continuing support from other sources.

To use resources efficiently, we believe SARP would need to employ decision criteria that favor proposals from researchers who have commitments for partnership from some relevant organizations or who make a convincing argument that their start-up efforts are likely to become self-supporting, perhaps through the availability of matching funds.

Pilot projects should represent a significant fraction of the overall SARP budget beginning in year two or three, with funds coming from reallocations of support from the research program and workshops. The number of pilot projects undertaken should depend on what is learned from the workshops about the number of networks that are ripe for successful pilot projects and on the SARP budget. We envision one pilot project beginning in year two. Given that an effective pilot project might cost up to $500,000 per year for 3 years, we do not expect that SARP will be able to afford to initially support more than one. Possibly two other projects could begin between year three and year five, when the program should be reassessed in light of what we hope will be a more adequate budget for the kinds of research recommended here.

Setting Priorities

Eight principles provide the rationale for our setting of priorities and can be used to select from among what is likely to be a surfeit of worthwhile activities in the priority areas:

1. link to NOAA mission and SARP objectives
2. promotion of social innovation in using climate science
3. high-impact decisions
4. leveraging investments through partnerships
5. fertile ground
6. increasing resilience and adaptability
7. equity
8. research of interest to social science

EVALUATING SARP

In response to the third question to the panel on evaluating SARP, the committee concludes that a standard "textbook" evaluation is not appropriate for SARP because of the small size of SARP; the expectation that desired outcomes will take a considerable period of sustained effort to achieve; the multiple types and levels of decisions that can be influenced by climate information; the variety of relevant decision makers; and the multiplicity of programmatic approaches to shape decision support systems.

Because standard evaluation approaches are not appropriate for the Sectoral Applications Research Program, we recommend that evaluation questions for the Sectoral Applications Research Program be addressed by a monitoring program.

Such a monitoring approach would aim at recording and analyzing trends in metrics that are appropriate for each type of SARP activity: pilot projects, workshops, and use-inspired research. It would employ multiple metrics, some of them recording processes in SARP and some tapping outputs and outcomes. Monitoring should rely wherever possible on data that can be reliably collected without substantial time and resources. Representatives from target audiences should contribute to decisions regarding the details of data collection and surveys that could be most useful for monitoring SARP performance.

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Introduction: The Sectoral Applications Research Program

Increasing scientific understanding of climate variability and change is improving the ability to anticipate some major environmental events at seasonal and longer time scales. Among those events are intense coastal storms (both tropical and nontropical), extended drought conditions in the interior regions, and changes in sea levels. The improved understanding of climate variability and change makes climate science increasingly relevant to local and state governments, natural resource managers, and other decision makers whose responsibility includes the welfare of human populations and ecological systems.

THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION AND THE SECTORAL APPLICATIONS RESEARCH PROGRAM

The National Oceanic and Atmospheric Administration (NOAA) has initiated several programs designed to make science-based climate information available in more accessible and useful forms to users. A new program, the Sectoral Applications Research Program (SARP), focuses on the needs for climate-related information to inform decisions in particular "sectors," defined by resources (such as coastal or water resources, forests, or agricultural lands) or by decision domains (such as emergency management or urban planning). The sectors of focus in the first phase of the program are coastal and water resource management, which are among the sectors most likely to be affected by climate variability and change.

Decision makers in those sectors should therefore be among the major beneficiaries of accurate and timely climate information and predictions.

As stated in the November 2006 program proposal (Vaughan and Beller-Simms, 2006:1), NOAA established SARP in 2005 to provide a focused pathway to generate new research-based insights and applications for climate information in support of decision making in high-priority, climate-sensitive socioeconomic sectors. Research supported by SARP's three predecessor programs—Climate Variability and Human Health; Environment, Science, and Development (initially, the Research Applications Program); and Human Dimensions of Global Change Research—as well as other ongoing NOAA-sponsored efforts, such as the International Research Institute for Climate and Society (IRI) and the Regional Integrated Sciences and Assessment (RISA) Program, has demonstrated the significant impacts and potential value of climate information. Climate information may be useful "in a number of diverse sectors, regions, and streams of economic activities, including those associated with human health, water resources, agriculture, disaster mitigation and management, and coastal and marine resource management, among others."

As the program proposal also notes, "NOAA's first decade of focused applications research provides insight into the role of climate and climate information in societal decision making; in addition, this experience also offers valuable lessons regarding effective programmatic approaches for building bridges" between climate-related science and decision making. This process of making science decision relevant (see, e.g., National Research Council, 1996b, 1999) has been variously described by scholars in terms of developing knowledge-action systems or networks (e.g., Cash et al., 2003), crossing boundaries between science and policy (e.g., Jasanoff, 1987; Gieryn, 1995), coproduction of science and policy (e.g., Lemos and Morehouse, 2005), and reconciling the supply of climate science with the demand for it (McNie, 2007; Sarewitz and Pielke, 2007). As noted in these sources and discussed in more detail below, decision-relevant climate information comes from both the natural sciences and the social sciences, and "building bridges" is best accomplished through processes that engage both the producers and consumers of information.

A review of social science in NOAA completed in 2003 noted the importance for NOAA's mission of an adequate investment in social science, as well as the absence of such investment (Anderson et al., 2003). The review noted the absence within NOAA of widespread understanding of what social science is and can contribute. It also noted the need for collecting and archiving mission-relevant social science data, investing in social science staffing (including at senior levels of administration), and incorporating social science research objectives in the strategic planning of NOAA line offices. The review recommended an increase in funding of $100 million per year (to NOAA's $3.3 billion budget) to improve the competency and contribution of social science to achieving NOAA's mission objectives; that recommended funding has not yet been forthcoming. The review also emphasized the need for NOAA officials at the assistant administrator level "to better define and understand their constituents and communicate with them" (p. 4).

In developing the new sector-based program, NOAA sought to integrate the most successful attributes of the three programs in which it has its roots; to complement the approaches taken by other programs; and to provide a new programmatic framework for articulating and achieving the connectivity, relevance, and impact related to climate and decision making in key socioeconomic sectors:

- From the Climate Variability and Human Health Program, NOAA gained appreciation for the importance of creating sector-based programs that are crafted in partnership with stakeholders (including decision makers, scientists, and other government entities) with a shared interest in resolving a particular suite of research questions and management challenges.
- From the Environment, Science, and Development Program, NOAA developed an understanding of how to conduct problem-defined and applications-oriented research, training, and outreach in partnership with various scientific, operational, and management agencies.
- From the Human Dimensions of Global Change Research Program, NOAA developed insight about climate's complex socioeconomic impacts and the potential returns from the integration of the social and physical sciences in support of decision making.
- From RISA, NOAA adopted regional, longer term funding.
- From IRI, NOAA adapted an international, applications focus.
- From the recently established Transition of Research to Applications for Climate Services (TRACS) Program, NOAA is using a focus on transition and partnerships with operational entities.

RISA is probably the closest cousin of SARP. Where SARP activities are organized by resource sectors, such as water and coastal management, or decision domains, such as emergency management, RISA activities are organized geographically. Thus, according to its program description, RISA "supports integrated, place-based research across a range of social, natural, and physical science disciplines to expand decision-makers' options in the face of climate change and variability at the regional level."[1] TRACS

[1]From the RISA fiscal 2007 information sheet. Available: http://www.climate.noaa.gov/index.jsp?pg=/opportunities/opp_index.jsp&opp=info_risa.jsp [accessed April 2, 2007].

is also a close relative of SARP. According to its program description, TRACS is intended "to transition experimentally mature climate tools, methods, and processes from research mode into settings where they may be applied in an operational and sustained manner" and "to learn from doing how better to accomplish technology transition processes for public goods applications and improved risk management."[2] All three programs are aimed at getting climate information used by decision makers in the United States (unlike IRI, which has an international focus), and all three are at least partly devoted to research. It is the sectoral focus that makes SARP distinctive and complementary to the other programs. However, the division of labor among these programs may be a less important point than their very small size, both separately and together (see below).

SARP Mission and Goals

The goal of the NOAA Climate Program is to "understand and describe climate variability and change to enhance society's ability to plan and respond."[3] SARP is responsible for pursuing this objective "by developing the knowledge base, decision support tools, capacities, and partnerships in sectors affected by climate in a substantial and increasingly visible way" (Vaughan and Beller-Simms, 2006:2). SARP is designed to catalyze and support interdisciplinary research, outreach, and education activities that enhance the ability of individuals and organizations in key socioeconomic sectors to plan for and respond to climate variability and change.

The "overarching goals" of SARP include:[4]

- the provision of new and/or synthesized science-based knowledge that results in the identification and reduction of vulnerability to climate variability and change in key socioeconomic sectors;
- the enhanced and increasingly sophisticated use of climate information, including forecasts, in decision making; and
- the development of a research and operations agenda that increasingly meets the needs of the nation and NOAA through an understanding by scientists and science managers of stakeholder requirements.

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[2]From the TRACS fiscal 2007 information sheet. Available: http://www.climate.noaa.gov/index.jsp?pg=/opportunities/opp_index.jsp&opp=info_tracs.jsp [accessed April 2, 2007].

[3]From the Climate Program Office statement. Available: http://www.climate.noaa.gov [accessed April 2, 2007].

[4]From the SARP home page. Available: http://www.climate.noaa.gov/cpo_pa/sarp/ [accessed April 2, 2007].

SARP Approach and Structure

As noted above, in contrast to RISA's emphasis on the needs of decision makers defined by geography, SARP's emphasis is on the needs of decision makers in "sectors" defined by the types of resources they manage or the kinds of decisions they make. SARP is premised on the belief, in which we concur, that decision makers defined by resources or decision functions often have common needs for climate-related information that will not be met efficiently by a program that is organized geographically. It is worth noting that "sector," when defined by function, can distinguish several distinct sets of decision makers within a single sector defined by resource. For example, the water resource management sector includes reservoir managers, irrigators, flood control engineers, and a variety of other functionally defined classes of decision makers whose information needs and decision support requirements may be quite different from each other. Thus, the water "sector" is heterogeneous in terms of decision makers and their decision support needs.

The sectoral framework provides a construct for defining the nature, requirements, and capabilities of relatively bounded suites of science users; the kinds of climate-related knowledge they need to support their decisions; the scientific communities to tap into (or stimulate) to address these needs; and the key partners needed to effectively create, disseminate, and apply climate information in a particular sector. The identification of sectors for emphasis in SARP depends on NOAA priorities, program budgets, and input from the federal, research, and decision-making communities. Each sector project currently includes two components: (1) competitively funded research and decision support development and (2) outreach and community building, including the creation of partnerships with sector-specific decision making and technical entities.

Each sector project can be viewed as an organizing system that serves as a platform to integrate many complex socioeconomic issues that are influenced by climate and for developing linkages with specific decision makers and partners. Although all SARP sector projects are alike in using competitive funding and in their focus on decision support resource development and stakeholder outreach, the exact nature of the research activities and partnerships developed varies across projects. Projects in one sector may or may not yield lessons that are transferable across sectors (Vaughn and Beller-Simms, 2006).

The Magnitude of the Program

SARP is a small program that is part of a national effort, the U.S. Climate Change Science Program (CCSP), which supports scientific understanding of climatic variability and change. CCSP justifies its more than $1 billion annual federal budget on the grounds that it provides knowledge, not otherwise available, that supports decisions that improve human well-being and environmental quality. The CCSP Strategic Plan (Climate Change Science Program and Subcommittee on Global Change Research, 2004:3) states: "CCSP's guiding vision: A nation and the global community empowered with the science-based knowledge to manage the risks and opportunities of change in the climate and related environmental systems."

However, CCSP has been criticized for its imbalance between climate science and other activities critical for achieving the program's decision support objectives. In particular, a recent review of the CCSP Strategic Plan by the National Research Council (2004:2) concluded: "[T]he CCSP should accelerate efforts in previously underemphasized program elements, including ecosystems, the water cycle, human dimensions, economics, impacts, adaptation, and mitigation, by rapidly strengthening the science plans and institutional support for these areas." Most of these areas—particularly human dimensions, impacts, and adaptation—are critical to improved decision making in response to climate information. CCSP expenditures for research in these areas are hard to determine precisely, but as of fall 2006, they were estimated to be about $25-30 million per year (National Research Council, 2007b), less than 3 percent of the program total. The amount includes basic research (e.g., on decision making under climate-related uncertainty, sponsored by the National Science Foundation), as well as the more applied activities usually associated with decision support objectives. The total indicates no increase in effort since the 2004 review; in fact, the effort in these underemphasized areas may have declined since that time.

With respect to NOAA, a 2003 review (Anderson et al., 2003:1) concluded "the position of social science within NOAA is weak" in terms of budgets for research, education, and staffing and in terms of the position of these fields in the organization. The review found a lack of understanding of what social science is and what its contributions can be, "leading to an organizational culture that is not conducive to social science research," and an underrepresentation and underutilization of social science in both research and staffing that diminishes NOAA's capacity to meet its mandates and mission (p. 2). The review also noted (p. 4) that "neither Headquarters nor the line offices have functional representation of social science," such as dedicated social scientist positions. It stated that "NOAA could easily justify over the next 5 years an increase of $100 million over the current $3.3 billion budget to improve the competency and contribution of social science to achieving mission objectives" (p. 35).

SARP, with a fiscal 2006 budget of $2.6 million, represents an important part of this underemphasized area of the CCSP. The entire collection of NOAA decision support research activities, including RISA, TRACS, and SARP, with a combined budget of about $7 million in fiscal 2006, represents a sizable proportion of the overall federal investment in research to make climate science useful for decision making. Yet this level of support is very small in comparison with the ambitious objectives of the program and of NOAA's larger climate science mission. We return to this point in the following chapters, because any strategic advice to SARP must take into account the disparity between objectives and available funds.

SCOPE OF THIS STUDY

As SARP was taking shape, NOAA approached the Committee on the Human Dimensions of Global Change of the National Research Council (NRC) with a request for strategic advice on three specific questions:

1. What role(s) should SARP play in improving understanding of the human dimensions of climate variability and change in ways that can improve decisions in key sectors?
2. What are the best approaches for organizing research support to meet program goals (e.g., grants, centers of excellence, series of workshops, etc.)?
3. How should NOAA monitor and evaluate the effectiveness of the program?

The NRC was asked to establish a panel that would identify appropriate ways NOAA could address these questions as it develops SARP, recognizing the need for the program to adapt to changing circumstances. The study was to focus on the two sectors of SARP's initial research—water and coastal resource management—but it is understood that SARP will support research in other sectors in the future. The Panel on Design Issues for the NOAA Sector Applications Research Program was organized to provide expertise in climate science, social sciences, coastal resource management, water resource management, and public policy.

As noted above, the central purpose of SARP is to make climate information useful for decision making. We interpret "climate information" broadly to include information about climate variability and change at various temporal and spatial scales and information necessary to consider the potential effects of such change on things that people value. Thus, it includes information from seasonal climate forecasts, which describe past climate variability and its relationship with major modes of atmospheric variability, such as El Niño-Southern Oscillation (ENSO) and Arctic Oscillation (AO); projections of climate change on longer timescales; and in some cases, paleoclimate descriptions. It also includes information relevant to the possible effects of climate variation and change—both information on physical effects (e.g., on storm intensity and frequency, drought severity) and on socioeconomic phenomena that combine with physical effects (e.g., estimates of future land use conversion, water demand, the condition of emergency response institutions, and citizens' understandings or misunderstandings of climate information). Thus, decision-relevant climate information involves applications of both natural science and social science.

To provide the strategic advice requested by NOAA, we began by developing and convening a SARP Design Workshop, which was held in Washington, D.C., on November 13, 2006. The event included climate scientists, various individuals and representatives of organizations involved with making science useful for decisions (including the RISAs), decision-making users of climate information, and evaluation experts, as well as representatives from NOAA and SARP.

The workshop focused on the purpose, needs, and structural features of SARP, as well as on the information provided by those experienced with other networks and programs that could prove valuable for the design of SARP. We were especially interested in participants' efforts in making scientific findings valuable to users, including decision support activities. Participants were also asked how their programs obtained feedback from their target audiences and how they measured success in reaching their audiences. Box 1-1 shows the questions we asked participants to discuss in the morning session. In the afternoon, workshop participants presented and discussed with us models and approaches for making science useful for decisions. Box 1-2 shows the framing questions we used for that session. The workshop concluded by soliciting participants' ideas on what NOAA and SARP can learn from past experience with decision support and on evaluation issues: What are reasonable expectations for the effects of SARP given its resources and the needs, and what process should be used to evaluate the program?

The workshop identified a set of social-scientific issues that could serve as substantive foci for SARP as well as various modes of delivery of support and criteria for the selection and evaluation of projects. The panel met after the workshop and again in March 2007 to analyze and review the basic design questions and to develop our recommendations. This report presents our analysis of the needs for decision support in SARP and our recommendations regarding the most appropriate design for the program. Our recommendations and other strategic advice represent the consensus judgment of the panel.

The next chapter presents two critical concepts underlying this study: the idea of climate information as innovation and the concept of decision

BOX 1-1
New Opportunities: Questions for Workshop Participants

For Climate Scientists:
Are there any emerging or "breaking" new issues in the research realm that are going to need transfer to be applied on the ground? What does climate science have now to offer to decision makers in the coastal and water sectors that not all of them are using? In what forms and from what sources is this information available?

For Decision Makers:
What would you like to know from climate science to help with your decisions? In what time frame do you need this information? Where would you normally look to find this kind of information?

For All Participants:
Why do decision makers in the sector you know best use, or fail to use, potentially relevant information about climate? What conditions make it more likely that the information will be used?

BOX 1-2
Models for Making Science Useful for Decisions:
Questions for Workshop Participants

What features of the design and operation of well-established programs for making science useful are responsible for their success?

How do the programs solicit research that keeps the programs strong?

How are networks among researchers, information transfer organizations, and users constructed and maintained?

How do the programs get feedback from their clients that they are providing what is wanted?

How do the programs make changes to research and practice when needed?

support. Chapter 3 presents our major conclusions about the need for use-inspired science and communication, the logic undergirding our recommendations regarding the substantive priorities for SARP for the next several years, and the recommendations themselves. Chapter 4 identifies a set of principles that provide the rationale for our setting of priorities and that can be used to select from among what is likely to be a surfeit of worthwhile activities within the priority areas. Chapter 5 deals with the issue of how to evaluate SARP.

2

Climate Forecasts as Innovations and the Concept of Decision Support

To define a clear and viable role for the Sectoral Applications Research Program (SARP), it is necessary to clarify the range of needs implied by the National Oceanic and Atmospheric Administration's (NOAA) climate mission and to place SARP in the context of a division of responsibilities among NOAA's activities. According to its official program description, the SARP objective is "to systematically build an interdisciplinary and expressly applicable knowledge base and mechanism for the creation, dissemination and exchange of climate-related research findings critical for understanding and addressing resource management challenges in vital social and economic sectors (e.g., coastal, water resources, agriculture, health, etc.)."[1] The capacity of NOAA and SARP to meet this objective depends on the adequacy of its science, including the full representation and utilization of social science (Anderson et al., 2003).[2]

In this chapter we first make explicit an important aspect of climate information that often goes unaddressed: that useful climate information is a type of innovation that must pass through a process of adoption by individuals and organizations that can be slow and difficult. We then discuss the concept of "decision support," which is critical to understanding and pursuing NOAA's climate mission.

[1]Description available: http://www.climate.noaa.gov/index.jsp?pg=./cpo_pa/cpo_pa_index.jsp&pa=sarp&sub=1 [accessed April 2007].

[2]See also the human dimensions web page of the National Centers for Coastal Ocean Science, http://www.nccos.noaa.gov/human/welcome.html [accessed April 2007].

IMPROVED CLIMATE FORECASTS AS AN INNOVATION

Climate scientists have only recently become skillful at forecasting climatic events months in advance—a scientific advance that is fundamentally new in human history.[3] Thus, only recently has it become possible for decision makers to achieve better outcomes by using information in climate forecasts than by ignoring them. Until recently, the best predictive rule available to water managers, land use planners, emergency managers, and many other decision makers for timescales beyond the reach of weather forecasting was to expect the future distribution of climate-driven events to mirror the past distribution for the same location and time of year.

It is important to emphasize that climate forecasting skill is still quite limited. It also varies considerably depending on lead time, geographic scale, location (e.g., the El Niño-Southern Oscillation [ENSO] effect is stronger in some places than others), time of year (for ENSO, the signal varies seasonally), phase of a climatic variation (e.g., forecasts are more skillful during the El Niño phase than during other parts of the ENSO cycle), the climate variable being predicted (e.g., temperature forecasts are typically more skillful than precipitation forecasts), and other factors. When forecasts combine climate information with information on other processes, such as the hydrological information in stream flow forecasts, the climate information may or may not increase forecasting skill. According to one recent assessment: "climate model forecasts presently suffer from a general lack of skill, [but] there may be locations, times of year and conditions (e.g., during El Niño or La Niña) for which they improve hydrological forecasts" relative to forecasts that do not use the climate information (Wood et al., 2005).

From the standpoint of potential climate forecast users, the current skill level of climate forecasts and related forecast products (e.g., hydrological forecasts that include climate) may or may not be sufficient to enable better decisions. Moreover, the same forecast may provide information that supports better decisions for some users but not others in the same geographic region: for example, hydropower producers may be able to use skillful forecasts of average conditions across a whole watershed,

[3]Forecasting skill involves comparing a compilation of forecasts, such as might be derived from a climate model used to predict climate attributes at multiple times, with what was later observed at the forecasted times. When one says that climate scientists have become skillful, we mean that the skill of their forecasts for time periods months into the future is greater than the skill of a forecast consisting simply of historical averages for the forecasted times. Climate researchers often distinguish climate forecasts, which typically have lead times on the order of months (as in ENSO forecasts), from climate projections, which have lead times on the order of decades.

while dryland farmers in the watershed may need finer spatial resolution for the forecast to be useful. Such imperfections and variations in the usefulness of forecast information, combined with the fact that the skill levels of climate forecasts can be expected to change over time at an uneven rate, create significant uncertainty for decision makers who are considering how a climate forecast should affect their actions. In addition, the usefulness of climate information depends on the decision-making contexts in which it is used. We discuss this issue further below, in the context of multilevel, multi-actor governance.

To make optimal use of climate forecast information, a user must have an appropriate understanding of the level of skill involved in relation to the decision at hand. However, the degree of forecasting skill in relation to practical decisions remains highly contested. Thus, decision makers will continue to act under great uncertainty when it comes to future climate. They can err in two directions: by ignoring useful forecast information and by giving greater credence to uncertain forecasts than their skill level warrants.

The potential adoption of climate forecast information by decision makers occurs in the context of their existing ways of using information. Over many decades, decision makers whose well-being is affected by weather and climate developed routines for gathering and using information, including weather forecasts and other information collected by scientific methods, but not including climate forecast information or input from climate scientists. For example, a decade ago, seasonal stream flow forecasts in much of the West were made after the January 1 snow surveys because, other than historical averages, snowpack was the only quantity considered relevant. In the fall, reservoir managers set weekly reservoir levels by following a set of "rule curves" derived only from historical experience. They did not take into account, and were not allowed to take into account (because the rule curves were mandated), information about the state of ENSO, even though that information was beginning to yield skillful forecasts of precipitation on a seasonal-to-interannual timescale.

In an iterative process of several years' duration, scientists showed water management agencies how the statistics of stream flow were shifted according to the phase of ENSO and how this phase could be predicted with some skill by late summer. Then the agencies began to consider ENSO predictions during the fall to see what they forecast and do some retrospective studies. Eventually, some agencies developed confidence in ENSO forecasts, and some are managing reservoirs differently in the fall as a result (for example, by generating more hydropower in years when seasonal forecasts suggest higher than average stream flow). Such management changes have the potential to generate an average of $150 million per year more hydropower with little or no loss of reliability for other management objectives (Hamlet et al., 2002). Yet, even as skill levels of ENSO-related forecasting products have improved, resistance to their use in water resources management has persisted (e.g., O'Connor et al., 1999, 2005; Rayner et al., 2005; Yarnal et al., 2006).

Many factors determine whether or not potentially beneficial information is used. Some of these relate to characteristics of new information as received and perceived by potential users. The key factors have sometimes been described in terms of salience, credibility, and legitimacy (e.g., Clark and Majone, 1985; Ravetz, 1971; Cash et al., 2003). Salience is closely related to decision relevance, which has long been recognized to affect the use of information (e.g., National Research Council, 1989, 2002b). It is also related to the issue of getting potential users' attention; thus, information is more likely to be used if it is sent through multiple communication channels and if it comes from known and trusted sources, including personal communication (see, e.g., Hovland et al., 1953; McGuire, 1983; National Research Council, 1984, 1989; 2002b; Mileti and Peek, 2002). Some of these attributes of information sources also increase the credibility and legitimacy of the information from a user's perspective. Credibility, which relates to the idea of competence, is also signaled by attributes of the information itself: for example, information is more credible if it recognizes and treats multiple perspectives in an even-handed way (e.g., Cash et al., 2003). These general principles have been found to apply across many areas of communication, including the use of climate-related information (see, e.g., Jacobs et al., 2006; McNie, 2007; Mitchell et al., 2006; National Research Council, 2005b, 2006, 2007c; Social Learning Group, 2001a, 2001b).

It is worth emphasizing that credibility of the information to scientists, which is the focus of major efforts to improve the skill of climate forecasts and related decision support products, does not necessarily confer credibility with potential users. Evidence is lacking that information is more likely to be used merely if it is made more credible scientifically. Research on scientific communication strongly suggests that as important as the scientific validity of information is to the quality of decisions based on it, other attributes of the information are more influential in determining whether it is used.

Whether information is used also depends on characteristics of the users. For example, the concept of path dependency (e.g., Pierson, 2000) describes organizations or processes that are shaped by users' histories and are therefore conservative and resistant to information that would change past practice. Conservatism may arise from legal or regulatory constraints or from established routines for seeking and interpreting information, which become entrenched and serve as barriers to information from outside sources. It may arise from a lack of capacity (e.g., scientific expertise, skills with geographic information systems [GIS]) in the organization to translate and use information produced outside the organization. Past practice also builds expectations among constituencies about being served in the ways they have come to depend on. Certain interests served by existing ways of doing things may perceive that change will harm their privileged positions, even if new practices mean increased benefits to the overall social welfare. Organizations also resist changes that make them vulnerable to political blame. Some organizations may not innovate until political cover is provided by leaders who embrace change and are willing to take the brunt of criticism for things that inevitably go wrong when something new is tried.

Thought about in another way, getting climate information used, and used appropriately, depends on transcending boundaries in knowledge-action systems (Gieryn, 1995; Guston, 2001; Jasanoff, 1987), such as between scientific and policy communities, between disciplines, between organizations and jurisdictions, and so forth. Such barriers may serve important functions in both science and government, but they can also impede communication, collaboration, understanding of complex systems, and coordinated action.

In short, using climate forecast information requires change that is not accomplished automatically or easily. Even if the United States is entering a new era of climate consciousness, it will take time for organizations to modify their routines of information gathering and decision making and establish new lines of communication—in this case, with scientists who can provide useful climate-related information. It will take time and effort to hire new kinds of people in organizations that need new and more appropriate expertise—for example, in climate science—or to construct new networks to convey information in or among organizations. Signs are beginning to appear of increasing development of such expertise and networks, particularly in private-sector organizations. One challenge for SARP is to find ways of pushing forward this process of multifaceted change in sectors and constituencies in which it is not yet occurring. To make progress, social science insights about processes of communication and innovation will be as important as is improved skill in climate forecasting.

In sum, when a qualitatively new and potentially valuable kind of scientific information becomes available, many of the beneficiaries are unlikely to take advantage of it until they can modify their information-gathering and decision-making routines. It is necessary to find new information sources, either within the decision-making organization (e.g., by hiring people with different expertise, such as climate scientists), by using existing networks, or by building new networks. New networks will require support, but if they produce benefits, those who benefit may well be willing to pay for them. New networks may also require that new organizations be created or that existing organizations take on new functions, acting as links between information sources and users—what have been called boundary organizations (Agrawala et al., 2001; Cash, 2001; Guston, 2001). All of this change takes time and requires overcoming barriers, building confidence, and improving communication among potential producers and consumers of the new information.

Social science research on diffusion of innovation, organizational change, and related topics can offer some insights about how the process can be advanced. In Chapter 3, we discuss this research in the context of a key factor on which the success of NOAA's climate mission depends: the need for innovation in decision routines and social networks so that decision makers can take into account climate-related information they did not previously consider.

DECISION SUPPORT

The term "decision support" is prominent in discussions of the value of federal research efforts under the U.S. Climate Change Science Program (CCSP). CCSP documents assert that such research produces value to society because it supports better decisions. However, the term "decision support" has no precise definition in CCSP documents, and officials in the program offer a wide variety of definitions. At some risk of oversimplification, we distinguish two quite distinct definitions that appear to be in common use in the program. Available research on the use of scientific information is much more supportive of one view than the other.

In one view, decision support is a matter of translating the products of climate science into forms useful for decision makers and disseminating the translated products. This view presumes that climate scientists know which products will be useful to which decision makers and that the potential users will make appropriate use of decision-relevant information once it is made available to them. Adherents of this view typically emphasize the importance of developing what are called "decision support tools," such as models, maps, and other technical products intended to be relevant to certain classes of decisions. They believe that once these tools are created and disseminated, the task of decision support is essentially complete. This approach can be called a translation model.

In the other view, decision support is defined more broadly as creating conditions that foster the appropriate use of information. Creating decision support tools may be part of the task, but it is not all, and it may not be the most important part. This view presumes that scientists do not automatically know what information they could provide that decision makers would find useful, that decision makers do not necessarily know how they could use climate information, and that decision-relevant information is not necessarily put to optimal use when it is received. In this view, the primary objective of decision support activities is to establish communication between climate information producers and users that ensures that the information produced addresses users' decision needs and gets to them in useful ways. Such communication is believed to change both the kinds of information that is produced and the ways it is used (e.g., National Research Council, 1989, 1996b, 1999, 2005a, 2006). This objective is sometimes described as reconciling supply and demand with respect to decision-relevant climate information (McNie, 2007; Sarewitz and Pielke, 2007) or as the coproduction of science and policy (Lemos and Morehouse, 2005).

This approach often requires efforts to strengthen the demand side (Cash et al., 2003). Success in achieving decision support objectives depends critically on effective and use-oriented two-way communication between the producers and users of climate information (Jacobs et al., 2005, 2006; Lemos and Morehouse, 2005; National Research Council, 1999b, 2006). Such communication can help bridge gaps between what is produced and what is likely to be used, thus ensuring that scientists produce products that are recognized by the users, and not just the producers, as useful. Effective use-oriented two-way communication can increase users' understanding of how they could use climate information and enable them to ask questions about information that is uncertain or in dispute. In this broader view, a collaborative approach to decision support centered on such communication will yield much greater and more appropriate use of climate information than will come from the translation model. It may also result in decision-relevant information that would not otherwise have been produced because scientists may not have understood completely what kinds of information would be most useful to the target decision makers. In the broader definition of decision support, the central issue is not the development of new tools or other products, but of social systems or networks that get decision-relevant climate information produced and used. In some instances, the most valuable form of decision support may come from a conversation, not a mathematical model.

The notion of conversation as a decision support tool brings into focus the importance of human relationships and networks in information utilization. The uptake of information is highly dependent on the extent to which the source is trusted and considered reliable by the recipient (e.g., Hovland et al., 1953; McGuire, 1983; Rosa and Clark, 1999; Mitchell et al., 2006). Trust is ordinarily the product of familiarity and repeated interactions. Decision support can involve the continual working and reworking of relationships.

Research on the use of scientific information consistently supports the second, broader view of decision support. Research on "science utilization," focused largely on government agencies as users, indicates that decision-relevant scientific information is not necessarily used, even when it is made available to those who can benefit from it. Nor is it used even when, as with government officials, it is their responsibility to make decisions on the basis of the best available information (e.g., Sabatier, 1978; Weiss and Bucuvalas, 1980; Freudenburg, 1989; Landry et al., 2003; Romsdahl, 2005). These conclusions emerge from research on environmental communication (e.g., McKenzie-Mohr and Smith, 1999; Schultz, 2002), disaster communication (e.g., Mileti, 1999; National Research Council, 2006), public health communication (e.g., Valente and Schuster, 2002), sustainable development (Cash et al., 2003; van Kerkhoff and Lebel, 2006), global environmental assessment (Mitchell et al., 2006), and risk perception and communication (e.g., National Research Council, 1989, 1996b; Fischhoff, 1989; Slovic, 2000). They are also beginning to emerge from studies of the use of climate information, including that produced by NOAA (e.g., Anderson et al., 2003; Jacobs et al., 2005; McNie et al., 2007; National Research Council, 2005b).

As noted above, key characteristics of information that is used are that, from the user's standpoint, it is salient (e.g., decision relevant and timely), credible (perceived as accurate, valid, and of high quality), and legitimate (uninfluenced by pressures or other sources of bias) (e.g., Social Learning Group, 2001a, 2001b; Cash et al., 2003; National Research Council, 2005b). Among the factors found to be important in determining whether such information is produced and used are the existence of good communication links, trust, and respect between scientists and users; the fit between the information and users' decision routines; the strength of communication networks among the information users; and the potential for decisions to be challenged and to be adapted.

Work on risk (e.g., National Research Council, 1996b) emphasizes that broad involvement of "interested and affected parties" in framing scientific questions helps ensure that the science produced is useful ("getting the right science"). Such involvement also helps ensure that formal decision support tools that make sense to the scientists are explicit about any simplifying assumptions that may be in dispute among the users. Science-driven climate forecasting efforts, in particular, have been criticized as inaccessible and unhelpful to their potential beneficiaries, especially highly vulnerable populations, and as drains on resources that could be applied to more effective ways to reduce climate vulnerability (Lemos and Dilling, 2007).

Evidence from multiple fields demonstrates that scientific information that is intended to be useful for practical decisions often goes unused and that a key reason is inadequate prior communication between the producers and users of the information. Considering this evidence, we adopt a broad definition of "decision support" that emphasizes communication and recommend that SARP and NOAA do the same. This understanding of the decision support task has influenced our thinking about how NOAA should work to achieve its climate mission and, within that, how SARP should set its research priorities for improving decision support systems. When decision support activities are conducted without adequate communication between information producers and users, many of the decision support products that are developed are seriously underutilized. The following examples illustrate the role of adequate communication with the intended users for decision support activities.

As noted in a previous study (National Research Council, 1999b:2), "a climate forecast is useful to a recipient only if the outcome variables it skillfully predicts are relevant and the forecast is timely in relation to actions the recipient can take to improve outcomes." An example of an interesting scientific result that was useless in an operational context was the prediction (Hamlet and Lettenmaier, 1999) that global warming would reduce summer stream flow volumes in the Columbia River. Water managers were concerned about the implications but were unable to apply the finding to their own situations because the statement was not sufficiently clear, quantitative, or geographically specific. Models in use by water resource management agencies typically required monthly flow data for some time span (50 years or more) at specific stream gauges. Feedback from users made it possible to produce information they could use. The Climate Impacts Group (the RISA for the Pacific Northwest) developed an online resource in which the hydrologic model output was available at selected stream gauges chosen by key stakeholders, both for much of the 20th century and for future climate scenarios (Snover et al., 2003). Once these data were available in this useful format, the Northwest Power and Conservation Council could use them in their existing models to estimate climate-related impacts on Northwest hydropower production and revenue (see Northwest Power and Conservation Council, 2005).

A related example concerns the Federal Emergency Management Agency's HAZUS model, a multihazard damage estimation model consisting of separate modules to address different hazard regimes (Federal Emergency Management Agency, 2006). HAZUS was developed as a tool to analyze information recorded in GIS to produce estimates of damages caused by natural disasters such as floods, hurricane winds, and earthquakes. For example, the flood hazard analysis module uses such characteristics as frequency, discharge, and ground elevation to estimate flood depth, flood elevation, and flow velocity and thereby calculate estimates of physical damage and economic loss from a flood event. Many decision makers for whose benefit the HAZUS model was developed have complained that the model demands too much detailed data—with significant up-front investment of time and financial resources—to get useful output. For example, the state of Hawaii's initial investment of $8 million to develop data for the seismic model has yielded considerable dividends, but the high cost may not be bearable by many other users. Closer collaboration between the creators of HAZUS and users might have led to a model that many more state and local users would have found useful.

3

Use-Inspired Science and Communication

As Chapter 2 makes clear, much more than the translation of climate information is needed for the National Oceanic and Atmospheric Administration (NOAA) to achieve its decision support objectives. The needs of decision makers must affect scientific activity if its outputs are to be considered useful. This chapter discusses two main elements necessary for an effective decision support program in NOAA: use-inspired science, especially behavioral and social science, and improved communication between scientific producers and users.

USE-INSPIRED SCIENCE

Use-inspired science consists of scientific investigation whose rationale, conceptualization, and research directions are driven by the potential use to which the knowledge will be put (Stokes, 1997). It sometimes involves the "application" of other "basic" or "fundamental" science, but it also includes investigations that advance or even transform scientific disciplines or that create entirely new scientific fields.

Use-inspired science is especially important in the field of climate variability and change, in which the purpose of research is not only to satisfy curiosity about the operation of Earth, but also to provide a sound foundation for decisions by relevant practitioners (see, e.g., Clark, 2007). Federal investment in research on climate change is to a great extent justified in terms of user needs. In the words of the U.S. Climate Change Science Program (CCSP) strategic plan, CCSP's guiding vision is of "a nation and the global community empowered with the science-based knowledge to manage the risks and opportunities of change in the climate and related environmental systems" (U.S. Climate Change Science Program and Subcommittee on Global Change Research, 2003:3). Appropriately organized, science-based knowledge can benefit a wide variety of decision makers at various geographic and political scales and over various time horizons who could make more effective choices if they integrated the best available understanding of climate dynamics and of related biogeochemical and socioeconomic systems. This understanding includes processes operating at the global level, their functioning over time, links among processes occurring at different spatial and temporal scales, and understanding of the limits and uncertainties of available knowledge.

Climate-related science is more likely to be useful if the efforts of science producers are informed by the actual needs and practices of consumers. This is use-inspired science. For example, consider the challenge to western water managers responsible for controlling stream flow in the Columbia and other rivers. As already noted, recent improvements in the ability to make skillful seasonal forecasts on the basis of the El Niño-Southern Oscillation (ENSO) phenomenon has provided a new source of information. To make this information useful, managers would need to know how climate variability will affect outcomes of importance to them, such as snow pack, expected water levels at reference locations on the river, and their potential impacts on flooding, water availability, and salmon migrations. If available in time for critical decisions, this knowledge could affect conservation plans, plans for water releases from reservoirs, and coordination among managers. Some of the needed knowledge could come from "downscaling" seasonal-to-interannual climate forecasts to meet needs defined by regional managers and, if more refined downscaling can be done, local managers. Such downscaling is, in fact, one goal of the NOAA Regional Integrated Sciences and Assessment Applications (RISA) Program.

Decision makers can benefit similarly from use-inspired social science. Managers whose responsibilities may be affected by climate variability and change need detailed understanding of relevant social, economic, organizational, and behavioral systems. In the case of water and coastal managers, this may include understanding of (1) the demographic and economic factors that shape demand for water, roads, and land conversion for residential and commercial development; (2) the factors that shape the possibilities for individuals and organizations to respond to anticipated environmental changes; (3) the social systems that provide, or fail to provide, resilience in the face of natural disasters related to climate; and (4) the organizational and individual processes that determine the salience, credibility, legitimacy, and ultimately the use of the kinds of complex and uncertain information that climate forecasts provide.

The ability of NOAA to empower communities to manage the risks and opportunities presented by climate variability and change depends in part on its ability to produce use-inspired science. This includes understanding of the full range of climatic, ecological, economic, and social factors that are important to climate-related decisions. We emphasize that the value of climate information also depends on the decision-making contexts in which it is used (see below). Given the focus of the Sectoral Applications Research Program (SARP) and of our charge, we focus on use-inspired social and behavioral science.

We agree with the NOAA Social Science Review Panel (Anderson et al., 2003) that NOAA should readjust its research priorities by additional investment in a wide variety of use-inspired social science projects. Our task, however, given the more limited purview of SARP, is to focus on the narrower range of social science research topics that are directly relevant to improving the use of climate-related information in sectoral applications.

This section discusses five topics, each of which has direct relevance to making climate information better serve the needs of various sectors. For each topic, we consider who needs to behave differently, why, and how climate information can be integrated into sectors. We also address how impediments to such transformations might be managed in facilitating societal change and adaptation to climate information in sectors. The research topics are human influences on vulnerability, communication processes, the transformation of science by users, information overload, and innovation to make use of climate-related information. Among these topics, the last is most important at this time in pushing forward the SARP mission of catalyzing and initiating change. Innovation in the production and use of climate-related information is a central issue in advancing decision support as we have defined it and to the task of building networks and linkages that facilitate interaction between users and scientists.

Human Influences on Vulnerability

Human activities not only drive climate change (e.g., National Research Council, 1992, 1997; Rosa et al., 2004; York et al., 2003), but also affect people and the nonhuman world of ongoing processes of climatic variability and change. For example, changes in human use of water, land, and other natural resources affect climate-related events by changing the populations and the adaptive capacities of the affected communities. Thus, effective climate decision support systems and other tools for addressing problems associated with climate-induced changes require a better understanding of human interactions with the environment and how they affect the impacts of climate variation and change on human and nonhuman systems. This understanding should be developed while recognizing the longer time frames associated with planning for transportation, water, and other infrastructure needs when changes in human demands and physical systems are interacting.

Communication Processes

As noted in Chapter 2, past research demonstrates the importance of effective two-way communication between the producers and users of climate science for producing information that is accepted as decision relevant and credible by the intended users. Decision support efforts using a one-way information transmission model have been at the root of many instances of elaborate efforts by scientists to characterize risks from various natural and technological hazards that were not credible to users because they addressed the wrong issues, relied on unrealistic assumptions, or produced advice that was impossible to follow (see, e.g., Wynne, 1989; National Research Council, 1996b). Consistent with these findings, a recent assessment of the RISA Program (McNie et al., 2007) recommends developing processes that link the producers and consumers of climate information in order to identify needs for use-inspired science and to foster the use of the findings of such science. However, insights from research on risk perception and communication in the contexts of risks from exposures to hazardous chemicals, technologies, and the like (e.g., National Research Council, 1989; Slovic, 2000) have not often been applied to the problem of informing people about climate risks. These insights can undoubtedly aid in designing decision support processes that incorporate climate information, but additional research is needed to understand the extent to which they transfer, or must be modified, to fit the climate context. This research could also examine the roles of different kinds of formal and informal modes of assessment of climate information for particular decision contexts.

Science Produced in Partnership with Users

The RISA Program represents what some scholars describe as a post-normal approach to science, in which scientists and users come together to produce science that is usable in specific decision contexts (e.g., Funtowicz and Ravetz, 1992; Rosa, 1998). Rather than scientists' pursuing disciplinary questions of interest, they work closely, in what may be called networked partnerships, with potential users of information, who know about the context and history of the topic as the scientists may not.

Together, the scientists and potential users engage in ongoing and continuous feedback about the topics pursued, context-specific interpretation of results, and development of products designed to improve or change behavior and decisions. This benefit to specific users, however, makes the results difficult to generalize to other settings.

Early results from the RISA Program seem to indicate that this approach to science has been productive in developing climate science products and information that users have shaped to meet their needs (Sarewitz and Pielke, 2007). To achieve NOAA's mission, it will be important to continue tracking the effectiveness of the RISAs and other efforts to create and disseminate usable climate science knowledge through two-way communication processes. It will also be important to understand how to organize such processes for greatest effectiveness. Research should address questions such as these: How does this user-inspired science influence decision making? Is network-produced science integrated into individual and organizational decision routines in different, perhaps more effective, ways than "normal" science? How does the climate science community integrate and learn from interaction with the users and from the context-specific results generated?

Information Overload

The electronic age has brought about a precipitous rise in the availability of and exposure to information (Lightman, 2003), which is reflected in the amount of information in the form of data, research findings, agency reports, and commission findings about climate variability and change. This growth in information cuts in two directions: it provides the opportunity for accessing more and more decision-relevant information, but it also exposes decision makers to information overload. Basic research on how decision makers respond to a surfeit of information (e.g., Schwartz, 2004), especially if focused on climate-related information, can be helpful in the development of decision aids for coping with and managing information about climate.

Innovations Needed to Make Use of Climate-Related Information

We emphasize throughout this report that recent improvement in climate forecasting creates a fundamentally new kind of decision-relevant information that introduces significant opportunities for those who can benefit from it. We have also emphasized that to take advantage of these opportunities, innovation is necessary in the processes affecting climate-related decisions and that there are many significant obstacles to such innovation. A critical need is for social science research to understand the opportunities and obstacles to innovation to make use of climate information.

Several lines of social science research offer general insights into this problem and need to be developed further in the specific climate information context. The research recommended here would build on past work (e.g., Pulwarty and Redmond, 1997; National Research Council, 1999; Rayner et al., 2005) to examine how and why decision makers who could benefit from appropriate use of climate-related information use or fail to use new information. Studies would examine factors internal to decision making by individuals, groups, or organizations; the influences of external forces and organizations on decision makers; the ways climate information is used and transformed within multi-actor decision systems; and the ways networks that link the producers and consumers of climate information develop, evolve, and function to make climate information more useful to decision makers. Studies might also investigate specific decision makers or classes of decision makers in a sector. Taken together, such research would build a body of knowledge that could be used to inform NOAA's efforts (and those of other agencies and organizations) to make climate-related knowledge more effective in improving the ultimate societal consequences of climate variability and change. The rest of this section explores in more detail issues related to innovation at multiple levels.

Innovation at the Individual Level

Climate-related information is potentially useful to individuals in their roles as decision makers for themselves and their households (e.g., in preparing for climate-related extreme events), as participants in other groups, and as citizens. Benefiting from improved climate information requires innovation in information gathering, thinking, and behavior.

The classical research on the diffusion of innovations uses the individual as the unit of analysis (e.g., Rogers and Shoemaker, 1971; Rogers, 1983). Similarly, the individual is the principal unit of analysis in studies of risk perception and behavior (e.g., Rosa, 1998; Slovic, 2000), environmental attitude formation and behavior change (National Research Council, 1984, 2002b, 2005a; Gardner and Stern, 1996), and many studies of innovation (e.g., Rogers and Shoemaker, 1971; Rogers, 1983). The insights from these lines of research have not yet been applied and extended to the problem of understanding the conditions under which individuals assimilate and act on climate-related information. SARP can benefit its constituency by developing empirical knowledge of the conditions under which decision makers in affected sectors demand climate-related science, how they learn of their need for and the availability of such knowledge, how they come to accept or reject that knowledge in their attitudes and decision making, the behavioral consequences of adopting this knowledge, and the diffusion of new behaviors. A sizable generic literature across several disciplines can guide use-inspired research that addresses the objectives of SARP while also contributing to the advance of disciplinary knowledge. So far, very few studies have addressed the conditions under which decision makers seek out climate information. An example is a study by O'Connor et al. (2005), which found that water managers who felt more vulnerable to climate risk were more interested in climate forecast information.

Organizational Learning

Like individuals, most organizations need to change their usual practices of information gathering and decision making to make the best use of new kinds of climate-related information. This is a process of organizational learning, that is, the development and use of knowledge for adapting to a changing environment (Leavitt and March, 1988; March, 1991; Parson and Clark, 1995). This is closely related to the idea of "adaptive management," a process by which organizations actively engage in feedback between monitoring and decisions (Holling, 1978; Lee, 1993). Learning may take place reactively, as when organizations learn incrementally by evaluating the actions taken that have led to past successes or failures. For example, municipal water utilities in desert regions have learned that the number of days since the most recent rainfall, combined with temperature, is a better predictor of elevated water use than temperature alone, and they have adjusted their management practices accordingly. Learning may also take place proactively, when organizations seek out information about their environments from internal or external sources and intentionally incorporate elements of their changed environments into particular procedures or changes in organizational structure.

Adaptive organizations vary considerably in the processes they use for learning and for the diffusion of new knowledge throughout the organization. There is a sizable social science literature that offers conceptual models, frameworks, and other tools for characterizing and describing organizational learning processes. As already noted, there is also a substantial body of knowledge on barriers to organizational change. To avoid pitfalls as it strives for its mission goal of facilitating the adoption of "science-based climate-related" information by decision-making organizations, NOAA needs to understand how these organizations assimilate and use climate-related information and the barriers to such learning.

Innovations in Complex Organizational Fields

When an organization has not integrated or used climate science even though it is quite obvious that the organization would benefit from that use, it is tempting to look to the organization's internal routines and decision processes for explanations. However, external forces, such as shared norms among associated organizations and incentives affecting organizations, may play an equally important role in determining how and when innovation actually takes place. An organization's larger institutional context can promote or limit organizational behavior related to innovation. Organizations with interdependent relationships belong to an "organizational field" (Scott, 1992) and share common norms, expectations, and in many cases, day-to-day practices. Decisions to innovate must be passed through this organizational field—either implicitly or explicitly—with pressures coming through various kinds of influences generated by the field (DiMaggio and Powell, 1983; Powell and DiMaggio 1991). For example, any attempt to integrate climate information into river management first has to pass through a quasi-legal vetting process by the Army Corps of Engineers, which determines whether the science is credible, reliable, and applicable. No single river management organization can step outside its organizational field.

To achieve NOAA's mission, it is critical to gain understanding of the external forces that promote and constrain the adoption of climate information by influential organizations in particular sectors. For example, do organizations treat information as legitimate only when it comes from other organizations in their field? Are "best practices" mandated by one or more regulatory bodies? Is there a perceived leader in the field whose use or non-use of climate information affects other organizations in the field? The ongoing development of new climate science and information introduces the prospect of innovation at a global level—all around the world and in all organizations and organizational fields. Understanding the role and impact of complex, multiple, and multilevel organizational fields will be critical to understanding how (and whether) climate science will be integrated into existing decision routines.

Multilevel, Multi-Actor Governance

The term "governance" refers to the collaboration of various actors, including nongovernmental organizations that may or may not be nonprofit and governmental entities at all levels from the local to the international, in making choices that can affect them all. Although these parties act together in governance arrangements, they may not have common goals or respond to common incentives. Coping with the challenge of decisions in sectors defined by resources or decision arenas, and with their socioeconomic effects, typically involves organizations at all levels of government (national, regional, state, and local), as well as nongovernmental public, nonprofit, and private organizations (environmental groups, trade and professional associations, business enterprises, etc.) (e.g., Salamon, 2002; Posner, 1998; O'Toole et al., 1997). Governance processes rarely involve straightforward or highly coordinated responses because different participants usually have very different missions and orientationsand relate to different kinds of constituencies with different values and interests. As they engage in the governance process, responses to calls for concerted action may be halfhearted because what is requested may be peripheral to their missions. Alternatively, they may become involved in a governance problem with the intent to remold and redefine the problem in terms that are closer to their organizational missions. Multilevel, multi-actor governance involves large numbers of veto points where action can be delayed or stalled. Multilevel governance renders even the conveyance of scientific or other information quite difficult since participants at different levels or sectors use different jargon or terminology, so that shared understanding may be very difficult to achieve.

In the absence of established links among interdependent actors in a common authority system, effective governance may depend not only on the exercise of authority by the system, but also on the actors themselves developing processes through which they hold each other accountable. Moreover, the lines of communication need to be open and transparent so that changes in the substance of agreements can be traced through various levels and sectors.

The use of information about climate change and variation in multilevel governance processes presents both a research challenge and an opportunity. Making climate science useful requires negotiating this difficult terrain and continual modification of the form and content of information and the rationale for information adoption. Social science research can help identify specific pathways that exist or could be forged between actors presently engaged in governance and others that could be involved to make coping with climate variability and change more effective, efficient, equitable, responsive, or accountable. Social science research can also identify appropriate tools that can be used to motivate recalcitrant actors or overcome impediments to effective governance that involves multiple levels and actors of various types.

Building and Maintaining Knowledge-Action Systems

As we emphasize throughout this report, two-way communication that involves the producers and users of science is critical to the innovations that make science useful. For most decision makers, who do not already have links to trusted sources of climate information, communication depends on formal or informal networks that link scientific producers and consumers, sometimes called knowledge-action systems (Cash et al., 2003; National Research Council, 2005b). Such systems consist of networks of linked individuals and organizations that perform knowledge-related functions, such as research, development, demonstration, and adoption of knowledge-based practices. Such networks are likely to be particularly important in making climate science useful because good decisions depend on insights from a very broad spectrum of scientific specialties, because many classes of decision makers do not have good sources for scientific information relevant to their decisions, and because networks can begin to establish the interorganizational understandings and norms that facilitate change in a complex, multi-actor system. The multidisciplinary nature of climate science cuts across traditional approaches and also across conventional institutional arrangements for conducting research and for informing policy. Furthermore, owing to the long timescales of the challenges associated with climate change and the changing nature of scientific understanding, there is a need for institutional arrangements, such as knowledge-action networks, that have continuity into the foreseeable future and the capacity to adapt.

For many decision contexts, such networks are not yet established, perhaps because many decision makers have found no potential benefit from climate science until recently, when forecasting skill began to exceed reliance on historical averages. However, many constituencies of potential climate information users—such as water, floodplain, and disaster managers; farmers; mayors; city managers; and coastal zone managers—already have professional associations or other organizations that serve them. Many of these organizations have long experience bringing together various kinds of knowledge for the benefit of their constituents, and they could potentially do the same with climate science information. One of the outcomes of NOAA's RISA Program may be to establish new networks that link such constituencies at the regional level to good sources of climate information. SARP could attempt to do the same for sectoral constituencies.

As a possible example, consider the decisions of some insurance companies not to write new homeowners' policies in certain coastal areas after recent hurricane-related losses and perhaps also in anticipation of increased losses in the future. These decisions are likely to reverberate through a variety of public- and private-sector organizations and individual households in ways that are hard to predict. Ideally, information about climate-related risks to coastal property would be useful to a range of actors, including insurance companies, home builders and remodelers, building code writers and other local and state government officials, real estate agents, and current and prospective homeowners. In addition, the decisions of these groups are interrelated, so they potentially form a social network that collectively could use and act on information from climate science. Some of these groups have constituency organizations and some do not; moreover, no network exists to connect them and thus reveal their common interest in information from climate projections. SARP could support research projects to investigate how information about climate change might be developed and made available for salient decisions about residential property in coastal regions. The same research might facilitate discussion among these decision makers about climate change, thereby promoting the creation of a network based on the climate-affected decisions they must all be making.

Some generic knowledge exists about how such networks come about, how they operate, and how they ensure their continuity over time. For example, research on process accountability and inclusive management (e.g., Feldman and Khadamian, 2000, 2001, 2007) suggests that such networks can build trust among diverse participants and can be managed, although doing so requires nontraditional management techniques. Other research suggests that in groups that manage common-pool resources, such as most water supplies, network resilience is a result of flexibility and adaptive capacity to accommodate changed circumstances and new sources of information (e.g., National Research Council, 2002a). At the local level, such institutions can be found in water users associations, some of which have existed for a century or more (e.g., Ostrom and Gardner, 1993; Bardhan and Dayton-Johnson, 2002), and associations of fishers (e.g., Berkes et al., 2001). Researchers have examined the ways in which such groups have sustained themselves by incorporating local knowledge and adapting to changing and uncertain circumstances (e.g., Wilson, 2002).

This existing generic research suggests a host of questions that are worth exploring in the context of knowledge-action networks for incorporating information about climate variability and change into sectoral decisions. For example:

- Must small and simple networks demonstrate success before larger ones can effectively tackle large, difficult problems?
- If bureaucratic structures have limited effectiveness for dealing with rapidly developing knowledge, are there alternative structures with fluid and adaptive networks that are likely to be more effective and useful?
- Is it possible to build effective knowledge-action networks under circumstances of high levels of distrust and conflicting goals?

- How do the development trajectories of networks influence the uptake and use of scientific information?
- What kind of leadership is essential to the continuity and success of knowledge-action networks?
- How can networks be held accountable when leadership is unclear and membership is constantly changing?
- When knowledge-action networks are organized to inform decisions, what kinds of decision rules take best advantage of diverse sources of information? Which decision rules or procedures are most effective when values are in conflict?

As discussed above, decision-relevant information is not necessarily used, even when it is delivered to users who can benefit from it. Information travels from producers to users only when it has certain characteristics (Jacobs et al., 2006). As already noted, it must be salient and important to potential users, and it must reach their awareness (e.g., National Research Council, 2005b). It must be perceived as legitimate, considering multiple perspectives in an even-handed way (e.g., Cash et al., 2003). Agencies may be suspicious of each other and generally of information that comes from the outside. And it must be seen as decision relevant and credible by potential users (e.g., Mitchell et al., 2006). As noted above, NOAA's seasonal forecasts were initially resisted by resource managers because they weren't accurate to the degree the managers desired for informing their decisions—an instance of the supply of climate science being misaligned with decision makers' demand (e.g., Rayner et al., 2005).

SARP is currently focusing on two resource sectors—water and coastal resource management—each of which involves various classes of decision makers and is likely to provide opportunities for a variety of knowledge-action networks. Some relevant networks may already exist or be in various stages of formation, though information linkages are likely to be weak or lacking.

SARP could benefit from a variety of research projects that would study existing knowledge-action networks, including those created by RISA centers, or assess the potential for creating new networks or strengthening the capacity of existing ones to use climate information. Such networks are vitally important to human adaptation and management of climate change. To pursue this line of work, SARP would require an intentional strategy for choosing research projects from among the many that could be proposed in the water and coastal resource management sectors.

Recommendations

We have identified a variety of kinds of use-inspired science that are critical for making improved climate forecasting useful to individuals and organizations. Given the focus of SARP and our charge, our recommendations are focused exclusively on social and behavioral science. And because SARP is a small program, we have had to prioritize needs for the short term. Thus, despite the importance of a wide spectrum of social and behavioral science questions that arise from specific needs in the water and coastal resource management sectors, SARP must focus its research efforts on a more circumscribed agenda.

We recommend that the Sectoral Applications Research Program support research to identify and foster the innovations needed to make information about climate variability and change more usable in specific sectors, including research on the processes that influence success or failure in the creation of knowledge-action networks for making climate information useful for decision making. This research should be the major focus of the Sectoral Applications Research Program support over the next 3-5 years. Support should go to research that offers the largest potential benefit to decision making across sectors.

The recommended studies would examine how the understanding and use of climate information are affected by various characteristics of decision-making individuals, groups, or organizations and their contexts, especially including the development and functioning of networks that link the producers and consumers of such information. Studies might investigate specific decision makers or classes of decision makers in a resource-defined sector or make comparisons across different kinds of decision makers in or among sectors; they might also include research on possible strategies for overcoming barriers to innovation. Three questions deserve particular attention:

- Under what conditions do existing networks or partnerships *effectively* incorporate sources of knowledge about climate change and variability? Many existing partnerships and networked relationships that deal with human problems may make more effective decisions if they incorporate appropriate information about climate. In water resource management, for example, local watershed groups bring landowners and other water users together on a regular basis to resolve local problems. For example, the Metropolitan Water District (MWD), a long-standing partnership among 13 Southern California water purveyors, is faced with many difficult problems that include uncertain and possibly diminishing supplies, growing demand, and threats to water quality. Climate change is likely to exacerbate all of these problems, although the MWD is convinced from past successes that it can surmount challenges. It would be important to better understand the factors conducive to success.

- How can individuals or relatively unorganized constituencies develop ways to become informed about how climate variability and change may affect them? The example mentioned above, concerning the risks to residential property in coastal regions from climate change and the associated actions of home insurers, points to the need to make climate change information useful to as-yet unorganized constituencies.
- What roles can *climate* information play in network construction and continuity? Resource management networks are often fragile. The recent example of CALFED, a joint state and federal collaborative effort to manage the Sacramento Bay delta, shows that even with enormous expenditures and the best of intentions, effective networks may become destabilized due to unexpected events and political challenges. In 2000, the California collaborative published a Record of Decision that committed federal and state agencies to jointly coordinating their regulatory, permitting, planning, and funding decisions, which was supposed to stabilize the institution in face of change in political party control of the federal executive branch. However, by 2003, events and circumstances began to unravel pieces of the CALFED coordinated approach. Formalization of agreements in the creation of a California Bay Delta Authority drained agency attention away from coordination. A lack of federal government funding and leadership was also a problem. Federal agencies such as the Bureau of Reclamation and NOAA fisheries disagreed about exporting more water out of the delta. Fisheries numbers crashed for unexplained reasons, and the whole enterprise fell under criticism by the legislature. A "Little Hoover Commission" reviewed CALFED and found it seriously flawed. Although CALFED survives and continues with some important work, its future remains uncertain (Innes et al., 2007).

It is difficult to know whether a network has sufficient resilience and ability to innovate in order to meet its members' needs. It is also very difficult to measure the outcomes of network activities on social and physical environments. Identifying the characteristics of effective networks and documenting their accomplishments is important for the success of NOAA's climate science mission and to the evaluation of SARP.

We are recommending that SARP devote all its research resources in the near term to issues of social innovation for the use of climate science in selected sectors and not support other areas of use-inspired social and behavioral science research that are also important to its mission goals.

We make this recommendation of focused, circumscribed funding because of SARP's limited resources and the central role of social innovation in getting climate science information used.

We believe, however, that achievement of SARP's and NOAA's mission goals will be hampered by lack of attention to other areas of social and behavioral science research. We therefore urge other agencies in NOAA or CCSP to support other important lines of research relevant to decision support. These lines include several research areas already noted above, such as human influences on vulnerability and collaborative production of climate science information, as well as other worthy lines of research not identified here. (Also see National Research Council, 2005a, which identifies a set of behavioral and social science research priorities for improving environmental decision making.) For instance, although interesting and perhaps critical to NOAA's mission, a study of the processes through which citizens come to take individual-level precautions to reduce vulnerability to climate variation and change is outside the research agenda we recommend for SARP.

COMMUNICATION BETWEEN SCIENCE PRODUCERS AND USERS

As we discuss throughout this report, social innovations that involve the creation of new practices of information gathering and decision making that take climate-related information into account require effective communication links between the producers and users of this information. Although some decision-making constituencies have organizations with the resources to produce or interpret the climate science information they need—for example, the Reinsurance Association of America has hired climate scientists—most do not. In most sectors, making climate science usable will depend on developing knowledge-action networks that link people who have not previously worked together, introducing decision makers to decision-relevant information that they have not previously considered, and encouraging scientists to develop information relevant to pending and upcoming decisions.

The Need

As the RISA Program's activities demonstrate, it is worth investing in developing knowledge-action networks for decision support at a regional level. Through the RISA Program, NOAA is investing in processes that support scientists going into the field to listen to users and learn their perspectives, needs, and problems as a way to develop such networks (National Research Council, 2005b). These networks are interactive between the producers and users of science and can link a wide variety of decision makers together to find information to help solve problems they have in common.

The RISA Program reinforces positive lessons from such programs as the National Weather Service (National Research Council, 2003a), Agricultural Extension (e.g., National Research Council, 1996a) the Sea Grant Program (e.g., National Research Council, 1994), and the Environmental Protection Agency's Science to Achieve Results (STAR) Program (National Research Council, 2003b), which have linked science to its users. Increasingly, the kinds of problems being encountered in environmental governance require the collaboration of actors from public and private realms at all levels to bring together decision makers from many organizations with a wide variety of expertise, including experiential knowledge. Scientific information is central to the operation of these networks as they are formed to understand or solve problems rather than simply to advance certain interests or narrow agendas. Because of their problem orientation, such networks foster useful links between use-inspired social and physical sciences and an iterative relationship between knowledge producers and users. They also generate demands for use-inspired research, some of which the RISA centers actually carry out for their constituents.

RISAs are organized geographically, bringing together decision makers from different levels of government, from universities, and from nongovernmental and private-sector organizations to tailor climate science for particular and localized problems that include water issues, fire management, drought, and public health. SARP could use this model to introduce climate science into existing networks defined by the resources they use or by their decision functions. SARP could also catalyze creation of knowledge-action networks among climate-affected decision makers that lack direct and usable access to climate information. For example, coastal zone managers are already networked through professional associations, journals, and other dissemination mechanisms. Projects under SARP could tap into such knowledge networks to introduce climate science to coastal decision makers. In some cases SARP could partner with existing science applications organizations, such as Sea Grant or Agricultural Extension, to translate climate information into action. Or SARP projects could work with postdisaster recovery, planning, and rebuilding professionals, who are less well networked, to elevate the importance of climate-related risks in postdisaster planning and rebuilding. "Critical moments"—such as the relicensing of infrastructure or adoption of comprehensive plans—may also provide opportunities for introducing climate science to new networks of users.

As the RISA Program experience is making clear, networks require ongoing support in terms of money and staff, both for new scientific activities driven by the needs of emerging decisions and for maintenance of working relationships. Continuing support of knowledge-action networks will compete with research support in a fixed budget, raising the possibility that over time, research activities will become so small in relation to the operational burden that the program no longer provides needed new knowledge. The SARP budget would not go very far in support and maintenance of multiple knowledge-action networks. With these considerations in mind, we propose several areas of emphasis for SARP in relation to promoting communication between science producers and users over the next several years.

Recommendations

The need for social and behavioral science knowledge to support the general mission of NOAA, or even SARP's narrower sectoral mission, is much greater than can be adequately served by current or likely future budgets and other resources. Resource scarcity dictates a focus on three primary types of investments over the next 3-5 years in addition to the use-inspired sectoral social science research projects recommended above: workshops, research on the development of networks, and pilot projects.

In terms of resources, we believe SARP should commit up to roughly half of its budget during the first year, and a declining fraction thereafter, to fund workshops in order to identify sectors and decision domains that may benefit from targeted efforts similar to those dedicated to water and coastal zone management. The pilot project or projects would represent a significant fraction of the overall SARP budget beginning in the second or third year and would require reallocations of funds from the research program and workshops.

Workshops

We recommend that the Sectoral Applications Research Program support several workshops each year for the next 3 years to identify, catalyze, and assess the potential of knowledge-action networks in sectors, defined by resource areas (e.g., water, coastal resources) or decision-making domains (e.g., emergency response, insurance, planning, and zoning). The Sectoral Applications Research Program should also support selected follow-up activities.

The recommended workshops would provide support to bring together individuals, organizations, or existing networks of potential users and producers of climate information from several communities:

information users (e.g., planners, policy makers, and managers in affected sectors); information producers (e.g., researchers, modelers, applications specialists); potential boundary spanners (e.g., extension agents, outreach specialists in professional and trade associations), and program managers involved in funding and supporting decision support systems. The workshops would establish and strengthen communication among information producers and consumers. They would aim to: (1) identify the climate-related issues important to the sector or decision domain, (2) characterize the kinds of climate-related information that would help inform decisions in the sector or domain, (3) determine whether existing climate information is adequate, and (4) identify climate or social research needed to produce information that is not yet available. The workshops would also be used to identify barriers to awareness, use, and integration of climate-related knowledge by decision makers and to identify barriers to production of the needed information by scientists.

SARP should encourage proposals that build on existing networks, such as the RISAs, extension programs (including Sea Grant), and national professional associations, linking them and their constituents to good sources of climate-related information. In addition to building on existing networks, SARP should encourage workshop proposals for developing new networks involving types of decision makers not already well networked. For example, homeowners in vulnerable coastal or floodplain areas who are facing steeply increasing insurance premiums may have a shared interest in making renovations that could protect their properties and lower insurance premiums. Another promising network might include members of planning and zoning commissions in small or medium-sized communities (who are rarely, if ever, brought together) to share experiences or to learn about how climate information could be used to make their communities less vulnerable and more resilient. Still another possible network might include actuaries or others in the insurance industry who need to consider changing risks from climatic events in their management guidelines and policy rates.

If a first workshop demonstrates effectiveness in promoting the creation of a new network or increasing the capacity of an existing one to produce innovation in the production or use of climate information or in decision routines and practices, SARP should provide two avenues to build on that success: a noncompetitive renewal option for up to two additional workshops to extend the success of the first workshop or support for a pilot project (see below).

We also urge SARP to support research on the processes that influence success or failure in the creation of knowledge-action networks for making climate information useful for decision making. Such research would use the recommended workshops in part as a laboratory for learning about network development. The work would draw on relevant knowledge to develop hypotheses and decide what sorts of observations to make about the workshops or what sorts of questions to ask participants and those who declined to participate. Of course, the participants in such workshops should be informed in advance that the workshops have research purposes as well as practical ones and should give informed consent to participation in research.

Pilot Projects

> **We recommend that the Sectoral Applications Research Program, beginning no earlier than 1 year after funding the first workshop, support one or more pilot projects to create or enhance a knowledge-action network for supporting climate-related decisions in a sector defined by resource or decision domain.**

The recommended pilot projects are a natural outgrowth of an initial workshop or set of workshops, with the purpose of carrying forward successful results of workshops toward the creation of new products or processes for making climate-related information more useful to decision makers. A pilot project would begin to create or improve a network that combines a base of use-inspired knowledge with effective interconnections between the potential producers and users of climate information to ensure that the science is decision relevant and understood as such.

The goal of the recommended pilot projects is to establish mechanisms for combining research and interconnections to perform a function of integrated information provision. This is an adaptive way to reflect changing decision needs and scientific advances. For example, if a workshop resulted in an idea to develop a new information product from climate-related natural or social science or a new process for communication about climate issues in the sector, the pilot project might include efforts to develop the innovation and test it with decision makers in the network. In considering proposals for pilot projects, SARP should carefully evaluate candidates' chances of success and recognize that there is considerable risk in network promotion, support, and growth. Consequently, SARP should take this risk with a small number of proposed networks.

A component of any pilot project should be the examination of the process of creating knowledge-action networks. Little is known about the factors that affect whether such networks can be purposefully constructed. The experience of the RISAs suggests that contiguous regions that share aspects of climate and resources can be the basis of very effective knowledge-action networks. However, it is not clear that this success can be created in heterogeneous circumstances, when sectors are not regionally based. An urban sector, for instance, may encompass such enormous variation among decision makers in their day-to-day responsibilities that differences overwhelm commonalities traceable to climate and so form barriers to functioning networks.

Applicants for a sector-based pilot project should be asked to make the case that the knowledge-action connections they propose to establish are likely to provide new and useful climate information to a significant group of decision makers and that the relationship established with SARP funding is likely to continue after the pilot period. They should also be asked to show how their effort will contribute to knowledge about building knowledge-action networks and making them effective links between climate science and decisions.

We recommend that SARP not sponsor pilot projects for at least 1 year after funding the initial workshops in order to provide time to build experience and knowledge from the research and workshop activities. We emphasize the need for pilot projects to include a significant research component devoted to improving knowledge of the human dimensions of climate variability and change. The RISA Program experience has shown that it is expensive to operate a network. We are reluctant to recommend using scarce research funds for operational costs.

The number of pilot projects undertaken should depend on what is learned from the workshops about the number of areas that are ripe for successful pilot projects and on growth in the size of the SARP budget. We envision one pilot project beginning in year two. Given that an effective pilot project might cost up to $500,000 per year for 3 years, we do not expect that SARP will be able to afford to support more than one initially. Possibly two other projects could begin between year two and year five, when the program should be reassessed in light of changing needs, scientific capabilities, and resources.

SARP should not support long-term maintenance of networks created by pilot projects, and it may not even be able to offer continued support for the delivery of scientific information through them. Emerging networks would need to seek such continuing support from other sources. SARP's decision criteria for support of proposed pilot projects should favor proposals from researchers who have commitments for partnership from some relevant actors and organizations and that can make a convincing argument that their start-up efforts are likely to become self-supporting, perhaps through the availability of matching funds.

Investments in research and in communication processes should be selected to be mutually beneficial. Use-inspired research projects can identify sectors and networks that are worthy candidates for future workshops and pilot projects. As already noted, research efforts should also be integrated into and funded as components of workshops and pilot projects so that they will add knowledge while also improving communication and decision support. For the first year, research efforts should take up roughly half of SARP's budget. The proportion of program dollars committed to use-inspired research may change in subsequent years as the portfolio of research, workshops, and pilot projects changes and other sources of support for the needed research are identified.

4

Principles for Selecting Activities and Modes of Support

Because the needs for research and nonresearch activities to support sectoral decisions far exceed the current resources of the Sectoral Applications Research Program (SARP), it is necessary to select among worthwhile activities so as to use SARP's very limited resources efficiently. This is why we recommend that certain areas of research and network-building activities have priority for near-term support.

The first section of this chapter identifies a set of principles that we adopted for recommending areas of research and that we believe SARP can use in selecting from among what is likely to be a surfeit of worthwhile activities. There is some potential for conflict among some of these principles, an issue we address below. The second section discusses the modes of support that are appropriate for the selected activities.

PRINCIPLES FOR SELECTING ACTIVITIES

Links to the National Oceanic and Atmospheric Administration (NOAA) Mission and SARP Objectives

The principal criterion for setting priorities for activities to be supported is the congruency between the proposed activity and the objectives of SARP, namely, to foster the appropriate use of climate information in key socioeconomic sectors, defined by resources or decision arenas. Central to the NOAA human dimensions mission are the goals of identifying and reducing "vulnerability to climate variability and change in key socioeconomic sectors" and promoting "the enhanced and increasingly sophisticated use of climate information, including forecasts, in decision making" (see http://www.climate.noaa.gov/cpo_pa/sarp/ [accessed April 5, 2007]). Thus, SARP should support research and network-building activities that link climate information with its ultimate users and that assess users' needs for climate-related information and promote, facilitate, and assess the adoption, use, and effectiveness of climate-related information by relevant decision makers and other users. This criterion encompasses a far greater range of worthwhile activities than SARP can support. All the activities we recommend for near-term support, as well as the other research activities we have highlighted, meet this criterion.

Promotion of Social Innovation in Using Climate Science

We emphasize throughout this report that getting decision-relevant climate information used requires innovation within and sometimes among potential user groups and the creation of new communication networks and organizational functions. The evidence from social science shows that simply creating and providing useful information does not usually create use. Without better understanding of the sources of innovations and knowledge-based efforts to promote their adoption, the potential societal benefits of NOAA's major efforts to improve climate forecasts may not be realized. Thus, we recommend that SARP's near-term investments in research emphasize understanding the conditions that favor change in information-gathering, communication, and decision-making routines and the emergence and maintenance of networks and knowledge systems that can better inform decisions in sectors affected by climate variability and change. One useful initial approach would be careful studies of apparently successful models for network building. Our recommended communication-related priorities are also focused on meeting this criterion.

We reemphasize, however, that there are important mission-related social science research activities that do not focus on innovation in decision and communication processes. Although we do not think support of these activities can be justified within SARP's current and likely future budgets, they nevertheless deserve support as part of NOAA's human dimensions research effort.

High-Impact Decisions

SARP should preferentially support research to understand and improve the integration of climate information into large-scale, long-lived, and large-sector decisions because of the potential for long-term practical effects. Thus, other things being equal, it should give priority to activities that can improve decisions that affect large geographic areas (e.g., comprehensive growth planning for large estuaries) or large environmental sectors (e.g., coastal erosion). It should give priority to activities that can better inform decisions with long-term implications through appropriate use of climate science, such as infrastructure-related decisions that can reduce the vulnerability of specific coastal areas to disasters related to expected climate variability and change. Other examples include floodplain mapping and relicensing of dams by the Federal Energy Regulatory Commission. SARP should also preferentially support activities that are timely in terms of critical junctures in climate-affected decisions, such as re-signing international water treaties on the Columbia River.

Leveraging Investments Through Partnerships

SARP and the recipients of its funds should seek partners in funding and in operations, including state and federal agencies, private-sector firms and associations, and other nongovernmental organizations whose constituents would benefit from the dissemination of decision-relevant climate information and its integration in particular issue areas. Such partners might be willing to help subsidize the process financially or to take on some of the functions in a knowledge-action system, such as communication with constituencies or customizing climate information for them. Thus, a criterion for project priority could be participation, resource allocation, or matching funds from non-NOAA organizations. Partnerships between agencies with knowledge-development responsibilities and agencies with outreach and extension capacity may be especially fruitful.

Fertile Ground

SARP should preferentially support research and network building in sectors or with types of decision makers who are especially likely to use climate science or who can benefit greatly from it. One way to do this is to give priority to activities focused on the types of decision makers who have demonstrated interest in incorporating climate science into their decisions and practices. This is a strategy to invest in activities for which a positive return is most likely.

Another promising opportunity lies in linking findings from research on climate and its effects to salient climate-affected problems that must be addressed by an identifiable class of decision makers who have not yet demonstrated interest in climate information. For example, many state and federal agencies are charged with managing environmental pollution. Climate change is likely to alter how regulated pollutants are emitted; how they interact in air, water, and soil media; and how pollution can be mitigated. The organizational routines for making such management decisions have not previously included the use of climate information, including seasonal forecasts, but there is an obvious potential benefit of including them. SARP should support work to understand whether and how climate science information begins to be used in such organizational decision processes. SARP should also support workshop activities with types of decision makers who rarely use climate-related information but for whom there is a clear potential for making better decisions by doing so.

Increasing Resilience and Adaptability

Climate variation and change are expected to increase the frequency, intensity, and stochastic uncertainty of climate-related extreme events. These effects will not occur uniformly across all geographic regions, resource sectors, and political decision-making units. Other things being equal, SARP should give priority to research and network-building activities that focus on highly vulnerable places, environmental sectors, and groups of people. SARP should also emphasize ways to increase resilience (the ability to recover, using available natural and human resources) and adaptability (the capacity to change quickly in response to anticipated or actual events and to learn new strategies for preparedness and coping).

Equity

For reasons well known in social science, some sets of actors are much better organized and have access to more resources than others (see, e.g., Truman, 1955). Such differences are likely to be as true in coping with the challenges of climate variability and change as in other areas of human activity. Thus, the results of use-inspired, climate-related research may improve decision making and provide benefits primarily for organizations and interests that are relatively well endowed while doing little for less-privileged but no less vulnerable actors (Lemos and Dilling, 2007). Thus, we propose the use of equity as a criterion in selecting among scientifically strong proposals—favoring projects that offer the prospect of improving decisions in key sectors for which disadvantaged actors are likely to benefit.

We note that this criterion may sometimes favor just those projects that look weak on the criterion of fertile ground. Vulnerable and disadvantaged groups are often difficult to organize and to engage in communication with science, so that efforts to reach them may take more time and expense than efforts to reach organized groups. Project selection should take these differences into account. SARP should support a portfolio of activities that includes both investments for which returns are likely and more challenging activities aimed at unorganized or vulnerable groups.

Research of Interest to Social Science

To meet NOAA's social science mission and the objectives of SARP requires the highest quality social science research. The research questions we have formulated about decision-making routines and network creation and functioning have the potential to attract such research, as the behavioral and social science issues are fundamental as well as relevant to NOAA's mission. Proposed research projects should be evaluated in terms of how well they are conceptualized both in relation to mission goals for improved use of climate information and in relation to basic underlying social and behavioral science questions. Keeping the interest of basic researchers in social and behavioral science is a good way to attract promising ideas and high-quality researchers from outside the climate science community and thus maintain the vitality SARP.

MODES OF SUPPORT

The principles described above should help SARP leverage resources and concentrate its limited funds to create a robust research agenda that advances knowledge of how climate information is disseminated and integrated into decisions and how networks of decision makers affect those actions. Various traditional approaches exist for funding research programs, each with its advantages, limitations, and cost considerations. Several of these are summarized in the SARP context in Box 4-1. The best mode of support depends on the need, and for the three near-term priorities we recommend, the appropriate modes of support are fairly straightforward to determine.

Workshops

Grants are the obvious mechanism for supporting the recommended workshops. They take advantage of the strengths of this mechanism for framing research questions, developing networks of researchers and of researchers and practitioners, and improving communication among groups that do not normally interact. However, to encourage submission of proposals that combine workshops with use-inspired research on networks, it is worth considering a competition, guided by a request for proposals that would allow for research proposals, workshop proposals, and combined workshop-research proposals.

Research on Networks

Openly competitive research grants can encourage the involvement of strong researchers, but they can lead to a lack of focus on mission goals unless the research is guided by requests for proposals or the use of a contracting mechanism. Depending on the context, a contract can be preferable to a competitive grant or vice versa. For the targeted research areas we recommend supporting, SARP should offer research grants through request-for-proposal mechanisms. Contract research can also be appropriate for highly targeted research activities, such as research to evaluate workshops or to compare the results of different workshop activities.

Pilot Projects

The recommended pilot projects are intended to catalyze and provide initial support for knowledge-action networks. Such projects can appropriately be supported through research grants or contracts. Pilot projects involve relatively long-term commitments to help such networks become established on a solid scientific footing. However, SARP's resources are insufficient to make many or very long commitments of this type unless long-term matching support can be found. Thus, SARP should support pilot projects that have developed partnerships with organizations that represent certain types of potential users of climate science and that can promise either shared support or the likelihood that shared support will be forthcoming after initial support from SARP.

Other Activities and Modes of Support

Centers of excellence can provide a predictable research budget for concerted efforts over time on topics that are likely to be critical to moving scientific understanding forward over several years. One such topic is that of social innovations that can integrate climate-related information into potential users' information-gathering and decision-making routines. There is a good argument in principle for supporting such centers for this kind of effort; in practice, however, we do not advise creation of centers of excellence in SARP at this time because, given the size of the SARP budget, such an expensive, long-term commitment would foreclose too large a proportion of other research opportunities. In the future, the possibility of establishing SARP research centers should be reconsidered.

Research support should be provided for the overall evaluation of SARP and of its research and communication-related activities, as recommended in Chapter 5. Considering that the metrics for evaluation are not yet well developed, research that includes an evaluation component should probably be supported through a grant mechanism, with a request for proposals that calls on applicants to develop metrics and monitoring approaches that can be repeatedly applied.

BOX 4-1
Modes of Research Support

Workshop Grants

Advantages

- Can bring together researchers and decision makers for collaborative development of a research agenda.
- Improve mutual understanding between researchers and decision makers.
- Improve realism in research designs.
- Increase investment by decision makers who see that their interests are seriously addressed.
- Help researchers link their findings to potential users' concerns.

Limitations

- Difficult to document products of workshop and new learning.
- Learning from "one-shot workshops" likely to disperse quickly unless reinforced by continued contact (e.g., listservs, regular reports, etc.).
- If not skillfully run, some participants may become alienated from research and become less willing to collaborate.

Costs

- Minimal to moderately expensive, depending mostly on reinforcement activities; travel is main expense, which can be managed by locating workshops close to most participants or selecting low-cost locations for workshops.

Competitive Research Grants

Advantages

- Researchers quickly identify opportunities.
- Can leverage knowledge through other sources of funding (e.g., the National Science Foundation, the Department of Energy, and the Environmental Protection Agency).
- NOAA has built a cohort of social science researchers.

Limitations

- Can generate excellent research that does not add to knowledge in a systematic way; request-for-proposal mechanisms can help overcome this limitation by requesting targeted research.
- Peer review process is demanding on academics' time.
- Progress is difficult to monitor.

Costs

- Expensive to administer, for agency and grantee, especially for very small programs.
- Funding of multiyear or multi-investigator projects reduces amount of new research possible each year.

Planning Grants

Advantages

- Useful for bringing researchers together across disciplinary boundaries, leading to special issues of journals and long-lasting teams of collaborators.
- Can engage nongovernmental and governmental organizations in research efforts.
- Facilitate entrance of new researchers into a field, who may then tap other sources of funding.

Limitations

- Productive researchers may not be attracted by such small grants.
- Limited resources may be invested in projects that never materialize.
- May lead to unreasonably high expectations for future funding.

Costs

- Administrative costs not much less than for larger, competitive grants.

Matching Grants

Advantages

- Leverage matching funds from other sources.
- Guarantee institutional support for researcher.
- Create incentives to build partnerships.

Limitations

- Finding matches can be difficult, especially for new researchers.
- Sources of matching funds may not be willing to take a chance on new ideas or unproved investigators.
- Finders may resist sharing credit with other partners.
- Managing shared sources of funds through a variety of contracts and subcontracts is often difficult.

Costs

- Lower than for unmatched grants.
- Administrative costs the same as for competitive grants.

Visiting Social Science Position in NOAA (sabbatical or fellowship visits from academic institutions, as done, for example, in the Water Resources Institute of the Army Corps of Engineers and by Resources for the Future)

Advantages

- Innovation in agency.
- Improved skills of agency permanent staff.
- Increased understanding by academics of institutional barriers and organizational culture.

Continued

BOX 4-1 Continued

Limitations

- Some visitors have difficulty working productively in new settings.
- Time and energy needed to integrate a visiting scholar.
- Talents of visiting scholars may not match needs of agency.

Costs

- Expense of salaries, benefits, housing for visiting scholars.

Centers of Excellence (funds for centers focused on a particular topic in a single university or consortium)

Advantages

- Can build a critical mass of researchers for pressing problems.
- Can allocate large amounts of money with relatively low costs for monitoring, peer review, budget oversight.

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Limitations

- Centers can create their own bureaucracies with all the attendant limitations of inertia and high cost.
- High risk because center grants are given for potential, not necessarily accomplishments.
- Potential for suspicion and jealousy from nonfunded organizations.
- Administrative burden on principal investigators.
- Difficulty fitting into universities' disciplinary structures; poor cooperation.
- Competition among universities to entice original investigators, which can harm the research enterprise.
- Not a good strategy for network building.

Costs

- Greatly reduces funding flexibility in a small research program.
- Closing out proposals from other organizations.
- Need for ongoing assessment of effectiveness, with additional costs and staff burden.

Interagency Personnel Agreements (IPAs)

Advantages

- Effective for networking by bringing together researchers from different agencies.
- Can create critical mass of researchers in a single agency.
- Increase capacity of both loaned personnel and receiving agency.

Limitations

- Require that needed researchers are in agencies that can make agreements.
- Agency reluctance to part with effective people.
- Concerns about diminished loyalty and commitment to institutional culture among reassigned employees.
- Conflicting demands on reassigned personnel who may sacrifice career opportunities at their own agencies.

Costs

- Relatively inexpensive way to bring new knowledge and ideas into an agency.
- Easy to arrange: personnel departments are skilled at making these arrangements.

Contracts

Advantages

- Provide for specific services in a particular time frame; good for meeting clearly specified needs.
- Contractors can be held accountable for performance and deliverables.
- Can often be completed quickly.
- Good for convening and facilitating workshops, maintaining networks, and other research support activities.
- For some purposes private contractors can quickly put together interdisciplinary teams of experienced researchers and practitioners and can build and maintain networks over time.

Limitations

- Not ideal for innovation because they require a very thorough statement of work.

Costs

- Effort of developing statement of work and fashioning of legal language to make contractors accountable (can be minimized in organizations that extend contracts regularly.
- Usually more expensive than competitive grants because they must include full administrative costs.

5

Evaluating SARP

Systematic evaluation of performance is crucial for any public program, including research programs. Political leaders and program managers want and need regular, accurate information on what programs are or are not accomplishing; well-conducted evaluations can provide information for refining or revising program design. For program managers, evaluation can be a source of organizational learning and improvement. Stakeholders care greatly about what a program produces. And formal mandates, such as the Government Performance and Results Act (GPRA), require the regular identification of program metrics and provision of information on program performance.

In this chapter we focus on internal evaluation: What the National Oceanic and Atmospheric Administration (NOAA) should do to assess how the Sectoral Applications Research Program (SARP) is performing. Because SARP is a new and small program and one focused on research, it needs evaluative methods and criteria that are appropriate and feasible for a program with these characteristics. We begin by presenting a brief look at the textbook approach to evaluation and then assess the extent to which such an approach is appropriate for SARP. The results of this consideration shape the approach that we recommend.

TEXTBOOK PROGRAM EVALUATION

The Formal Model

In theory, a program should be assessed against the stipulated outcomes it was meant to produce. A full program evaluation would include a process evaluation, which assesses the quality, consistency, and comprehensiveness of a program's implementation, and an outcome assessment. The data for the assessment would include valid and reliable quantitative measures of the desired outcomes. For programs aimed at achieving a variety of results, metrics could be included for all of them. In theory, outcome data are available regularly, in time series, so that routine review of progress for both formative and summative evaluations can be undertaken.

Textbook evaluations presume a fully developed causal model that includes all the factors (including other public programs) that can contribute to the outcomes of concern. Only if all these influences are taken into account is it possible to determine the extent to which the program itself independently influences the results. The most convincing demonstrations of cause and effect depend on experimental and quasi-experimental research designs (see, e.g., Campbell and Stanley, 1966). When experimentation is not feasible, evaluations can measure a broad range of influences and statistically separate the effects of the program from the effects of other variables.

All these methods require a large number of cases, with the program applied in some and not others. They also depend on having policy objectives that are clear, unambiguous, and noncontradictory and on having all the required data. When these characteristics are not present, evaluation is much more complicated.

In fact, the textbook approach to evaluation has been possible only with some medical, public health, and social programs in which well-defined interventions are used in fairly large populations with well-defined objectives. And even in some of these programs, the evaluation has been difficult because the policy is vague or has multiple, partially incompatible goals (such as prison programs aimed simultaneously at punitive and rehabilitative outcomes). Outcome measures are also likely to be prone to multiple interpretations or to be controversial among the stakeholders.

Evaluating Research Programs

Research programs are often particularly difficult to evaluate by the textbook model (see Bozeman and Melkers, 1993; National Research

Council, 2007a). One reason is that the outcomes of research are various, and the paths to those outcomes are both varied and poorly understood. Thus, successful research activities can produce different kinds of outcomes, and any individual outcome measure is likely to be an imperfect evaluation tool. Moreover, concerns are commonly raised about the validity of the more readily available quantitative measures of research outcomes, such as citation counts, reputational studies, and so forth. Another reason for the inapplicability of textbook evaluation for research programs is that the fruits of research are rarely visible in the near term. A third reason is that applied research, such as that supported by SARP, has both scientific and societal objectives, so that specifying the outcomes and determining the appropriate metrics for them is very complex.

A number of approaches for assessing the outcomes of research programs, including research programs focused on science and technology utilization, have been used with some success (see Youtie et al., 1999). These include comparisons between those who use the research results and those who do not and identification of the reasons for use and non-use; studies of the effects of the program on networks of scientists and users; and an emerging "research value mapping" approach that examines the various ways a research program can produce value and then assesses effects using both quantitative and qualitative methods (see http//www.rvm.gatech.edu/aboutrvm.htm [accessed August 2007]). The research value mapping initiative aims to evaluate both the output produced by such a program and also the capacity—the scientific and human capital generated. Such capacity could be seen in enhanced cognitive skills, knowledge, or craft skills of those involved (Bozeman and Kingsley, 1997; Bozeman et al., 2001).

This brief review makes clear that there is no single, cookbook approach even to standard program evaluation and that such evaluation is far from a trivial undertaking. Evaluation of research programs is likely to be more complex than evaluation of large-scale operating programs. Because of these difficulties, programs are sometimes advised to spend approximately 10 percent of their annual budgets for evaluation (e.g., U.S. Government Accountability Office, 2002).

PRACTICAL CHALLENGES IN EVALUATING SARP

A number of features of SARP and its context suggest the need to carefully consider what can and should be expected in evaluating SARP. Most obviously, SARP is a research program, and as such, it is difficult to know which outcomes to expect, especially in the short term. This issue is a familiar one that scientific research programs face, including programs focused on climate change research (National Research Council, 2005c). Also, SARP is a new program. Techniques for evaluating research programs, like the value-mapping approach, often require data developed over an extended period of time—in short, they can be used only for mature research programs. An evaluation of the California Irrigation Management Information System (CIMIS), a program in the Office of Water Use Efficiency of the California Department of Water Resources (see http://www.cimis.water.ca.gov/cimis/welcome.jsp), based its conclusions largely on a comparison between conditions when users began taking advantage of the system—as far back as in 1982, when the program began—and recent conditions (Parker et al., 1996; 2000). Similarly, evaluations of the Sea Grant Program have had the benefit of being able to use an extensive time horizon going back to 1967 (e.g., National Research Council, 1994). In addition to lacking a track record, SARP is not connected to a causal model that can be used to identify expected outcomes from program inputs and outputs. Moreover, because the purpose of SARP is to generate new kinds of practical outcomes from climate research in diverse decision-making settings, with different kinds of decision makers and at different levels of analysis, it is not obvious in advance who will be affected or how their decisions may be changed. In this situation, the relevant outcome measures cannot be specified.

The relevant causal model for generating expected outcomes would be a model of human decision making. However, given the highly diverse decision contexts faced by such actors as floodplain managers, farmers, urban planners, and insurers, it is likely that different decision models may apply in different settings. It is certain that the right decision model(s) to use is unknown. Moreover, the outcomes of a use-inspired research activity are likely to be quite different from the outcome of a network-building workshop. Thus, assessing the outcomes of SARP will require different metrics for different elements of the program, as well as a fairly open-ended assessment process to allow for the possibility of very different kinds of benefits in different contexts.

Identifying the SARP "treatment" that is to be evaluated is also problematic. We recommend that SARP support three different kinds of activity—use-inspired research projects, workshops, and pilot projects—all of which have different objectives and therefore require different causal models as a basis for evaluation and also require assessment against different metrics. Developing these different models and the associated metrics presents significant assessment challenges. (See Box 5-1 for a summary of input, process, output, outcome, and impact metrics for assessing climate change programs generally.)

Some additional challenges for evaluation also deserve mention. One concerns the scale on which outcomes may appear. Climate change is by definition global, so that its costs, and the benefits of improved decision

BOX 5-1
General Metrics for Assessing Climate Change Programs

Process Metrics (measure a course of action taken to achieve a goal)

1. Leader with sufficient authority to allocate resources, direct research effort, and facilitate progress.
2. A multiyear plan that includes goals, focused statement of task, implementation, discovery, applications, and integration.
3. A functioning peer review process in place involving all appropriate stakeholders, with (a) underlying processes and timetables, (b) assessment of progress toward achieving program goals, and (c) an ability to revisit the plan in light of new advances.
4. A strategy for setting priorities and allocating resources among different elements of the program (including those that cross agencies) and advancing promising avenues of research and applications.
5. Procedures in place that enable or facilitate the use or understanding of the results by others (e.g., scientists in other disciplines, operational users, decision makers) and promote partnerships.

Input Metrics (measure tangible quantities put into a process to achieve a goal)

1. Sufficient intellectual and technologic foundation to support the research.
2. Sufficient commitment of resources (i.e., people, infrastructure, financial) directed specifically to allow the planned program to be carried out.
3. Sufficient resources to implement and sustain each of the following: (a) research enabling unanticipated scientific discovery, (b) investigation of competing ideas and interpretations, and (c) development of innovative and comprehensive approaches.
4. Sufficient resources to promote the development and maintenance of each of the following: (a) human capital; (b) measurement systems, predictive models, and synthesis and interpretive activities; (c) transition to operational activities where warranted; and (d) services that enable the use of data and information by relevant stakeholders.
5. The program takes advantage of existing resources (e.g., U.S. and foreign historical data records, infrastructure).

Output Metrics (measure the products and services delivered)

1. The program produces peer-reviewed and broadly accessible results, such as (a) data and information, (b) quantification of important phenomena or processes, (c) new and applicable measurement techniques, (d) scenarios and decision support tools, and (e) well-described and demonstrated relationships aimed at improving understanding of processes or enabling forecasting and prediction.

2. An adequate community and/or infrastructure to support the program has been developed.

3. Appropriate stakeholders judge these results to be sufficient to address scientific questions and/or to inform management and policy decisions.

4. Synthesis and assessment products are created that incorporate these new developments.

5. Research results are communicated to an appropriate range of stakeholders.

Outcome Metrics (measure results that stem from use of the outputs and influence stakeholders outside the program)

1. The research has engendered significant new avenues of discovery.

2. The program has led to the identification of uncertainties, increased understanding of uncertainties, or reduced uncertainties that support decision making or facilitate the advance of other areas of science.

3. The program has yielded improved understanding, such as (a) more consistent and reliable predictions or forecasts, (b) increased confidence in our ability to simulate and predict climate change and variability, and (c) broadly accepted conclusions about key issues or relationships.

4. Research results have been transitioned to operational use.

5. Institutions and human capacity have been created that can better address a range of related problems and issues.

6. The measurements, analysis, and results are being used (a) to answer the high-priority climate questions that motivated them, (b) to address objectives outside the program plan, or (c) to support beneficial applications and decision making, such as forecasting, cost-benefit analysis, or improved assessment and management of risk.

Impact Metrics (measure the long-term societal, economic, or environmental consequences of an outcome)

1. The results of the program have informed policy and improved decision making.

2. The program has benefited society in terms of enhancing economic vitality, promoting environmental stewardship, protecting life and property, and reducing vulnerability to the impacts of climate change.

3. Public understanding of climate issues has increased.

SOURCE: National Research Council (2005c:6-7).

support systems, may occur much more broadly than where a program activity is initially targeted. In principle, the evaluation of SARP should take international ramifications into account, although in practice this almost certainly is not feasible.

Another challenge is that part of SARP's mission is to generate connections that involve networked links across actors and organizations. Thus, some of the benefits of SARP may be realized through changes in other agencies and organizations at the federal, state, and even local levels. Such benefits are likely to be hidden or undervalued in most kinds of evaluations. As the Government Accountability Office (GAO) has noted, the GPRA process does not effectively address questions about program performance under these conditions (Government Accounting Office, 1999:32):

> Allocating funding to outcomes presumes that inputs, outputs, and outcomes can be clearly defined and definitionally linked. For some agencies, these linkages are unclear or unknown. For example, agencies that work with state or local governments to achieve performance may have difficulty specifying how each of multiple agencies' funding contributes to an outcome.

To the extent that SARP's success relies on the effective collaboration of multiple actors, especially organizations that span sectors, levels, and functional specialties, the usual processes for evaluating government programs under GPRA have serious limitations (for further analysis of the broader point, see Meier and O'Toole, 2006:63-64).

In addition, SARP operates in a "crowded" policy space in which multiple agencies are players and their collaborative action may be essential in delivering desired outcomes. Distinguishing SARP-specific outcomes from those that are a result of other agencies' initiatives may be exceedingly difficult and costly to accomplish.

Finally, we note the important difference in objectives between an evaluation carried out for assessing results for possible reprogramming of budget monies (the usual purpose of evaluations for the U.S. Office of Management and Budget [OMB]) and an evaluation conducted for organizational learning within NOAA. Given the newness of SARP and the uncertainties about the nature of its possible benefits, such learning is an important objective for any evaluation of SARP.

A MONITORING APPROACH TO EVALUATION

Because the standard evaluation approaches are not appropriate for the Sectoral Applications Research Program, we recommend that

evaluation questions for the Sectoral Applications Research Program be addressed by a monitoring program.

Monitoring requires the identification of process measures that could be recorded on a regular (for instance, annual) basis and of useful output or outcome measures that are plausibly related to the eventual effects of interest and can be feasibly and reliably recorded on a similarly regular basis. Over time, the metrics can be refined and improved on the basis of research, although it is important to maintain some consistency over extended periods with regard to at least some of the key metrics that are developed and used.

Such a monitoring emphasis would likely satisfy congressional mandates such as those of GPRA and the needs of OMB. Although it would not provide the ideal information to facilitate organizational learning for NOAA, such a monitoring system could nevertheless help to catalyze certain forms of learning: for instance, by noting apparent progress or lack of progress in developing some of the early and intermediate results anticipated by the program's managers and thereby leading to directed searches for better project designs or decisions to redirect funding toward project types that have showed the greatest apparent payoff in outputs.

In considering a practical approach to assessing SARP and its progress, it is important to bear in mind that the overall mission SARP was created to support requires a much broader range of research activities and a much greater level of investment than is available in the current SARP budget. Thus, it is important to assess SARP against reasonable expectations for what can be achieved within its areas of activity. In terms of the metrics identified in the National Research Council (2005b) report on this topic, the inputs to SARP are seriously limited, which puts corresponding limits on expectations for outputs, outcomes, and impacts. The following discussion is therefore organized around the three lines of activity we recommend that SARP emphasize in the next several years. It also includes our ideas on how to collectively assess the progress of these activities.

As detailed in Chapters 3 and 4, we recommend three lines of activity for SARP: a limited program of use-inspired social and behavioral science research to inform climate-related decisions in sectors defined by resources or decision arenas; workshops; and, at some point following the first year of workshops, one or more multiyear pilot projects aimed at facilitating existing networks or initiating new ones, to support and study the evolution of sectoral knowledge-action networks of decision makers and scientists. All three activities have some similar long-term objectives in terms of outcomes: to induce decision makers to consider and use climate information in their decisions and to do so appropriately. Thus, relevant outcome indicators include the extent to which decision makers in a sector seek out and then use climate information in their work. The eventual impacts of the use of climate information may be very difficult to determine and will certainly vary by sector and type of decision. However, a properly designed monitoring effort can track certain kinds of output and outcome metrics that are related to the key impacts of interest.

The three lines of activity are different, however, in how closely tied they are to the shared practical objectives. Pilot projects can reasonably be expected to change the actual information-collecting and information-using behavior of participating decision makers, and perhaps the information-collecting behaviors of participating scientists. Workshops may lead to establishing better communication between the producers and users of climate information, but other behavioral changes may occur only after effective communication has been in place for a while. The recommended research can improve understanding of these communication and behavioral processes. This understanding is an important outcome in its own right, and it should be evaluated as a contribution of SARP to basic science. In addition, the recommended research is intended to contribute indirectly to practical outcomes of importance to SARP, possibly by helping SARP do a better job of selecting promising projects or helping those who run workshops or pilot projects do so more effectively. It may also change understandings of the process of linking science to its users in ways that eventually alter some of the criteria for program evaluation. Thus, different kinds of activities require somewhat different metrics and different interpretations of the metrics. We begin by discussing pilot projects, which are most consonant with the program's desired practical outcomes, and then discuss workshops and use-inspired research.

Metrics for Monitoring Pilot Projects

An assessment of outcomes would seem to be especially appropriate for monitoring the performance of a pilot project devoted to the development of a knowledge-action network. Two types of outcomes are likely to result from successful efforts: (1) climate-related data will increasingly reach and influence target audiences of decision makers or potential decision makers, and (2) there will be increased capacity in decision systems to create decision-relevant climate information and make it available to users, including increased linkages between and among relevant groups and decision makers who could benefit from the use of such information. These outcomes may also be useful for assessing other components of SARP, including workshops.

Reaching and Influencing Target Audiences

Climate-related information may be valid and highly relevant to the needs of decision makers, but it will not influence choices that are made unless it reaches decision makers—and reaches them in a form that can be understood and used. What sorts of metrics might be useful for tapping the extent to which target audiences are being influenced by climate-related information? In this regard, it is helpful to keep in mind several characteristics of useful metrics, as explicated in a recent report of the National Research Council (2005c) "metrics should be easily understood and broadly accepted by stakeholders. Acceptance is obtained more easily when metrics are derivable from existing sources or mechanisms for gathering information." In addition: "Metrics should assess process as well as progress" (p. 51), and "a focus on a single measure of progress is often misguided" (p. 52).

Among the metrics that could be recorded fairly easily and regularly and that can be captured by minor modifications or additions to existing data systems, five stand out: the number of new partners receiving climate-related information; the variety of users; the number of new decision areas in which climate-related information is involved; the number and extent to which existing models, maps, texts, documents, assessments, and decision routines are modified to integrate climate-change information; and the judgment of target audiences. "New partners" can be considered in terms of individual decision makers, organizational units, and types of decision-making units. For example, in coastal zone management, units could be the number of coastal management organizations that request or receive information from the pilot project. In an effective SARP pilot project, this number in this metric should increase steadily over time.

The metric of the variety of users assesses the extent to which climate-related information is reaching a broadening array of decision makers, not merely a count of users. Over time, one would expect SARP as a whole to facilitate the distribution of climate-related information to more kinds of users, especially users previously unfamiliar with the decision relevance of such information, users drawn from very different kinds of decision contexts, users with widely varying experience with such information, users with differing degrees of professionalism (including, for example, laypeople), and users in more widely varying geographic settings. A SARP pilot project should, over time, reach an increasing number of the types of users operating in the sector of the project.

For the metric of new decision areas, a decision area can refer to something as broad as coastal decision making, agricultural decision making, health-related decision making. In the context of a pilot project in the coastal management sector, for example, the term could refer to classes or kinds of decision settings, such as decisions about infrastructure, strategic planning, or emergency preparedness. The expectation once again is that SARP will stimulate the penetration of climate-related information into more and more types of decision areas; pilot projects should do so in the sector they target.

For the metric on documents and decision routines, modifications may be relatively easy to track. Currently, for instance, virtually all floodplain maps ignore what is known about the likely effects of climate change on vulnerability to floods. The information is widely known to insurers and other relevant stakeholders, but the key documents on which important land-use decisions are being made in places like New Orleans and Sacramento do not include the best available climate knowledge. Slowly, success in SARP should be reflected in changes in these kinds of documents and other materials to more frequently and more regularly incorporate the best information drawn from climate-change research. The extent of incorporation can be tracked for each major type of document, decision aid, or decision routine if the documents, aids, and decisions can be identified in advance. Proposals for pilot projects should identify target tools or decision routines.

Finally, the judgments of target audiences are a useful metric. Potential users of climate science information can themselves provide valuable information regarding the extent to which their decision-making context has been altered in relevant ways, the kinds of information available and used in making decisions, and the extent to which they are aware of climate information and believe it to be relevant to their decisions. Surveys can be directed to specific types of users and customized with respect to the sorts of decisions and decision settings that are relevant. Focus groups can also be used as a supplement or alternative source of audience data. Since the range of possible users and decisions may be large, surveys would have to be aimed at selected, key target groups. For a pilot project, the target user groups should be known in advance. These effects will take time to become apparent, even in the best cases. Pilot projects should be monitored over several years. Over time, a successful SARP should see increasing knowledge and utilization of climate-related information among such critical groups.

Increasing Capacity

Improving decision support systems to make use of climate-related information means not simply influencing target audiences, but also expanding the capacity of varied groups of decision makers to consider and use climate information. New capacity includes the creation of networks and communication links that can make this information more readily useful. Four important metrics for assessing capacity are new links among target groups, the emergence of new kinds of organizations or functions, new products, and new investments in networks.

For target groups, one can monitor whether communication links, particularly between scientists and the users of science or groups representing the users, emerge as a result of SARP's efforts. Are the links sustained? Do they in turn trigger other patterns of networking toward still additional groups of users? Survey data or follow-up assessments, possibly at annual intervals, can help assess the extent to which these kinds of connections have been established. As SARP moves forward, and especially to the extent that the program chooses to emphasize capacity-building approaches, one should expect some linkages to dissolve while others develop, persist, and stimulate still additional connections—and thus additional capacity building.

One way the use of climate science information becomes institutionalized is by the creation of new organizations or organizational roles to fulfill intermediary functions between climate information producers and users. For example, weather forecasters and newsletters for decision-making groups (e.g., farmers, water managers) could begin to offer seasonal forecasts and recommendations for taking advantage of expected unusual seasonal conditions. Professional associations of users (e.g., city managers, floodplain managers) could create new working groups or staff roles for making climate science results accessible to members. Such changes usually take considerable time, but they might be expected from a multiyear pilot project. With still more time for climate information to work its way into a decision arena, monitoring could search for actual use of the information disseminated by the new organizational activities.

Over time, effective knowledge-action networks such as those to be catalyzed by the pilot projects are likely to change the activities of science producers so that some of them create new kinds of outputs to meet users' needs. In the case of regional decision makers, downscaled climate forecasts are an example of such outputs. For sectoral users, new outputs on the seasonal-to-interannual scale might include snowpack forecasts and estimates of growing season length; on the time scale of climate change, new outputs might include new estimates of the "100-year" and "500-year" flood or hurricane. Social scientists may also produce new outputs taking climate information into account, such as estimates of economic impact, population dislocation, or inequality effects due to future extreme events. Such changes in the behavior of scientists are likely to occur only after years of development of a knowledge-action network and thus might begin to emerge at the end of a multiyear pilot project.

Finally, increased capacity should result in new investment in networks. As the users of climate information become convinced over time of its value to them, large organizational users and well-funded associations of climate-affected decision makers may begin to invest money and staff time in developing new climate information products or in intermediary activities to make better use of climate information.

Metrics for Assessing Workshops

The main rationales for the recommended SARP workshops are to identify potential knowledge-action networks, to provide initial incentives for gathering and exchanging information among the producers and potential users of climate-related information, and to assess the feasibility of more sustained networking efforts. Workshops should therefore be assessed against those objectives and, over time and in the aggregate, the workshop activities should lead to more long-lasting, expanded, and substantive networks of the type the pilot projects are designed to help create. Some data to be used as metrics can be gathered from each workshop, and it is important that additional cross-sectional assessment be undertaken so that SARP can begin to understand why some network-building efforts are more successful than others.

We propose six candidate metrics for monitoring workshops:

1. Participation: Number of potential network actors (decision makers) who participate in the workshop activity, number of types of such participants, range of representation of science producers and users who have the potential to develop a sustainable network.
2. Partnership: Commitment of assistance or partnership from other potentially relevant organizations, such as extension organizations or professional associations of scientists and decision makers.
3. Participants' Judgment: Participants' overall assessment of the value of the activity, decision makers' judgment that climate science information can be useful to them, level of interest in continuing to participate, participants' desire to share information with other types of participants following the workshop, and participants' willingness to commit resources to continuing the effort.
4. Changes in Knowledge: If feasible and valid, preworkshop-postworkshop comparisons of participants' level of knowledge of the relevance of climate-based information to their decisions or of the types and variety of actors with whom they should regularly interact.
5. Changes in Communication: Increased efforts by scientists involved in the workshop to discuss research results with users involved in the workshop and other users in the same decision arena, increased efforts

of users to seek out scientists for climate-related information, additional meetings of science producers and users outside the workshop.

6. Capacity Building: Actual plans for and establishment of new forms and channels of network infrastructure (websites, listservs, newsletters, software, in-service training activities, committees or working groups, an executive group or secretariat, etc.), creation of new organizational roles or positions for linking climate science and users.

Many of these indicators are similar to those suggested for assessing pilot projects. However, workshops involve a lower level of program investment over a shorter period of time, and they occur when less is known about the relationship between available climate information and users' needs and about how to link science producers and users most effectively. Therefore, workshops should be considered as an early phase in the social innovation process, and expectations should be set accordingly.

SARP should also sponsor research across workshops to compare their outputs and outcomes, with a view to understanding the reasons for what are likely to be considerable differences in outcomes. These comparisons can be a major source of learning for SARP. In addition to measuring outputs and outcomes, this effort should include measures of inputs, initial expectations, and process variables for each workshop and a characterization of the decision context being addressed. Thus, it could be useful to gather from participants (or principal investigators) such information as:

1. characteristics of the projected network (e.g., number of different kinds of actors),
2. number of total actors,
3. number of different levels of decision-making responsibility (temporal and spatial scale of decisions involved),
4. level of initial interest,
5. evaluation of workshop format,
6. extent of participation by network participants/invitees in workshop design,
7. involvement by both climate and social scientists,
8. balance between scientists and practitioners,
9. degree of perceived salience of climate-related information to decisions of invitees in advance of the workshop,
10. extent of prior organization of participants, and
11. extent of partnership or cofunding for networking initiative.

Metrics for Monitoring Use-Inspired Research

The limited research program that we recommend for SARP should be assessed both for its contributions to basic knowledge and for its contributions to NOAA mission goals.

Contributions to Basic Knowledge

As with other climate research programs, SARP's research activities should be assessed against relevant input metrics (see National Research Council, 2005c), such as the sufficiency of intellectual and technological foundations to support the research and of resources to execute and sustain the work. The research should be assessed against such relevant process metrics as program leadership and strategic planning, strength of the peer review system, and strength of processes to facilitate the use of research results within the SARP planning process and by relevant outside audiences. The scientific contributions should also be assessed against relevant output metrics for science, such as producing peer reviewed and accessible results, developing a research community and associated infrastructure to support continued development and dissemination of the use-inspired work generated by the program, and developing institutional and human capacities to address related research issues. The key scientific outcomes from the research are likely to be improved understanding of the processes by which climate-related information comes to be produced in a use-inspired way and the means by which such information comes to be used or not used by those it can benefit. The nature of this understanding is unlikely to be measurable by quantitative indicators because of the nature of the processes being studied. However, it can be assessed qualitatively by advisory groups, and it can be seen in the effects of the knowledge on thinking in the relevant scientific communities.

Contributions to Mission Goals

SARP's use-inspired scientific activities can be expected to have outputs, outcomes, and impacts related to the NOAA climate science mission. The outputs can be assessed in terms of reports, journal articles, and similar writings that speak explicitly to the efforts in SARP and in related NOAA programs such as the Regional Integrated Sciences and Assessment Program to improve the links between climate science and its potential user communities. The outcomes of successful research efforts are likely to include changes in thinking among NOAA staff and others involved in building and maintaining knowledge-action networks about how best to catalyze the use of climate science information. The outcomes may include increased knowledge-based confidence among those audiences in their ability to organize effective programs. Research may also lead those involved in network-building activities, including those responsible for SARP-sponsored workshops and pilot projects, to organize these activities in new and more effective ways. Research may also lead to changes in the way workshops and pilot projects are evaluated and in the specifications written to request proposals for such projects.

An important ultimate impact of research would be more effective integration of climate information by decision makers. However, such mission-related impact metrics are unlikely to show discernible progress in the short term, for the several reasons discussed above. On a longer timescale it will be even more difficult, if not impossible, to separate the impacts of research efforts from those of program implementation.

CONCLUSION

Textbook program evaluations can be very valuable. However, given the small size of SARP, the expectation that desired outcomes will take at least several years to achieve, the multiple types and levels of decisions that could be influenced by climate information, the variety of relevant decision makers, and the multiplicity of programmatic approaches to shape decision support systems, such an evaluation approach is not appropriate for SARP. Instead, we recommend a monitoring approach.

A monitoring approach aims at recording and analyzing trends in metrics appropriate for each type of SARP activity (pilot projects, workshops, and use-inspired research). We have drawn on earlier work to identify several possible metrics for each type of activity. Multiple metrics should be sought—some that record processes in SARP and some that tap outputs and outcomes—in a regular monitoring scheme. Data should be recorded at regular intervals, perhaps annually. Whenever possible, monitoring should rely on existing sources of data and data that can be reliably collected without substantial time and resources, to limit the level of effort for monitoring this small program. Representatives from target audiences themselves should be asked to contribute to decisions regarding the details of data collection and surveys that could be most useful for monitoring SARP performance. We recognize that because the program is small and its context is rapidly changing, any form of evaluation will be challenging. Nevertheless, it is important for SARP to be able to learn from experience. It is therefore worthwhile to conduct careful comparative research on the results of major SARP initiatives and to seek to understand how outputs and outcomes are affected by program inputs, characteristics of the decision arenas, and other factors.

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