CREATING BROADER RESEARCH IMPACTS THROUGH BOUNDARY ORGANIZATIONS

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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 2000's federal funding has led to the creation of transdisciplinary regional climate workgroups to facilitate integrative knowledge co-production and to promote shared use of research results by scientific and non-scientific 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 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. The study 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 knowledge-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.

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In 1995, new federal grant funding by NOAA in the Department of Commerce incentivized the creation of regional workgroups tasked with conducting multi-disciplinary 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 re-imagine 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 then conducting or directing the research, the regional workgroups facilitate connections between multiple stakeholders across overlapping sectoral and organizational boundaries for co-productive 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 non-scientific stakeholders representing a wide variety of physical and social science disciplines. The purpose of these partnerships is to address complex physical and social science phenomenon that overlap multiple disciplines and cross organizational sectors. Our research purpose is to identify the broader impacts provided by climate assessment workgroups, as boundary organizations. Do they facilitate co-production 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 via 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 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% 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, policymakers and other key stakeholders collaboratively share expertise and experience. The results become usable knowledge when they are disseminated this 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 society faces.

Within the heuristic of social science, knowledge produced by research has typically been recognized as interdisciplinary or multi-disciplinary. 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 complex 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 creating 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 partnership between multiple organizations and stakeholder groups. Mauser and collaborators (2013) describe 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 translated for dissemination 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 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, the National Oceanic and Atmospheric Administration (NOAA), NASA and the 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 emphases 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 20+ years. Currently there are eleven 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 in an effort to coordinate the production of usable knowledge to improve climate related hazard planning and promote resilience activities to mitigate the 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 SCIPP serves (Texas, Oklahoma, Arkansas, Louisiana, Mississippi and Tennessee). Why is drought research a valuable case for studying 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 U.S. 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 co-production of usable knowledge and promote adaptive management in the drought arena to provide broader societal impacts. The two research questions we address are: 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 via 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 co-produce 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 public management literature, Byerly & Pielke observed that: “Society expects substantial benefits based on the justification scientists offer for federal support." (1995, 1541). 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 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 and colleagues (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 via attention to the creation of usable knowledge.

Combining interdisciplinarity and the participation of additional non-scientific 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, co-production 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, 397). 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, both are 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 co-production and the utilitarian interpretation of co-production (Lövbrand 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 n.d.; Mauser et al. 2013). Producing deliverables that reflect synergistic knowledge production (as in Star and Griesemer's 'boundary objects' (1989)) 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. Beginning in 1995, transdisciplinary workgroups have been organized within academic institutions and work closely with the NOAA's Climate Program Office (CPO). 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. (Click the About tab at http://www.climas.arizona.edu).

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.

[Figure 1 here]

The research findings of RISAs are boundary objects which 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); non-profit 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 or working papers, workshop reports, podcasts, brochures, blogs, listserves, 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 RISA's and the inclusion of RISA results in public policy discussions. Scholars also concur with these conclusions. Kirchoff and collaborators (2013) confirmed that RISAs engage in boundary work and foster interactions, aid in forming and maintaining dedicated user networks and have information uptake. Meadow concludes: "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 (Kirchhoff, Carmen Lemos, and Dessai 2013, 400). Another study concluded that RISAs facilitate effective two-way communication to co-produce 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, Kirchhoff, and Ramprasad 2012, 276).

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 if 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 drought 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.

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 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

(CCSP) strategic plan (Abraham, Evans, and Marburger, III 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 Climate Program Office and the Regional Integrated Science Assessments.

Each of the three strategic plans included goal statements, prioritized topics and areas of focus (objectives), examples of key research activities, and expected timeframes for results. We content analyzed 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 if there have been changes over time to better serve the needs of both scientific researchers and non-scientific practitioners. The research deliverables were divided into two categories:1) scholarly literature (including books, book chapters and journal articles) and 2) "grey literature" (including things like research reports, workshop summaries, working papers, newsletters, briefing documents, power point 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 the scientific/academic audiences. Items in the grey literature category were coded as being appropriate to the non-scientific 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 grey literature categories reflects the fact that, over time and in part due to 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 (http://www.southernclimate.org/). This means there is less reliance on academic journal publications in favor of the production of grey 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 was obtained from four sources: the American Meteorological Society journal database, JSTOR/Google Scholar, the Web of Science, and RISA documents and websites. These sources allowed for the identification of single and multi-disciplinary research deliverables. They also provided a mix of scholarly and grey 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 also searched specifically for the term RISA. We then refining 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 Appendix). 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 multiple disciplinary bibliographic databases, the multiple source search strategy mitigates threats to validity associated with reliance on a single database. have (Franceschini, Maisano, and Mastrogiacomo 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 the 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, the 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 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 non-climatic knowledge, and communicated in order to best serve societal needs?"(Abraham, Evans, and Marburger, III 2003, 57). Progress on this goal was estimated to be measurable in 2-4 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 non-climate knowledge (such as was necessary in the CHAN 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 continuation of the themes in later strategic plans.

[Table 1 here]

The *2020 RISA 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 multi-level and multi-disciplinary partnerships between the Regional Climate Centers, State Climatologists, the National Weather Service and other federal agencies. The partnership emphasis was being pursued via "…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 these statements: "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 (p. 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 emphases 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 multi-disciplinary 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 non-climatic 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-hand 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-hand 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 non-climate knowledge and advances shared interests and impact. In the next section, drought research deliverables are analyzed to see if there is a parallel evolution in the integration of climate and non-climate science and the facilitation of user-focused partnership in the language of research results.

Changes in Research Deliverables

With this description of how specific RISA activities and outcomes are encouraged through national strategic plans, the analysis turned 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 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% before the 2003 national strategic plan to just over 40% of all drought publications.

[Figure 2 here]

By comparison, the top two bars in Figure 2 represent multi-disciplinary 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 2nd set of bars from the top in Figure 2), the research deliverables begin as 22% of the total in 2003 and rise to 27% by 2017. Improvement is also seen in the partnership goal, with the percentage of drought research deliverables increasing from 19% to 29% 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 is expanding to include researchers from a wider range of disciplines and that the research that is being produced is better aligned with national strategic plans over time.

The introduction of the RISA's 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 multi-disciplinary 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 grey literature; however, for all years, 53% of deliverables are academic publications that support the integrate science goal, while 47% are grey literature items that support the partnership goal. What Figure 3 suggests is that the RISAs are producing deliverables that are 100% multi-disciplinary and support the goals articulated in the 2003, 2009 and 2015 strategic plans.

[Figure 3 here]

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 the collaborators with whom the RISA is collaborating. Analysis of the 2017 project database provided an in-depth examination of projects, partners and processes to assess knowledge co-production and intended information users to discern the current trajectory of usable knowledge.

In 2017, the RISAs were working on 185 projects with non-federal partners included on more than ½ 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, they include: Communication (21%), Academic Publication (26%), White Papers (7%), Decision Support (12%), Data Tools (17%), and Presentations or Meetings (17%).

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. They are: 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 have projects in 2017 designed to advance science policy; overall 11% of all the reported objectives for the 185 projects were designed to advance science policy. Nine of 11 RISAs have projects intended to innovate services; overall 18% of all reported objectives were in this area. Each of the RISAs have projects that support knowledge exchange and enhance the understanding of context and risk, these objectives represent 35% and 37% 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 allows 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 that seek to integrate climate and non-climate science with those that enhance literacy, build partnerships and inform 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 that are often only available with a subscription or for a one-time user fee.

Expanding the collaborations between scientific and non-scientific stakeholders is desirable since the non-scientists have front-line knowledge of implementation contexts, contingent circumstances and strategic behaviors (Fowlin and Cennamo 2017; Meadow et al. 2015). This means the knowledge producers have a direct communication pathway to the knowledge users, increasing the likelihood of evidence informing policymaking 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 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 find that, over 15 years, two primary strategic plan emphases (the integration of climate and non-climate science and the facilitation of user-friendly partnerships) has 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 co-production does provide 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’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 phenomenon. The public value created by boundary organizations is not limited to academic reports, nor to 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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REFERENCES

Abraham, Spencer, Donald D. Evans, and John H. Marburger, III. 2003. *Strategic Plan for the U.S. Climate Change Science Program* (A Report by the Climate Change Science Program and the Subcommittee on Global Change Research). Washington D.C.:U.S. Congress. https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/ccspstratplan2003_all.pdf.

Bell, Sarah, Ben Shaw, and Annette Boaz. 2011. Real-world Approaches to Assessing the Impact of Environmental Research on Policy. *Research Evaluation* 20(3): 227–237. https://doi.org/10.3152/095820211X13118583635792

Binder, Laura W., and Caitlin Simpson. 2009. *RISA 2010A: A RISA community vision for future Regional Integrated Sciences and Assessments (RISA) efforts to match advanced in climate impacts science with the needs of resource managers and planners*. http://cpo.noaa.gov/portals/0/Docs/RISA/RISA%202009%20Vision%202020.pdf.

Boezeman, Daan, Martinus Vink, and Peieter Leroy. 2013. The Dutch Delta Committee as a Boundary Organisation. *Environmental Science & Policy* 27: 162–171. https://doi.org/10.1016/j.envsci.2012.12.016.

Brunner, Ronald D. 2010. Adaptive Governance as a Reform Strategy. *Policy Sciences* 43(4): 301–341. https://doi.org/10.1007/s11077-010-9117-z.

Byerly, Jr. Radford, and Roger A. Pielke. 1995. The Changing Ecology of United States Science.

Science 269(5230): 1531–1532. https://doi.org/10.1126/science.269.5230.1531.

Clark, William C., Thomas P. Tomich, Meine van Noordwijk, David Guston, Delia Catacutan, Nancy M. Dickson, and Elizabeth McNie. 2016. Boundary Work for Sustainable Development: Natural Resource Management at the Consultative Group on International Agricultural Research (CGIAR). *Proceedings of the National Academy of Sciences* 113(17): 4615–4622. https://doi.org/10.1073/pnas.0900231108.

Climate Program Office. 2014. *Strategic Plan 2015-2019*. Washington, D.C: U.S. Department of Commerce. http://cpo.noaa.gov/WebSimple/Leigh-Test/PID/6226/evl/0/TagID/492/TagName/strategic-plan.

Cornell, Sarah, Frans Berkhout, Willemijn Tuinstra, J. David Tàbara, Jill Jäger, Ilan Chabay, Bert deWit, Richard Langlais, David Mills, Peter Moll, Ilona M. Otto, Arthur Peteresen, Christian Pohl, and Lorrae van Kerkhoff. 2013. Opening Up Knowledge Systems for Better Responses to Global Environmental Change. *Environmental Science & Policy* 28: 60–70. https://doi.org/10.1016/j.envsci.2012.11.008.

Dilling, Lisa, and Maria Carmen Lemos. 2011. Creating Usable Science: Opportunities and Constraints for Climate Knowledge Use and Their Implications for Science Policy. *Global Environmental Change* 21(2): 680–689. https://doi.org/10.1016/j.gloenvcha.2010.11.006.

Ebdon, Carol, and Aimee L. Franklin. 2006. Citizen Participation in Budget Theory. *Public Administration Review* 66(3): 437–447.

Eynon, Rebecca, 2012. The Challenges and Possibilities of the Impact Agenda. *Learning, Media and Technology* 37(1): 1–3. https://doi.org/10.1080/17439884.2012.63636.

Fowlin, Julaine, and Katherine Cennamo. 2017. Approaching Knowledge Management Through the Lens of the Knowledge Life Cycle: A Case Study Investigation. *TechTrends: Linking Research & Practice to Improve Learning* 61(1), 55–64.

Franceschini, Fiorenzo, Domenico Maisano, and Luca Mastrogiacomo. 2016. Empirical Analysis and Classification of Database Errors in Scopus and Web of Science. *Journal of Informetrics* 10(4): 933–953. https://doi.org/10.1016/j.joi.2016.07.003.

Franklin, Aimee L., and Carol Ebdon. 2007. Democracy, Public Participation, and Budgeting: Mutually Exclusive or Just Exhausting? In R. C. Box (Ed.), *Democracy and Public Administration* (pp. 84–106). Armonk, N.Y.: M. E. Sharpe, Inc.

Guston, David H. 2001. Boundary Organizations in Environmental Policy and Science: An Introduction. *Science, Technology & Human Values* 26(4): 399–408. https://doi.org/10.1177/016224390102600401.

Hirsch Hadorn, Gertrude, David Bradley, Christian Pohl, Stephan Rist, and Urs Wiesmann. 2006. Implications of Transdisciplinarity for Sustainability Research. *Ecological Economics* 60(1): 119–128. https://doi.org/10.1016/j.ecolecon.2005.12.002.

Jahn, Thomas, Matthias Bergmann, and Florian Keil. 2012. Transdisciplinarity: Between Mainstreaming and Marginalization. *Ecological Economics* 79: 1–10. https://doi.org/10.1016/j.ecolecon.2012.04.017e

Jilke, Sebastian, Steven Van de Walle, and Soonhee Kim. 2016. Generating Usable Knowledge through an Experimental Approach to Public Administration. *Public Administration Review* 76(1): 69–72. https://doi.org/10.1111/puar.12488.

Kersting, Nicole B., Karen B. Givvin, Belinda J. Thompson, Rossella Santagata, and James W. Stigler. 2012. Measuring Usable Knowledge: Teachers' Analyses of Mathematics Classroom Videos Predict Teaching Quality and Student Learning. *American Educational Research Journal* 49(3): 568–589. https://doi.org/10.3102/0002831212437853.

Kirchhoff, Christine J., Maria Carmen Lemos, Suraje Dessai. 2013. Actionable Knowledge for Environmental Decision Making: Broadening the Usability of Climate Science. *Annual Review of Environment and Resources* 38(1): 393–414. https://doi.org/10.1146/annurev-environ-022112-112828.

Klaster, Esther, Celeste P. M. Wilderom, and Dennis R. Muntslag. 2017. Balancing Relations and Results in Regional Networks of Public-Policy Implementation. *Journal of Public Administration Research and Theory* 27(4): 676-69. https://doi.org/10.1093/jopart/mux015.

Lasda Bergman, Elaine M. 2012. Finding Citations to Social Work Literature: The Relative Benefits of Using Web of Science, Scopus, or Google Scholar. *The Journal of Academic Librarianship* 38(6): 370–379. https://doi.org/10.1016/j.acalib.2012.08.002.

Lemos, Maria C., Christine J. Kirchhoff, Scott E. Kalafatis, Donald Scavia, and Richard B.

Rood. 2014. Moving Climate Information off the Shelf: Boundary Chains and the Role of RISAs as Adaptive Organizations. *Weather, Climate, and Society* 6(2): 273–285. https://doi.org/10.1175/WCAS-D-13-00044.1.

Lemos, Maria C., Christine Kirchhoff, and Vijay Ramprasad. 2012. Narrowing the climate information usability gap. *Nature Climate Change* 2(11): 789–794. https://doi.org/10.1038/nclimate1614.

Lemos, Maria C., and Barbara J. Morehouse. 2005. The Co-production of Science and Policy in Integrated Climate Assessments. *Global Environmental Change* 15(1): 57–68. https://doi.org/10.1016/j.gloenvcha.2004.09.004.

Li, Jiang, Mark Sanderson, M., Peter Willett, Michael Norris, Charles Oppenheim. 2010. Ranking of Library and Information Science Researchers: Comparison of Data Sources for Correlating Citation Data, and Expert Judgments. *Journal of Informetrics* 4(4): 554–563. https://doi.org/10.1016/j.joi.2010.06.005.

Lindblom, Charles E., and David Cohen. 1979. *Usable Knowledge: Social Science and Problem Solving*. New Haven and London: Yale University Press.

Lövbrand, Eva. 2011. Co-producing European Climate Science and Policy: A Cautionary Note on the Making of Useful Knowledge. *Science and Public Policy* 38(3)L 225–236. https://doi.org/10.3152/030234211X12924093660516.

Ludwig, Donald. 2001. The Era of Management Is Over. *Ecosystems* 4(8), 758–764. https://doi.org/10.1007/s10021-001-0044-x.

Mauser, Wolfram, Gernot Klepper, Martin Rice, Bettina Susan Schmalzbauer, Heide Hackmann, Rik Leemans, and Howard Moore. 2013. Transdisciplinary Global Change Research: The Co-creation of Knowledge for Sustainability. *Current Opinion in Environmental Sustainability* 5(3-4): 420–431. https://doi.org/10.1016/j.cosust.2013.07.001.

Meadow, Alison M. 2017. *An ethnohistory of the NOAA RISA program*. http://cpo.noaa.gov/Portals/0/Docs/RISA/Meadow_2017_RISA_History.pdf?ver=2017-07-05-142106-183.

Meadow, Alison M., Daniel B. Ferguson, Zack Guido, Alexandra Horangic, Gigi Owen, and Tamara Wall. 2015. Moving toward the Deliberate Coproduction of Climate Science Knowledge. *Weather, Climate, and Society* 7(2)L 179–191. https://doi.org/10.1175/WCAS-D-14-00050.1.

Meyer, Morgan. 2010. The Rise of the Knowledge Broker. *Science Communication* 32(1): 118–127. https://doi.org/10.1177/1075547009359797.

Michaels, Sarah. 2009. Matching Knowledge Brokering Strategies to Environmental Policy Problems and Settings. *Environmental Science & Policy* 12(7): 994–1011. https://doi.org/10.1016/j.envsci.2009.05.002.

NIDIS Program Office. 2016. *The National Integrated Drought Information Information System Implementation Plan*. Washington D.C. https://www.drought.gov/drought/nidis-implementation-plan-2016-update.

Nowotny, Helga. 1990. *In Search of Usable Knowledge: Utilization Contexts and the*

Application of Knowledge. Campus/Westview.

O'Brien, Liz, Mariella Marzano, and Rehema M. White. 2013. "Participatory Interdisciplinarity": Towards the Integration of Disciplinary Diversity with Stakeholder Engagement for New Models of Knowledge Production. *Science & Public Policy (SPP)* 40(1): 51–61.

Pielke, Roger A. 1997. Asking the Right Questions: Atmospheric Sciences Research and Societal Needs. *Bulletin of the American Meteorological Society* 78(2), 255–255. https://doi.org/10.1175/1520-0477(1997)078<0255:ATRQAS>2.0.CO;2.

Pielke, Roger A., Jim Abraham, Elliot Abrams, Jim Block, Richard Carbone, David Chang, Kelvin Droegemeier, et. al. 2003. The USWRP Workshop on the Weather Research Needs of the Private Sector. *Bulletin of the American Meteorological Society* 84(7): 934–934. https://doi.org/10.1175/BAMS-84-7-Pielke.

Polanyi, Michael. 1962. The Republic of Science: Its Political and Economic Theory. *Minerva 1:* 54–73.

Pregernig, Michael. 2006. Transdisciplinarity Viewed from Afar: Science-Policy Assessments as Forums for the Creation of Transdisciplinary Knowledge. *Science and Public Policy* 33(6): 445–455. https://doi.org/10.3152/147154306781778867.

Provan, Keith G., and H. Brinton Milward. 1995. A Preliminary Theory of Interorganizational Network Effectiveness: A Comparative Study of Four Community Mental Health Systems. *Administrative Science Quarterly* 40(1): 1. https://doi.org/10.2307/2393698.

Pulwarty, Roger S., Caitlin Simpson, Claudia R. Nierenberg. (n.d.). *The Regional Integrated Sciences and Assessments (RISA) Program: crafting effective assessments for the long haul*. http://cpo.noaa.gov/portals/0/Docs/RISA/CitationPulwartyetal.pdf.

Raadschelders, Jos C. N., & Whetsell, Travis A. 2017. Conceptualizing the Landscape of Decision Making for Complex Problem Solving. *International Journal of Public Administration*. https://doi.org/10.1080/01900692.2017.1347946.

Rizvi, Afroz H. 2016. Knowledge Management--Emerging Concept of Education. *International Journal of Multidisciplinary Approach & Studies* 3(1): 1–5.

Roux, Dirk J., Richard J. Stirzaker, Charles M. Breen, E.C. Lefroy, and Hamish P. Cresswell. 2010. Framework for Participative Reflection on the Accomplishment of Transdisciplinary Research Programs. *Environmental Science & Policy* 13(8): 733–741. https://doi.org/10.1016/j.envsci.2010.08.002.

Shah, Syed R. U., Khalid Mahmood, and Abdul Hameed, A. 2017. Review of Google scholar, Web of Science and Scopus Search Results: The Case of Inclusive Education Research. *Library Philosophy and Practice* (1544).

Shanley, Patricia, and Citlalli Lopez. 2009. Out of the Loop: Why Research Rarely Reaches Policy Makers and the Public and What Can be Done: Biological Research Beyond Academy. *Biotropica* 41(5): 535–544. https://doi.org/10.1111/j.1744-7429.2009.00561.x.

Star, Susan L., and James R. Griesemer. 1989. Institutional Ecology, `Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate

Zoology, 1907-39. *Social Studies of Science* 19(3): 387–420. https://doi.org/10.1177/030631289019003001.

Stein, Zachary. 2009. Educational Crises and the Scramble for Usable Knowledge. *Integral Review* 5(2): 355–367.

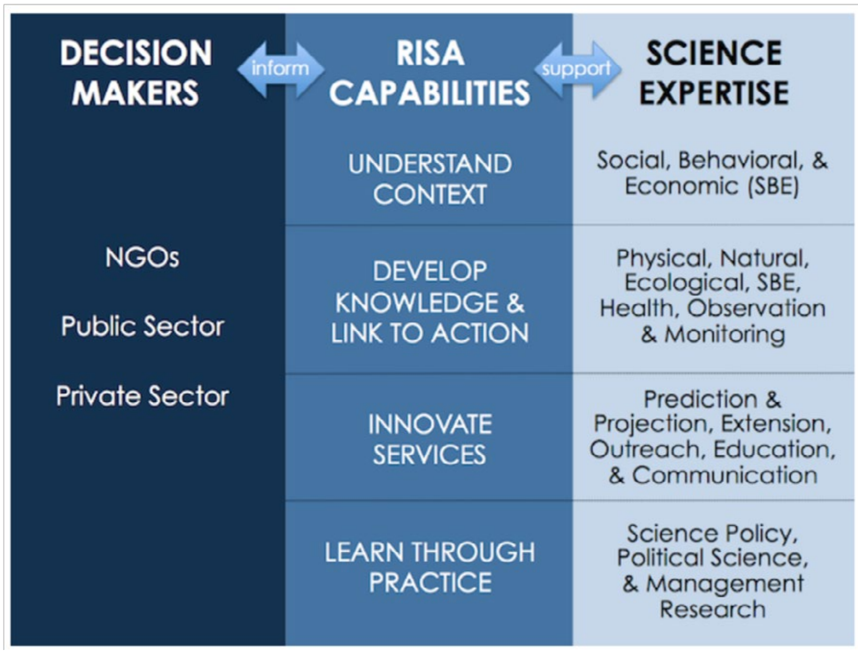
Thompson Klein, Julie. 2004. Prospects for Transdisciplinarity. *Futures* 36(4): 515–526. https://doi.org/10.1016/j.futures.2003.10.007.

Waldo, Dwight. 1973. Reflections on Technoscience Policy in a Troubled Milieu. In A. H. Rosenthal (Ed.), *Public Science Policy and Administration* (pp. 254–272). Albuquerque, N. M.: University of New Mexico Press.

Wang, Qi, and Ludo Waltman. 2016. Large-scale Analysis of the Accuracy of the Journal Classification Systems of Web of Science and Scopus. *Journal of Informetrics* 10(2): 347–364. https://doi.org/10.1016/j.joi.2016.02.003.

Wilhite, Donald A., and Michael H. Glantz.1985. Understanding the Drought Phenomenon: The Role of Definitions. *Water International* 10(3): 111–120. https://doi.org/10.1080/02508068508686328.

Figure 1: The RISA Model



Source: About the Regional Integrated Sciences and Assessments Program. Climate Program Office. http://cpo.noaa.gov/Meet-the-Divisions/Climate-and-Societal-Interactions/RISA/About-RISA. 7/12/17.

Table 1: Major Emphases Related to Drought in National Strategic Plans

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

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

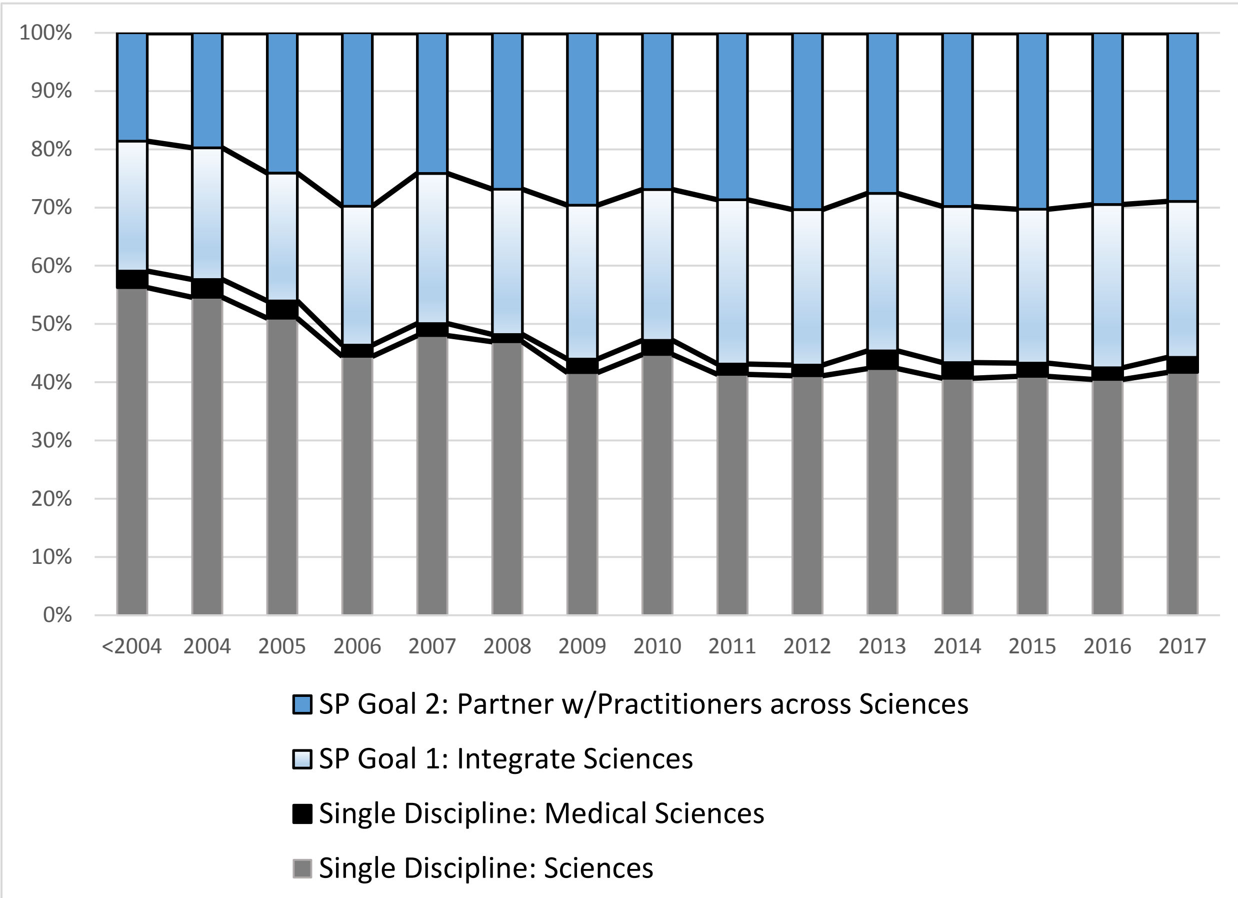
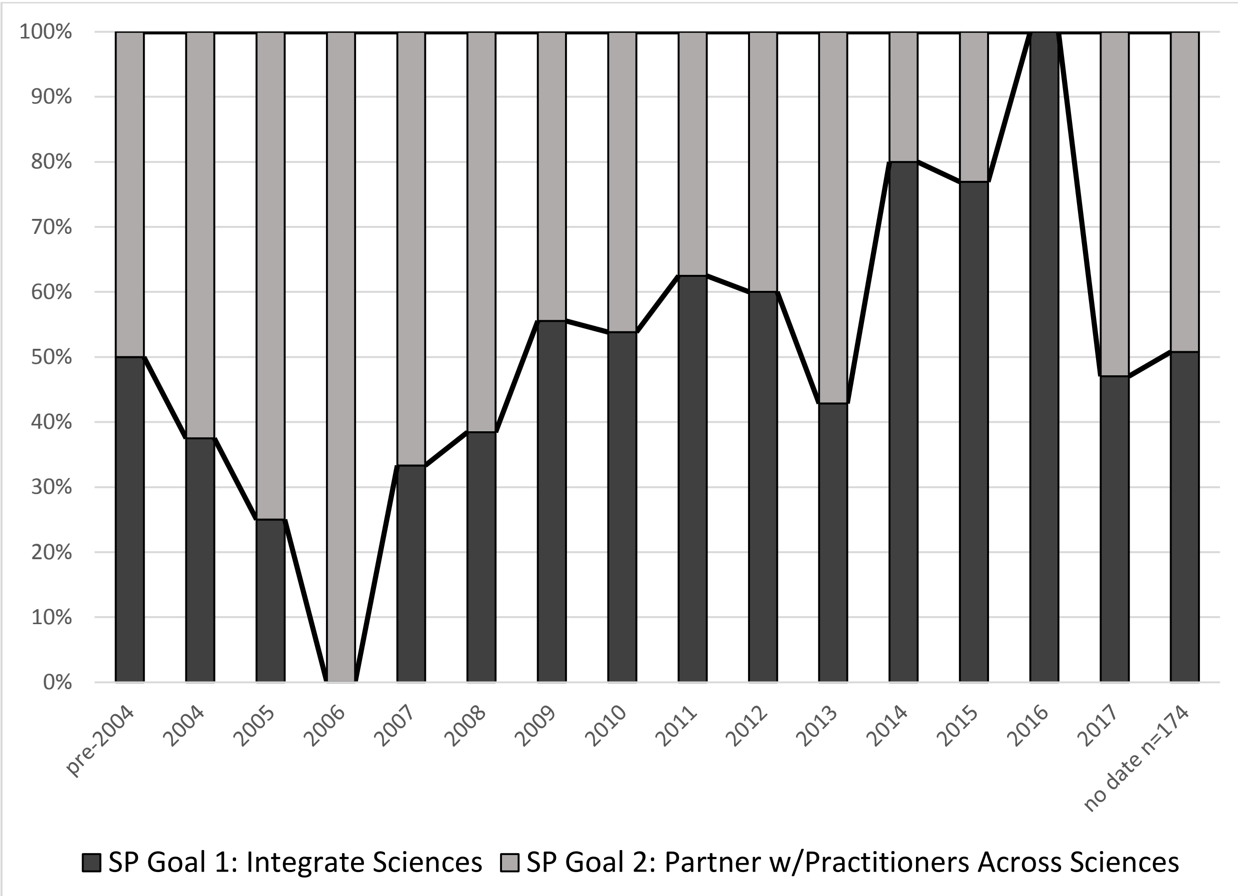


Figure 3: Changes in RISA Drought Deliverables by Strategic Plan Goal (n=306)



Appendix

This appendix provides additional details about the identification of research deliverables for each the four sources of data (AMS journals, JSTOR/Google Scholar, WoS, and RISA documents/websites) as well as the search and analytical process.

The first source was the American Meteorological Society website featuring 11 of the highest impact journals for natural science researchers. We began with the drought or RISA search term and then narrowed the search results to the climate science categories resulting in 1494 citations. The title and abstract of the AMS items were reviewed by the research team and categories were assigned based on the NIDIS Drought Reporter categories that are commonly used by researchers and practitioners to describe the topical area of the document. Each of the Drought Reporter categories was then assigned to the integrating research or partnership goals identified during the strategic plan review.

The second source of data was searches of JSTOR and Google Scholar, again starting with the drought and RISA search terms, then searching for drought and climate. These searches yielded 173 items that represented scholarly literature (n=46) and grey literature (n=127). Similar to the AMS items, the researchers reviewed titles, abstracts and documents' content to assess the multi-disciplinarity of the item and to assign it to the Drought Reported categories.

The third source of drought data were the RISA documents and websites. The RISA data are included in the full analysis. They are also presented as a subset analysis to provide a granular understanding of the deliverables RISAs create related to strategic plan goals prescribing partnerships with stakeholders and the integration of drought science results into policy discussions through the production of user-friendly deliverables.

The fourth source of drought research data was the Web of Science. This database featured the widest range of journal articles, including open access journals as well as conference abstracts and proceedings from professional association meetings. As noted above, we started with the search term drought, which resulted in 72,385 records. Filters for the United States, English language, peer-reviewed Document Types, and U.S. research or university Organizations-Enhanced were then applied to make this data set as similar as possible to the search criteria used for the AMS journals and JSTOR/Google Scholar searches. After the filters were applied, there were 10,338 publications from the Web of Science.

Reviewing these records using the analyze function within the Web of Science database brought to light the significant number of single discipline physical science and medical science items. We segregated these single discipline items from multi-disciplinary drought items by selecting the Web of Science natural science categories that were multi-disciplinary and the social science categories that appeared when using the search term “drought”.

Next, the Web of Science citations were split into two pools. The first citation pool includes publications that represent single disciplines based on keyword codes for the physical sciences (5618, or 54%) and medical sciences (556 or 5%).

The discussion now switches from citation counts to item counts since the Web of Science database often assigns multiple keyword categories to a single publication. Because of this, the average number of assigned categories for publications in a single year ranges from 124% to 194% of the number of drought publications included from the Web of Science. The second pool includes the publications that included codes for multiple disciplines accounted for 4164 items (40%).

The 4164 items representing multiple disciplines were further divided based on the WOS categories. There were 3280 keyword categories that included the words "multi-disciplinary" or combined one or more natural or social science disciplines. These were assigned to the integration code. In addition, there were 3640 keyword categories used with the social science disciplines. Since these items combined the search term drought and the Web of Science social/behavioral science categories, these were assigned to the partnership code. After removing duplicated entries from other databases and searchers, this final data set has 12,111 items suitable for comparing longitudinal trends in single versus multi-disciplinary drought research.

Item Count Reconcilation	**Academic**	**Grey**	**Total**
AMS	1494	0	1494
JSTOR/Google	46	127	173
RISA	163	143	306
WOS Physical Science	5618	0	5618
WOS Medical Science	556	0	556

WOS Multi-disciplinary	4164	0	4164
Total Items	12041	270	12311
Percentages	98%	2%	