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Creating Broader Research Impacts through Boundary Organizations

Research Article

Abstract: *Climate science research documents and predicts changes in the physical environment. This information informs policy decisions and public programs through the design of human interventions that promote adaptive management. Since the early 2000s, federal funding has led to the creation of transdisciplinary regional climate workgroups to facilitate integrative knowledge coproduction and promote shared use of research results by scientific and nonscientific stakeholders. Labeled “boundary organizations,” these workgroups are tasked with facilitating partnerships between climate science researchers and practitioners with expertise in multiple physical and social science disciplines. When these organizations are successful, scientific findings and practitioner experiences are integrated to synergistically create usable knowledge about adaptive management that provides direct public value and creates broader societal impacts. This article explores the broader impacts provided by these boundary organizations through the establishment of regional research agendas and the communication of research results in ways that influence regional public policy and promote adaptive management.*

Evidence for Practice

- Boundary organizations integrate scientific findings and practitioner experiences to synergistically create usable knowledge about adaptive management.
- Providing a variety of user-focused research communications enhances issue literacy and salience and informs policy decisions and societal actions.
- Boundary organizations amplify public value creation and promote broader impacts.

In 1995, new federal grant funding by the National Oceanic and Atmospheric Administration (NOAA) in the U.S. Department of Commerce incentivized the creation of regional workgroups tasked with conducting multidisciplinary climate science assessments and translating research results in ways that inform policy decisions and foster social/behavioral programmatic actions that enhance community resilience. These workgroups reimagine the conduct and transfer of physical science research that is particularly relevant to the geographic area directly to local stakeholders who can utilize the findings. Instead of determining research agendas and then conducting or directing the research, the regional workgroups facilitate connections between multiple stakeholders across overlapping sectoral and organizational boundaries for coproductive processes and outcomes. When successful, research results are broadly communicated to policy makers, scholars, professionals, local industry members, and the public in a variety of ways to promote adaptive management through mutually interactive processes that inform decisions (Polanyi 1962).

Boundary organizations have as their main task the facilitation of voluntary, fluid, and informal partnerships with scientific and nonscientific stakeholders representing a wide variety of physical and social science disciplines. The purpose of these partnerships is to address complex physical and social science phenomena that overlap multiple disciplines and cross organizational sectors. Our research purpose is to identify the broader impacts of climate assessment workgroups as boundary organizations. Do they facilitate coproduction of usable knowledge that encourages societal action? Connecting physical science research with the design of social interventions can broaden the impacts of the regional workgroups and has the potential to enhance public value.

Boundary Organizations in the Climate Sciences

The creation of public value is not the sole domain of government programs—increasingly it is accomplished through collaborative interactions designed to leverage the subject matter experience of practitioners and the research expertise of scholars. This can be done through the work of boundary organizations, whose

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purpose is to create and sustain a link between knowledge producers and knowledge users. Building bridges between the research producers and consumers is challenging. A survey of 268 researchers from 29 countries found that institutional incentives support the linear, top-down communication of results through academic peer-reviewed journal articles (Shanley and Lopez 2009). While 34 percent of respondents ranked scientists as the most important audience for their work, only 15 percent considered peer-reviewed journals effective in promoting the usability of research findings.

Shanley and Lopez (2009) invited researchers to develop ways to catalyze knowledge production, transfer, and utilization. One way to do this is through the creation of synergistic knowledge networks, defined as knowledge that is produced when research scientists, practicing professionals, policy makers, and other key stakeholders collaboratively share expertise and experience. The results become usable knowledge when they are disseminated in ways that make research deliverables usable to other internal and external stakeholders (Lindblom and Cohen 1979, 69). Accountability, evaluation, and governance scholars have studied how to document the outcomes that occur in public programs, the impacts in policy arenas, and the broader impacts for civil society. Thus, public policy, administration, and management scholars are well positioned to catalyze knowledge transfer related to the wicked problems that society faces.

Within the heuristic of social science, knowledge produced by research has typically been recognized as interdisciplinary or multidisciplinary. The atmospheric sciences have an extended record of connecting research with practical problems that address societal needs, noting that basic and applied research contribute to the development of technology and products (Pielke 1997). Over time, as the collective understanding of coupled human and natural systems (CHANS) has expanded, scholarly research in the natural and social sciences has broadened to engage more experts, including social science researchers, practitioners, and public experts. To be successful, these broadened collaborations emphasize the need for transdisciplinary teams that create user-focused and usable knowledge.

Creating usable knowledge that transcends the knowledge produced in a single social or natural science discipline is possible through boundary organizations tasked with facilitating partnerships between multiple organizations and stakeholder groups. Mauser et al. (2013) described the work of boundary organizations as facilitating a seamless blend of stakeholder and academic involvement that leads to scientific integration to translate relevant scientific knowledge into action-focused results that are disseminated in a variety of communication formats to a wide range of stakeholders. These informal arrangements employ a framework for knowledge creation and use that is not like a linear production model but rather like an open systems and fluid access model (Bell, Shaw, and Boaz 2011; Cornell et al. 2013; Lemos et al. 2014).

The need for better understanding of the connections between physical science research and societal needs, especially at the interface of climate science research and the weather information needs of society, was recognized in the 2003 U.S. Weather Research Program supported by the National Science Foundation, NOAA, NASA, and the U.S. Navy (Pielke et al. 2003). Following the 2003

national climate plan, the 2010 and 2015 plans reiterated and expanded the national climate science research agenda to include emphasis on the integration of climate science into practice and the inclusion of policy professionals and practitioners in the knowledge creation cycle.

The climate science arena was an early adopter of the kinds of transdisciplinary research envisioned in the 2003 plan for a national weather research program. Beginning in 1995, federal funding of Regional Integrated Sciences and Assessments workgroups (RISAs) in NOAA's Climate Program Office (CPO) incentivized the creation of boundary organizations tasked with facilitating a research to practice approach that would impact policy decisions and climate adaptation by individuals, industries, and communities (Binder and Simpson 2009). Since the original RISA was funded, the number of RISAs has increased incrementally, with 15 RISAs funded over more than 20 years. Currently, there are 11 RISAs that are funded. This approach has made it easier for stakeholders to interact to improve social, conceptual, and instrumental learning and to enhance severe weather adaptation and improve climate change literacy (O'Brien, Marzano, and White 2013).

For example, the Southern Climate Impacts Planning Program (SCIPP) is a RISA funded in 2008 to coordinate the production of usable knowledge in order to improve climate-related hazard planning and promote resilience activities to mitigate economic, human, and environmental impacts on society. Drought is a primary area of focus for SCIPP research, since it is particularly pertinent to the six states that SCIPP serves (Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Tennessee). Why is drought research a valuable case for studying the contributions to policy making and broader impacts that boundary organizations, such as RISAs, can create? Consider this: between 1980 and 2014, 22 drought events had impacts costing a billion dollars or more *each* (NIDIS Program Office 2016, 9). According to the National Centers for Environmental Information, since 1980, droughts have cost the United States more than \$200 billion.

The creation and evolution of the RISAs offers a contextual example for exploring the extent to which synergistic knowledge produced by a boundary organization fosters interactive relationships between knowledge producers and users to inform decision making and to influence next-generation strategic plans and research. The development of a reflexive knowledge production cycle enlarges public value creation and enhances the potential for broader societal impacts. Effective boundary organizations offer the potential to efficiently align empirical research, theory development, policy decisions, and professional practice. To gain an understanding of how well they do this, our research examines how RISAs facilitate the coproduction of usable knowledge and promote adaptive management in the drought arena to provide broader societal impacts. We address two research questions: (1) are there improvements over time in the alignment of research results with strategic plan emphases, and (2) are research results more frequently communicated in ways that are user-friendly?

Literature Review

Theory development and the creation of knowledge that informs (and improves) practice is particularly important in public policy,

administration, and management (Ebdon and Franklin 2006; Franklin and Ebdon 2007; Waldo 1973). To produce public value from synergistic knowledge requires the combined and interactive efforts of multiple stakeholders, especially researchers and practitioners. More than 20 years ago, collaboration through the development of a network of actors was recognized as a critical mechanism for addressing complex issues in the public policy literature (Provan and Milward 1995). Networks that effectively and efficiently coproduce publicly valued outcomes are espoused as useful for decision making and implementation, even if the actors work independently in different time frames and for distinctly different purposes and/or outcomes. The knowledge of one network actor provides the outcome feedback necessary for other actors to contribute to desired impacts.

At roughly the same time that networks were introduced into the public management literature, Byerly and Pielke observed that “society expects substantial benefits based on the justification scientists offer for federal support” (1995, 1531). Society’s expectations have been articulated as top-down pressure from funders and research policy makers who desire greater social and economic research impacts. Doing this requires the involvement of multiple communities of experts (Clark et al. 2016; Eynon 2012). This suggests a gap between what scientists understand as useful information and what information users need for decision making (Lemos, Kirchhoff, and Ramprasad 2012). For pragmatic as well as normative purposes, empirical results must be purposively communicated in formats that are accessible to a wide range of users (Hirsch Hadorn et al. 2006). User-focused research deliverables embrace the realities that multiple types of knowledge can be applied to complex public problems and that decision-making processes benefit from information that balances scientific evidence with multiple stakeholder preferences (Raadschelders and Whetsell 2017).

The engagement of a wide range of stakeholders underscores the process model of boundary organizations and has been described as “a negotiation support process engaged in creating usable knowledge and the social order that creates and uses the knowledge” (Clark et al. 2016). An earlier model in the Netherlands was successful through its internal processing and external continuous advisory practices with information users (Boezeman, Vink, and Leroy 2013). Combined, these activities increased acceptance of the legitimacy of knowledge by policy makers, leading to a condition of adaptive governance. Reporting on the Dutch experience, Klaster, Wilderom, and Muntslag (2017) concluded that regional networks are good for translating national policy into action, but there is a need for an administrative organization to facilitate network relations and short-term goals. The organization they describe is a boundary organization.

According to Brunner (2010, 306), adaptive governance develops in response to the failure of scientific management approaches that compartmentalize wicked problems and have an overreliance on technocratic solutions. Instead, it is necessary to factor a large problem into smaller problems and to harvest experience from local communities into knowledge networks, each more tractable scientifically and politically, which can open additional opportunities for advancing common interests on the ground. Three

decades earlier, Nowotny (1990, 165) promoted the importance of connecting the resilience of natural environmental systems to human forms of intervention through attention to the creation of usable knowledge.

Combining interdisciplinarity and the participation of additional nonscientific actors is the pragmatic definition of transdisciplinarity; it is both an attitude and a form of action (Jahn, Bergmann, and Keil 2012). Transdisciplinarity fosters new understandings of the relationship of science and society (Thompson Klein 2004) by integrating the domains of science, management, planning, policy, networks, coproduction, and practice through interactive processes. Knowledge produced in this way is more relevant and usable for solving problems and managing the fit between what users want and what science offers (Jahn, Bergmann, and Keil 2012, 5). This, in effect, changes the social contract; researchers are not merely producers of information but also active partners in knowledge production with accountability for enhanced program outcomes and policy impacts related to wicked problems (Roux et al. 2010).

Key to transdisciplinary knowledge production are knowledge brokers (people or organizations) tasked with sharing and integrating knowledge around, and creating connections between, researchers and various audiences (Meyer 2010). When successful, knowledge brokers are intermediaries that inform, consult, match make, engage, collaborate, and build capacity between collaborators (Michaels 2009).

To be certain, scholars realize that transdisciplinary research is not the Rosetta stone for producing usable knowledge (Jilke, Van de Walle, and Kim 2016; Kersting et al. 2012; Stein 2009). In practice, there is often an emphasis on the physical over the social sciences; however, each is impacted by the other (Wilhite and Glantz 1985). Transdisciplinarity requires a plethora of stakeholders with scientific and experiential expertise; there are no single disciplinary experts (Ludwig 2001). Creating useful knowledge through the facilitation of boundary organizations must also overcome problems with the critical/reflexive ambition of coproduction and the utilitarian interpretation of coproduction (Löfbrand 2011), instead considering the multiplicity of worldviews present in contemporary science. This increases legitimacy, ownership, and accountability for wicked problems, as well as for the solution options (Hall and Battaglio 2018; Mauser et al. 2013). Producing deliverables that reflect synergistic knowledge production (as in Star and Griesemer’s [1989] “boundary objects”) is a “delicate merging process... of simultaneously positioning and negotiating with multiple social worlds” (Boezeman, Vink, and Leroy 2013, 169). Next, background information on drought boundary organizations is provided to explore the prospects for boundary objects to enhance public value.

Drought Science Background Information

Nearly two decades ago, drought researchers and practitioners formed collaborative workgroups made up of experts from a variety of social, physical, and natural sciences who worked to develop sustainable answers to regional climate challenges. Since 1995, transdisciplinary workgroups have been organized within academic institutions and work closely with NOAA’s Climate Program Office. Uncertainties surrounding interactions between climate change and society were a primary rationale for creating RISAs. This uncertainty

prompted decision makers to seek out teams of natural and social scientists for collaborations to better understand climate and social interactions and to jointly produce synergistic knowledge designed to be actionable for reducing risk and enhancing resilience in the face of climate variability and change (see, e.g., <http://www.climas.arizona.edu/about>).

The RISAs facilitate interactions that inform decision makers and support science experts conducting climate science research in order to expand the nation’s capacity to prepare for and adapt to climate variability and change. When this facilitation is successful, researchers and practitioners jointly produce regionally relevant research that informs resource management, planning, and policy decisions. Figure 1 depicts the vision of how RISAs work with public and private user communities.

The research findings of RISAs are boundary objects that are produced in a manner that emphasizes usable information for stakeholders, meaning anyone who has an interest in climate science. Examples include (but are not limited to) federal, state, and local resource managers; elected officials; community planners; utilities; tribal governments; the private sector (e.g., farmers, property owners, consulting firms, businesses); nonprofit organizations; media; researchers; educators; and members of the general public (Binder and Simpson 2009, 61).

Research deliverables can include general research findings, models, data, forecasts, research papers, decision support tools, public information announcements, outreach and education materials, organization information communicated in publicly accessible databases, GIS mapping tools, fact sheets, webinars, newsletters, pictures, videos, maps, white papers or working papers, workshop reports, podcasts, brochures, blogs, Listservs, and social media postings. These types of research deliverables are critical for “developing a mixed portfolio of products, research reports, communication approaches, and applications credible to scientific

and operational communities” (Pulwarty, Simpson, and Nierenberg 2017, 388).

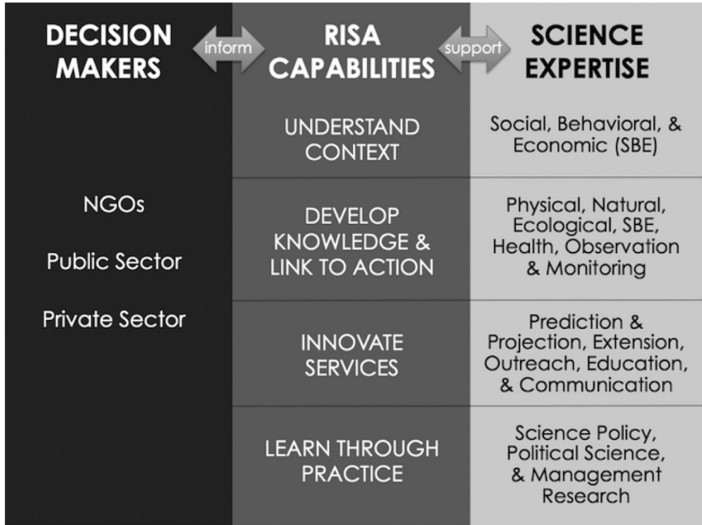
Through their annual reports, the RISAs and the CPO conclude that the RISAs are successfully fulfilling their purpose through the processes they use. These claims are supported by data analytics demonstrating the large number of stakeholders who use the information disseminated by the RISAs and the inclusion of RISA results in public policy discussions. Scholars also concur with these conclusions. Kirchoff, Lemos, and Dessai (2013) confirmed that RISAs engage in boundary work and foster interactions, aid in forming and maintaining dedicated user networks, and promote information uptake. Meadow concluded, “The RISA model has become an enduring network of people focused on providing usable science to the public. Staff and researchers often stay with the teams for years” (2017, 23).

The deliverables that RISAs produce have been applauded by several scholars. Lemos and Morehouse (2005) found that RISAs foster higher levels of innovation and produce research that has direct social impacts. RISAs have been successful in providing usable deliverables because they reduce barriers and leverage drivers of information use to produce usable knowledge through sustained and frequent interaction between scientists and stakeholders (Kirchoff, Lemos, and Dessai 2013, 400). Another study concluded that RISAs facilitate effective two-way communication to coproduce user-driven knowledge that results in credible, salient, and legitimate information (Lemos et al. 2014, 275). This is possible because the knowledge network collaborators have continuous interaction across the producer-user divide which critically enhances knowledge usability (Lemos, Kirchoff, and Ramprasad 2012, 789).

Does the RISA model of a boundary organization produce direct social impacts? One way to assess this is to gain an understanding of the extent to which strategic plans, which communicate long-term directions and the short-term activities necessary to contribute to impacts, influence research deliverables. A second way to assess this is to examine how the research results are communicated to determine if the knowledge can be used by the intended audience. Our research considers how drought knowledge production has changed over time to improve public policy decisions and drought resilience programs.

Methods

A two-stage analytical strategy was used to assess whether broader research impacts have been occurring over time and how this trajectory varies as a result of two events: (1) the creation of the RISAs in 1995 and (2) the nationwide 2003 strategic plan emphasizing integrative science and partnerships between scientific researchers and practitioners. In the first stage, we comparatively analyzed strategic plan emphases using the 2003, 2009, and 2015 national strategic plans related to climate science and drought. In the second stage, we analyzed drought research deliverables before the 2003 national strategic plan and then every subsequent year up to 2017. The research team included a professional drought/ climate science researcher who provided subject matter expertise for the research design and guidance in identifying areas of emphases in strategic plans, the keywords for identification of research deliverables, and coding categories.



Source: Climate Program Office, NOAA, “About the Regional Integrated Sciences and Assessments Program,” <http://cpo.noaa.gov/Meet-the-Divisions/Climate-and-Societal-Interactions/RISA/About-RISA> (accessed July 12, 2017).

Figure 1 The RISA Model

In the first phase, national strategic plans were analyzed to assess the expected role of RISAs as boundary organizations charged with the facilitation of integrative climate science, particularly in the area of drought and improving community resilience. Even though the RISAs were created in 1995, there was no national strategic plan specifying areas of emphasis in drought research or climate science until the 2003 U.S. Climate Change Science Program strategic plan (Climate Change Science Program and Subcommittee on Global Change Research 2003). Two additional strategic plans, the 2009 RISA and the 2015 CPO strategic plans, articulated additional expectations for RISAs related to drought research. Even though the federal organization that authored the three strategic plans has not been consistent over time, the strategic plans used in this analysis were all authored by some unit within the Department of Commerce/NOAA, which houses the CPO and RISAs.

Each of the three strategic plans included goal statements, prioritized topics and areas of focus (objectives), examples of key research activities, and expected time frames for results. We analyzed the content of each document to identify the expected processes and outcomes related to RISAs and/or drought. The strategic plans were human coded at the sentence, or sentences within a paragraph, level. This coding was verified by other members of the research team. The expected processes and outcomes emphasized in each of the three strategic plans were documented to identify commonalities and trajectories over time.

In stage two of the analysis, we examined research deliverables related to drought to determine whether there have been changes over time to better serve the needs of both scientific researchers and nonscientific practitioners. The research deliverables were divided into two categories: (1) scholarly literature (including books, book chapters, and journal articles) and (2) “gray literature” (including things such as research reports, workshop summaries, working papers, newsletters, briefing documents, slides from collaborative meetings, accessible data portals, and other non-peer-reviewed publications).

Items in the scholarly literature category were coded as being targeted to scientific/academic audiences. Items in the gray literature category were coded as being appropriate to the nonscientific community since they are often developed interactively with partners and research results are communicated in a variety of formats that are user-friendly and prompt action. The assignment of the research deliverables to the scholarly or gray literature categories reflects the fact that, over time and in part because of the creation of the RISAs, drought research is done by professional research scientists as well as faculty researchers. For example, the SCIPP RISA currently has 21 investigators and partners, of which the majority do not hold traditional full-time faculty appointments (see <http://www.southernclimate.org/>). This means there is less reliance on academic journal publications in favor of the production of gray literature research deliverables. These deliverables are reported in a variety of formats that are user-focused to encourage utilization. Additionally, they have the advantage of being faster to release since they do not require peer review.

To identify research deliverables, data were obtained from four sources: the American Meteorological Society journal database, JSTOR/Google Scholar, Web of Science, and RISA documents and

websites. These sources allowed for the identification of single and multidisciplinary research deliverables. They also provided a mix of scholarly and gray literature items. For each of the four data sources, the original search term was “drought.” This search term yielded in excess of 75,000 potential items for analysis. Second-round search terms combined “drought” and “climate” and searched specifically for the term “RISA.” We then refined the results to make the data more comparable and to limit the items to the United States and the English language (additional detail is provided in the Supporting Information in the online version of this article). The search strategy identified more than 8,000 research deliverables with an aggregated count of more than 12,000 Web of Science keywords that were used in our analysis.

According to empirical studies analyzing the comparative strengths and weaknesses of single and multidisciplinary bibliographic databases, the multiple-source search strategy mitigates threats to validity associated with reliance on a single database (Franceschini, Maisano, and Mastrogiacommo 2016). While the American Meteorological Society journals do not represent a single discipline, historically they have been favored as the authoritative source for those in the natural sciences. Similarly, JSTOR is revered primarily for scholarship in the social sciences (Lasda Bergman 2012). Combined, however, these sources provided a way to explore natural and social/behavioral science drought research integration.

The research strategy included two data sources that were truly multidisciplinary: Google Scholar and Web of Science. However, these databases are not without their critics. While Google Scholar is credited with having a wealth of data continuously scraped by its web crawler, the indexing feature does not benefit from expert judgment (Li et al. 2010). Additionally, Web of Science has received criticism for not addressing omitted citation errors (Wang and Waltman 2016). While no one bibliographic database is superior, the utilization of a combination of databases (Shah, Mahmood, and Hameed 2017), as well as a population sample for the RISA deliverable subset analysis, is expected to produce a robust data set for this analysis of drought research.

Results

To identify the broader social impacts of the RISA’s over time, we first reviewed federal strategic plans, then we reviewed the research deliverables to determine their alignment with strategic plan goals. This section provides descriptive information about the emphases in strategic plans since 2003 and analyzes the volume and kinds of drought deliverables produced over time.

Changes in Strategic Plan Emphases

In 2003, the U.S. Climate Change Science Program strategic plan included Question 4.5: “How can information on climate variability and change be most efficiently developed, integrated with nonclimatic knowledge, and communicated in order to best serve societal needs?” (Climate Change Science Program and Subcommittee on Global Change Research 2003, 57). Progress on this goal was estimated to be measurable in two to four years. The strategic plan specifically mentioned the RISAs’ contribution to this goal.

We inductively analyzed the emphases mentioning RISAs or drought in national strategic plans. Reviewing the language in

context, we determined that climate research was to be developed with an intended purpose of providing information about adaptive management practices. Additionally, there was a strong desire to integrate climate with nonclimate knowledge (such as was necessary in the CHANS concept), then to communicate this knowledge in ways that could serve societal needs. To accomplish this, two themes were identified in the 2003 strategic plan. These themes were partnerships and integrated climate science. As shown in table 1, our analysis confirmed the continuation of the themes in later strategic plans.

The RISA 2020 vision document reported that gains had been made in the nationwide goal of integrating climate science. By 2009, there were complementary regional and local climate research agendas that featured multilevel and multidisciplinary partnerships between the Regional Climate Centers, state climatologists, the National Weather Service, and other federal agencies. The partnership emphasis was being pursued through “the long-term relationships RISAs have developed with decision makers and stakeholders at multiple levels of government and the private sector” (Binder and Simpson 2009, 1). In addition, societal needs for decision making to be guided by evidence were being served, as suggested by this statement: “The types of products and management efforts undertaken by the RISAs vary widely but share the common feature of emerging from real-world challenges faced by stakeholders.” The impact of these partnerships was suggested by this statement: “Coincident with this expansion, RISA teams are increasingly asked to serve a broader network of users, adding state and local legislative, policy, and planning entities to the existing base of operational constituencies, as well as responding to steady growth in information demands from the general public and the media” (Binder and Simpson 2009, 1).

Looking to the future, the 2009 plan predicted that by 2020, the RISAs “would need to assist local decision makers to understand climate trends, anticipate impacts and formulate adaptation strategies through sophisticated information and information delivery techniques” (Binder and Simpson 2009, 2). Within the language of the 2009 strategic planning document (18–19), the overarching goal emphases to accomplish this were to (1) provide continued leadership and innovation, (2) improve climate literacy of decision makers and build community capacity to adapt to climate, (3) inform policy through knowledge and stakeholder dialogue, (4)

pursue new collaborations, and (5) promote use of the expanding suite of data and capabilities to prepare for climate variability and change (data and modeling/prediction tools).

Many of these areas of emphasis appeared in the 2015 strategic plan, which included a focus on developing regional integrated information systems for (1) monitoring and forecasting, (2) risk assessment and scenario generation, (3) education and public awareness, and (4) embedding information in preparedness and adaptation (Climate Program Office 2014, 16).

To summarize, starting in 2003 with language emphasizing multidisciplinary research integration and communication and meeting societal needs, later plans included calls for the development of data and predictive models and communicating impacts and adaptation strategies for specific geographic regions as well as the nation. The language in the strategic plan goals suggests a shift from integrating climate science with nonclimatic knowledge (human behavior and professional experiences) and emphasizing collaborative relationship development in 2003 to an emphasis on enhancing climate literacy through regional stakeholder dialogues to inform policy decisions in 2009. Beginning in 2009, and continuing in the 2015 plan, there is a growing emphasis on creating tools for the measurement and prediction of drought impacts, as well as assessing the effectiveness of adaptation strategies. All plans emphasized the development and transfer of tools for drought measurement and forecasting that must be integrated with professional knowledge and communicated to improve climate adaptation literacy and evidence informed decision making.

The underlined words in table 1 draw attention to the overlapping keywords across the strategic plans. On the left side, there is an overarching emphasis on the integration of climate science research that provides information through the development of monitoring and prediction tools. This information is then useful for decision-making and adaptive management that has societal impacts. Communication of this information is consistently emphasized on the right side of table 1, with a desire for information that educates, improves literacy, and informs policy dialogue. Facilitation of user-focused partnerships around this information allows for the integration of climate and nonclimate knowledge and advances shared interests and impact. In the next section, drought research deliverables are analyzed to see whether there is a parallel evolution in the integration of climate and nonclimate science and the facilitation of user-focused partnership in the language of research results.

Table 1 Major Emphases Related to Drought in National Strategic Plans

Integrate Climate and Nonclimate Science	Facilitate User-Focused Partnerships
2015: Advance scientific understanding, monitoring, and forecasting of climate change and its <u>impacts</u> Embed information in <u>decisions</u>	2015: Provide information for <u>education</u> and public awareness Build on mutual strengths and interests to advance value and <u>impact</u>
2009: Build <u>adaptive</u> capacity Provide innovation in climate science Promote use of drought tools for <u>decisions</u>	2009: Improve <u>climate</u> literacy Develop new collaborations and <u>partnerships</u> with <u>decision</u> makers Inform policy through knowledge and <u>dialogue</u>
2003: Develop <u>climate</u> information for <u>adaptive</u> management	2003: <u>Integrate</u> w/nonclimate knowledge <u>Communicate</u> to serve societal needs

Changes in Research Deliverables

With this description of how specific RISA activities and outcomes are encouraged through national strategic plans, the analysis turns to the question of what is the record of producing user-friendly research deliverables? To answer this question, we first established trends over time in drought research deliverables. Recall that our search for drought research-related publications yielded over 8,000 items with more than 12,000 Web of Science keywords associated with the items. Figure 2 illustrates changes over time through four stacked bar layers, with each layer representing the percentage of those research deliverables in relation to all that were published in that year. The bottom two layers are items from single physical

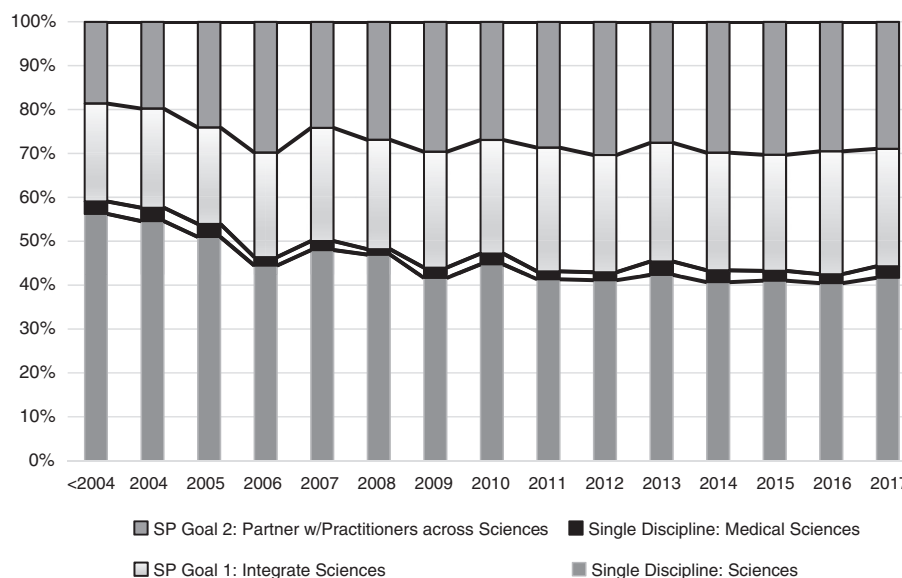


Figure 2 Changes in Drought Research Categories ($n=12,311$)

science disciplines, as well as items that represented single medical science disciplines. Over time, the proportion of single discipline drought publications has dropped from just under 60 percent before the 2003 national strategic plan to just over 40 percent of all drought publications.

By comparison, the top two bars in figure 2 represent multidisciplinary research deliverables only. These items were coded within the categories that align with goals stated in national strategic plans beginning in 2003. For the strategic plan goal calling for integrated climate science that includes natural and/or social science disciplines (the second set of bars from the top in figure 2), the research deliverables began as 22 percent of the total in 2003 and rose to 27 percent by 2017. Improvement can also be seen in the partnership goal, with the percentage of drought research deliverables increasing from 19 percent to 29 percent between 2003 and 2017 (the top set of bars in figure 2). When considered as a whole, figure 2 suggests that the drought research community has expanded to include researchers from a wider range of disciplines and that the research produced has become better aligned with national strategic plans over time.

The introduction of the RISAs in 1995 heralded a new era for federal funding that emphasized researcher partnerships intended to produce usable knowledge for a wide range of climate science stakeholders, and in particular practitioners. By the 2003 national climate science strategic plan, the RISA model of facilitating multidisciplinary partnerships and collaboration with practitioners in the design, conduct, and use of research project results was secure.

We analyzed a subset of the drought deliverables produced by the RISAs to provide comparative data concerning the extent to which the intended outcomes from the strategic plans were being achieved. Figure 3 displays the distribution of the 306 RISA deliverables between the two strategic plan goals. The “no date” column represents 174 items of which the majority are gray literature; however, for all years, 53 percent of deliverables were academic publications that supported the integrate science

goal, while 47 percent were gray literature items that supported the partnership goal. Figure 3 suggests that the RISAs produced deliverables that were 100 percent multidisciplinary and supported the goals articulated in the 2003, 2009, and 2015 strategic plans.

A recent development in the RISA operations model has been the submission of annual database information describing projects that each RISA is currently working on and its collaborators. Analysis of the 2017 project database provided an in-depth examination of projects, partners, and processes to assess knowledge coproduction and intended information users to discern the current trajectory of usable knowledge.

In 2017, the RISAs were working on 185 projects with nonfederal partners included on more than half of the projects. The stakeholders identified as end users of the knowledge produced included other scholarly and professional researchers, decision makers, practicing professionals, the media, and residents of the local community. The boundary objects to be created from these projects are wide-ranging. Overall, 426 different uses were identified, including communication (21 percent), academic publication (26 percent), white papers (7 percent), decision support (12 percent), data tools (17 percent), and presentations or meetings (17 percent).

How these projects are intended to contribute to the strategic plan emphases is also clear. For each project, the RISA identifies how it is linked to the four program objectives established by the CPO: (1) advancing policy science, (2) innovating services, (3) supporting knowledge exchange, and (4) understanding context and risk. RISAs could select multiple objectives from this list for a single project. Eight of the 11 RISAs had projects in 2017 designed to advance science policy; overall, 11 percent of all the reported objectives for the 185 projects were designed to advance science policy. Nine of the 11 RISAs had projects intended to innovate services; overall, 18 percent of all reported objectives were in this area. Each of the RISAs had projects intended to support

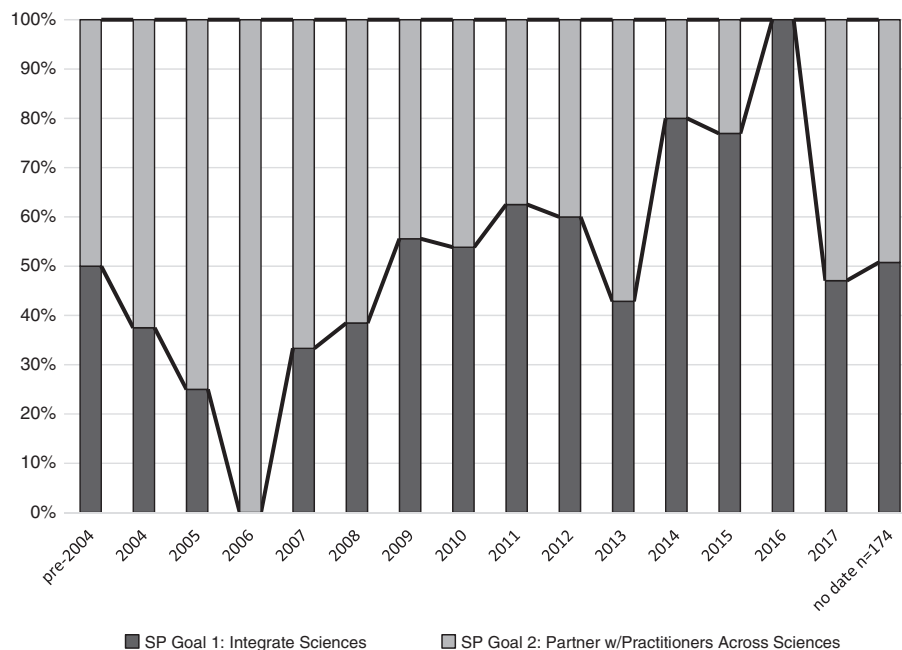


Figure 3 Changes in RISA Drought Deliverables by Strategic Plan Goal ($n=306$)

knowledge exchange and enhance the understanding of context and risk; these objectives represent 35 percent and 37 percent of all reported project objectives, respectively. From this information, it appears that the RISAs continue to be engaged in projects that are aligned with strategic plans emphases and intended to produce usable knowledge.

Combined, the data from multiple sources allow us to conclude that there have been improvements in the alignment of research results with strategic plan emphases over time. In the years leading up to and following the 2003 strategic plan, the focus was fairly evenly balanced between research deliverables seeking to integrate climate and nonclimate science with those aimed at enhancing literacy, building partnerships, and informing decisions related to policy and practice. When analyzing the projects currently in progress, there is an ever-increasing number of stakeholder partners and greater variation in the type of research deliverables produced by the RISAs. The second research question also has a positive conclusion: over time, there has been a noticeable effort to communicate research results in ways that are user-friendly and more readily accessible through websites rather than in academic publications, which are often only available with a subscription or for a one-time user fee.

Expanding collaborations between scientific and nonscientific stakeholders is desirable since nonscientists have frontline knowledge of implementation contexts, contingent circumstances, and strategic behaviors (Fowlin and Cennamo 2017; Meadow et al. 2015). This means that knowledge producers have a direct communication pathway to knowledge users, increasing the likelihood of evidence informing policy making and policy implementation (Dilling and Lemos 2011; Guston 2001). This matching of research demand and supply is one of the benefits of boundary organizations expected in theory and is demonstrated in practice based on this analysis of the regional climate science workgroups.

Conclusion

Leveraging the drought policy arena as a case, this research compared strategic plan emphases and research deliverables to identify patterns over time in the creation of broader societal impacts provided by regional climate science workgroups functioning as boundary organizations. We found that over 15 years, two primary strategic plan emphases (the integration of climate and nonclimate science and the facilitation of user-friendly partnerships) have resulted in research deliverables that communicate knowledge in ways intended to foster utilization by both researchers and practitioners. Operating as boundary organizations, the RISAs facilitate collaborative processes that improve knowledge production and provide research deliverables that describe current conditions to inform adaptive management policy and practices. This trajectory of coproduction provides broader societal impacts through the creation of usable knowledge for adaptive management.

These results are in line with Lindblom and Cohen's call (1979, 54) for professional social inquiry that promotes interactive problem-solving. They also support Jahn, Bergmann, and Keil's conclusion (2012) that the agency funding science model creates synergism and provides broader social learning impacts since it is user inspired and collaborations feature diverse stakeholder participation. Combined, these processes lead to broader impacts including enhanced collective wisdom and the ability to develop principles and archetypes (Rizvi 2016).

Pregernig (2006) argues that many of the characteristics that make up a successful transdisciplinary research effort cannot be determined empirically by looking at the project itself; instead, a broader conceptual and empirical framework is needed. This research contributes empirical knowledge by looking at the potential for broader impacts but does not go as far as suggesting that the integration of planning and research deliverables will result in meaningful models of transdisciplinary science. It is only one small piece of a larger puzzle.

As meaningful models are developed, the result will be more efficient and effective ways of doing natural and social science research to understand complex human and natural systems phenomena. The public value created by boundary organizations is not limited to academic reports or improved program outcomes. The engagement of a community of stakeholders, working collaboratively on complex human and natural system projects and creating usable knowledge at the local, state, federal, and international levels that allows for knowledge accretion that leads to more effective government programs, policies, and governance decisions, is a very important contribution of boundary organizations as well.

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Supporting Information

A supplementary appendix may be found in the online version of this article at <http://onlinelibrary.wiley.com/doi/10.1111/puar.12985/full>.