

Title: Advancing knowledge for use in coastal and estuarine management: Competitive research in the National Estuarine Research Reserve System

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Introduction

Estuaries and coasts—including nearby human and natural communities—have long been on the frontlines of global and regional environmental change. Decades of research have produced knowledge and tools to help understand and respond to these impacts. Yet, in many places progress remains slow when it comes to applying this knowledge towards achieving desired improvements to coastal and other environs (McNie 2007). This sluggish pace is cause for concern when viewed alongside accelerating impacts of sea-level rise, pollution, and human development (Scavia et al. 2002; Steffen et al. 2015). Such impacts threaten to offset prior progress in conservation or management and create new challenges. So, how can we, as researchers, funders and coastal managers, secure the long-term sustainability of our socially and ecologically vital coastal resources (Allison and Bassett 2015)?

For the past twenty years the National Estuarine Research Reserve System (NERRS or reserve system) funded by the National Oceanic and Atmospheric Administration (NOAA) has tried to answer this question by producing usable knowledge that informs and aids coastal managers and practitioners seeking to conserve, manage, and restore coastal resources. Since 1972, the reserve system has been a platform for research, stewardship, education, and training in support of the Nation’s estuarine and coastal areas. Since 1998 the program’s competitive research program has invested \$70.6 million dollars in 313 research and science transfer projects to develop and deliver knowledge and tools in support of coastal and estuarine resource management. Over this 20 years of competitive funding, periodic evolution in program design has created opportunities for expanded incorporation of user needs. This work has led to new scientific discoveries, innovative tools for resource monitoring and management, and added capacity to reimagine how coastal and estuarine areas can be sustainably managed. This has helped the reserve system and partners make incremental improvements in the applied research process in hopes of better supporting place-based research conducted by coastal management

professionals and scientists nationwide. A cornerstone of these improvements has been the development of collaborative structures at both local and national levels to nurture science-to-practice and practice-to-practice engagement. These developments have fostered advances in the knowledge base and technologies for understanding, monitoring, and managing the impacts of pollution, land use change, climate change, and other perturbations. For a collection of NERRS research, including outputs sponsored by competitive funding, see special issues of the *Journal of Coastal Research* (2008, Special Issue 55) and *Estuaries and Coasts* (2018, Vol. 41(1)).

In this essay, we explore how relationships and engagement among funders, scientists and technology developers, managers, and practitioners, helped to deliver information and tools to address critical coastal and estuarine issues. Being place based, research and monitoring conducted in the NERRS is often focused on clearly defined coastal management needs. While the emphasis on broadening the social impact of environmental research has seemed to grow almost exponentially in the past few years (e.g., see Vano et al. 2017 for analysis of "science to action" abstracts for the American Geophysical Union), the NERRS program is relatively unique in its systematic and nationwide, long-term adaptive and innovative approach to intentionally push for the creation of usable science through funding requirements. We argue that an unusual combination of political mandate and degrees of freedom afforded to the funding managers of the program to experiment with different interventions to make the program more responsive to management needs created a unique opportunity to push the envelope towards the creation of usable knowledge. The success of the NERRS program in creating usable science suggests a more societally effective model of science funding and science-practice interaction, leading to collaborations that help achieve sustainability and conservation objectives.

A common refrain in the pages of this journal and in other venues of discussion about improving coastal management science and implementation is the need for more and better directed funding (e.g., Leschine et al. 2003). Yet, less attention has focused on what funders have actually done to augment, refine, and redirect resources in ways that may more likely achieve desired outcomes (but see Ford, Knight, and Pearce 2013; DeLorme et al. 2016; Turner and Jordan 2017).

We write as a combined group of program managers and science policy researchers to tell the story, with examples from projects supported over time, of how the National Estuarine Research Reserve System has organized to support the making of coastal science and technology for—and increasingly *with*—coastal and estuarine resource managers.

The next section summarizes the history of the reserve system's competitive funding with an emphasis on key developments. Then, we provide a conceptual model and examples to understand this evolution as part of a new way to think about the relationships and mechanisms for interaction among funders, researchers, and users of research. We conclude with a discussion about lessons that should be considered and perhaps embraced more widely in the realm of coastal science and management.

A brief history of NERRS competitive funding

What makes the history of the NERRS program's competitive funding both interesting and valuable is that the primary goal to produce usable knowledge for coastal management has remained constant while the approach to funding has evolved significantly. NERRS was established through the Coastal Zone Management Act of 1972 during a wave of landmark legislation aimed at strengthening protection and management of the nation's environmental resources. In 1997, an additional portion of funding was established to augment research that could support coastal and estuarine management. Ever since, the reserve system's national research funding program has been based at a university and jointly managed with NOAA. During the first thirteen years, the research program was known as the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) hosted by the University of New Hampshire (UNH). In 2010, the program was restructured into the NERRS Science Collaborative (NSC) and continued to be managed by UNH from 2010-2014. Since 2014, the University of Michigan Water Center has managed the NSC. Each phase of the program has noteworthy features that characterize a continuously evolving—an intentionally adaptive—approach to funding science for coastal management.

In 1997, Congress approved seed funding to establish CICEET at UNH. NOAA recognized an opportunity to encourage UNH to think broadly about this new research program as a way to leverage NOAA's limited funding for the reserve program; in 1997 the total budget for the reserve program was only \$4.3M vs. \$27M today. Subsequently a memorandum of understanding between NOAA and UNH established CICEET as “a national center for enhanced cooperation and collaboration among academia, the private sector, and federal, state and local governments in developing and fostering the use of innovative environmental technologies and management approaches to the long-term conservation of the nation's coastal and estuarine ecosystems.” The program was co-managed by Co-Directors from NOAA and UNH who were given a great deal of latitude to develop and steer the program.

The core mission of the reserve system's extramural research program has always been to fund high quality, peer reviewed science in support of coastal management under the auspices of the Coastal Zone Management Act. But as the program matured and the social science of how to move research and technology into practical application advanced, this extramural, applied research program evolved into new configurations and applied different strategies to achieve its mission. The following sections tell this story along with examples of meaningful impact that was achieved in coastal resource management.

Cooperative Institute for Coastal and Estuarine Environmental Technology (1997-2009)

In the first two years CICEET followed a conventional approach for science and technology production, focusing mostly on the publication of peer-reviewed articles as the main means of disseminating knowledge it produced. The program focused on funding high quality science and technology with the thought that its intrinsic merit would generate interest among resource managers—or private companies who would manufacture products for the use of

practitioners—in the NERR system. One early project, for example, investigated the land-based sources of nitrogen pollution in coastal areas. While the researchers interacted very little with resource managers or decision-makers during the performance of the research, heightened public interest in environmental issues drove regional and state entities to consider the findings of this research in future monitoring and regulatory actions. Other projects, however, were not as successful at uptake despite the technical rigor of the work conducted. For example, one project created an innovative coastal monitoring technology that was considered useful by reserve management, yet ultimately the company that was initially interested in the work decided to pursue commercialization of a different, internally developed technology. The “hit and miss” nature of projects and concerns from coastal managers that much of the research—though scientifically excellent—was of questionable value to resource managers resonated with NERRS program management. This prompted CICEET to modify its approach to competitive funding in subsequent years in order to improve the program’s ability to generate credible, meaningful, and usable technology and science. Changes in funding requirements and proposal design took into consideration feedback from coastal managers provided through a 1999 coastal manager survey. For example, managers suggested that the program would be more effective if it prioritized supporting research and technology projects that addressed priority coastal management issues such as eutrophication, habitat modification, and toxic contaminants.

From 2000-2005, CICEET added a “technology transfer” component to its funding program to better support projects with commercialization potential, in a similar fashion to other government initiatives like the Small Business Innovation Research programs. Increasingly paying attention to the needs of potential users of the technologies, CICEET strove to generate meaningful research for the NERR system. For example, CICEET required that proposed projects focus on broad, priority coastal management issues identified in the 1999 survey and be associated with a reserve. During this phase, the program had a two-stage funding process where, initially, resources were allocated to projects developing scientific information and technology. Later, the program supported technology transfer projects for products that had been generated during the first stage. It also established different categories depending on the development state of the technology. The categories were: proof of concept, environmental technology development, and technology transfer.

During these years, CICEET again solicited feedback on the program’s performance, using a survey of coastal managers conducted in 2004 and an external program review in 2005. Coastal managers expressed a conviction that federal agencies that support coastal and ocean science should ensure their research and sponsored activities align with the priorities and needs identified by the States. Meanwhile, program staff and managers observed that new strategies were needed to better link intended users of research and technology to the research process in order to improve technology use. Under the existing structure, technology transfer activities were weak and limited by the program’s inability to influence directly the movement of technology from research and development into real-world application. Most of these restrictions were associated with the technology development costs and budget restrictions in the reserve system.

Based on the 2005 survey, CICEET began to change its focus from technical innovation and commercialization potential to user relevance and decision support. From 2006 to 2009, the program required projects to engage with intended users prior to proposal submission with the intention of initiating technology transfer as soon as possible. CICEET also prioritized support for projects that showed a commitment to collaboration with adopters and producers, emphasized cost-effectiveness of technologies designed, required explicit attention to the regulatory context of technology development, and eventually included the requirement of an “application specialist” among the proposal team. The “application specialist” would be responsible for facilitating collaborative processes with users defined as any person who may benefit or otherwise be impacted by a research product. CICEET also tailored a series of Requests for Proposals (RFPs) that addressed specific needs identified by the coastal management communities. The objective of this approach was to engage with the management community, identify their needs and request in the RFP that proposal teams seek to meet these needs in their projects.

NERRS Science Collaborative at University of New Hampshire (2010-2014)

Beginning in 2010, CICEET was renamed as the NERRS Science Collaborative (NSC). The NSC deepened user engagement to inform the science funded by the program. It made the collaboration process explicit in the RFPs (Matso 2012) and established the position of a neutral, collaborative lead who would be responsible for the collaboration process. The main rationale behind this approach was that the credibility, legitimacy, and salience of research is intrinsically linked to a deliberate engagement with the intended users of science (Cash et al. 2003).

During this program phase, all RFPs emphasized the importance of the collaboration lead team member, placed at the same level of importance as other members of the research team (Matso 2012; Matso and Becker 2014). The new guidelines also requested that proposal reviewers and panels evaluate participatory methods with the same level of scrutiny as natural and social science methods. In this sense, the NSC took a step further in user engagement to produce science by focusing on not just including user needs and expected products of research, but also by asking researchers to identify who the users would be and collaborate with them so that the new knowledge developed would be used. Indeed, the longstanding *goal* of knowledge transfer was accompanied by supporting the *requisite capacity* of project teams for knowledge transfer. This explains the emphasis on including someone on the proposal with participatory process expertise as distinct from ecological or engineering expertise.

An example activity funded during this period focused on generating actionable knowledge about the implementation of low impact development (LID) strategies. LID strategies, including green infrastructure, have been a considerable focus area for urban planning and environmental engineering research that was viewed as a potentially viable solution for coastal communities facing heavier precipitation and more extreme coastal storms. This project convened multiple stakeholder meetings and roundtable discussions to inform the drafting of a science-based guide. Stakeholder input, which included potential users of the planning guide,

enabled the project team to be highly detailed in describing how the guide could relate to both the planning context and decision-making and planning criteria. Both the final project report and follow-up interviews provided detailed description of how the planning guide had been adopted by counties and municipalities in the region. A user later stated: “I use it all the time. I've referred to it all the time. I get links to it all the time.”

Another significant change in the program was a new emphasis on addressing reserve-specific coastal management issues. A primary lesson learned during this phase of the program was that collaboration takes significant time, resources, and commitment to be successful. Good collaboration generates a shared understanding of the issue being researched and how it aligns with user needs. As a result, initial engagement had a very structured approach. Later it evolved into a more organic structure where applicants could define the mechanisms for user engagement that made the most sense for their specific projects.

NSC (UM) (2014 - present)

The NSC, now managed by the University of Michigan, continues to require collaboration between researchers and users. The program seeks to increase effective and meaningful collaborations by ensuring users are engaged at pertinent stages of projects and providing targeted resources to do so. Applicants are asked to be explicit about how users helped to shape the proposal and provide the rationale behind the proposed collaborative approach. And rather than adhering strictly to formal participatory methodologies, teams are asked to detail the approaches that make sense to those engaged and for achieving their objectives. Proposed primary users are required to participate during the final stage of the panel review to help panelists gauge their level of commitment to the project, beyond the proposal narrative and letters of support. Additionally, the program retained the innovation of ensuring that the review panel reflect a balance between ecological, social science, and participatory process expertise, which was shown to be so critical in the development of the UNH NSC (Matso 2012).

This latest generation of the NSC also introduced new types of projects, which include resources dedicated specifically to support user engagement and develop collaborative research processes. Capacity building grants, for example, allow reserves to undertake a variety of activities to better position a reserve to write a strong collaborative research or integrated assessment proposal. Examples of relevant activities and expenses include personnel time, training, facilitation, needs assessment, and convening of users and researchers. In addition, the NSC provides partner engagement funds to reserves to facilitate user engagement during proposal development. These small grants cover costs of engagement, such as, travel costs for meeting participants, meeting space, refreshments, and any other reasonable expenses associated with bringing current and potential collaborators together for proposal development.

For example, capacity building funds were used by a group of reserves to assess management needs and build an advisory committee of professionals interested in the topic of thin layer sediment placement to increase the elevation and resilience of coastal marshes. The initial needs assessment results and strong relationships with diverse agencies and partners

positioned the team well to lead an ambitious but targeted project involving field experiments at eight different reserves across the country. With ongoing feedback from their advisory group, the team is conducting a robust evaluation of the sediment placement methods that coastal managers are currently considering to preserve the services provided by coastal marshes.

The NSC has also invested considerably in conducting evaluation research on prior grants and performing pre- and post-project surveys with users of currently supported projects. The goal of both activities is to understand the level of product use and measure changes in attitudes about engaging in collaborative research projects in order to inform future proposal development and selection processes, as well as project management support.

In addition to programmatic innovations, the community of potential applicants to the NSC has also evolved and deepened their own skills as leaders and active participants in collaborative, applied research. Members of the NERRS community have had the opportunity to lead and participate in multiple grants, adjusting their own collaborative and project management approaches, enabling the whole community to benefit from their learning.

Towards a new model of science funding and engagement

Twenty years of adaptive design in the NERRS extramural research program illustrates both a pragmatic and innovative model for understanding the dynamics among the funding, execution, and use of research. The conventional model for research funding is typically represented as a pipeline with flows of resources and impact moving in one direction, from creation of knowledge to possible use. In this model, sponsors allocate research dollars to researchers, who in turn produce findings that are disseminated through the peer-reviewed literature and scientific conferences, which eventually may (or may not) lead to knowledge being incorporated into decisions or actions undertaken by individuals or organizations.

In contrast, the evolution of NERRS-sponsored research exemplifies a turn toward a more interactive, iterative, and relationship-oriented funding model that explicitly seeks out and nurtures multiway engagement among the individuals and organizations involved in research sponsorship, research, and use (Figure 1). The mission-oriented and relatively narrow set of regional and topical contexts in which reserve system-funded research takes place allows for three significant feedback mechanisms between sponsors, researchers, and users. First, ongoing effort to improve funding programs and provide meaningful support, enables research teams to succeed in producing usable science and technology creating a back and forth (directly and mediated through ongoing program evaluation) between research sponsors and researchers. For example, over the 20 years of annual competitions, requirements for user engagement by researchers increased, compelling researchers to expand into more collaborative modes of science. Said one researcher funded during a later stage of the program evolution: “I’ve been a professor [...] for 30 years, [...] and this is a completely different approach for me.” (Arnott et al. in review)

Second, with prompting from sponsor requirements and encouragement, the interest of researchers, research reserves, and users to pursue and participate deliberately in collaborative

research projects has increased. For example, the 20-year history of research in and around Waquoit Bay Reserve, Massachusetts, is illustrative of the consistent mission to deliver usable, context-relevant science. In the early years, one researcher from the Marine Biological Lab in Woods Hole worked in loose partnership with the reserve to conduct monitoring on nutrient pollution. The outcomes of this research alerted the reserve as well as advocacy and governmental organizations about the need for expanded monitoring and control over these harmful nutrient pollutants, which later came to be enforced by the state government. In later years, the reserve itself led collaborative research efforts on ‘blue carbon’ –or, how to incentivize the protection of coastal areas as sources of carbon sequestration–which they pursued in collaboration with regional stakeholders. Previously, the reserve represented either an end- or intermediate- user of the sponsored research. As time evolved, they became a leader in collaborative research, working to provide support to stakeholders in their community.

Third, because of the mission-oriented nature of the research program and its connection to applied and local settings, NERRS has been able to engage with users to understand their needs and to measure changes that occur in their context as a result of its sponsored research. Reserve staff and research teams do this regularly through one-on-one conversations, focus group discussions, and in larger settings, such as workshops that engage their surrounding community members and decision-makers. In recent years, the NSC program has also worked with project teams to circulate pre and post surveys of users to understand how involvement with the project has influenced their ability to use science to achieve their goals.

Conclusion

As the evolution of the NERRS extramural research program demonstrates, increasing the application of science to solve coastal management issues requires applied research programs to adopt funding models that allow for a deeper, multiway engagement of users in order to be successful. In many ways, this is a departure from the traditional approach for many funders, scientists, and resource managers. Changing established norms is always a challenging process at both institutional and individual levels. While scholarly research into reserve-funded projects have shown many of the benefits of collaboration at the project levels, a purposeful and adaptive evaluation of the program itself is needed to innovate and push the boundaries of what funding can achieve towards the production of usable knowledge. Ideas for improving the reserve system’s sponsored research programs include the following. First, we need to better track and articulate the full suite of benefits collaborative approaches can offer for coastal management objectives. Second, we need to understand how best to catalyze and sustain these novel configurations and relationships in such a way that they have the highest likelihood of success. And, finally, we need to better understand how to scale up structures for knowledge exchange and collaboration to achieve and engage more researchers and practitioners with limited resources.

In 1998, Jane Lubchenco (the Administrator of NOAA from 2009-2013) wrote in *Science*, “The whole system of science, society, and nature is evolving in fundamental ways that

cause us to rethink the way science is deployed to help people cope with a changing world.” (Lubchenco 1998, 496). In many ways, the two decades of reserve system competitive funding reflects this evolution, contributing insight to a still active discussion happening across the scientific community about how best to engage with and support society. The reserve system experience provides an example of how scientists, users, and funders are working together to address both longstanding and rapidly emerging challenges to coastal and estuarine protection.

Acknowledgments: This work was sponsored by the National Estuarine Research Reserve System Science Collaborative, which supports collaborative research that addresses coastal management problems important to the reserves. The Science Collaborative is funded by the National Oceanic and Atmospheric Administration and managed by the University of Michigan Water Center (NA14-NOS4190145).

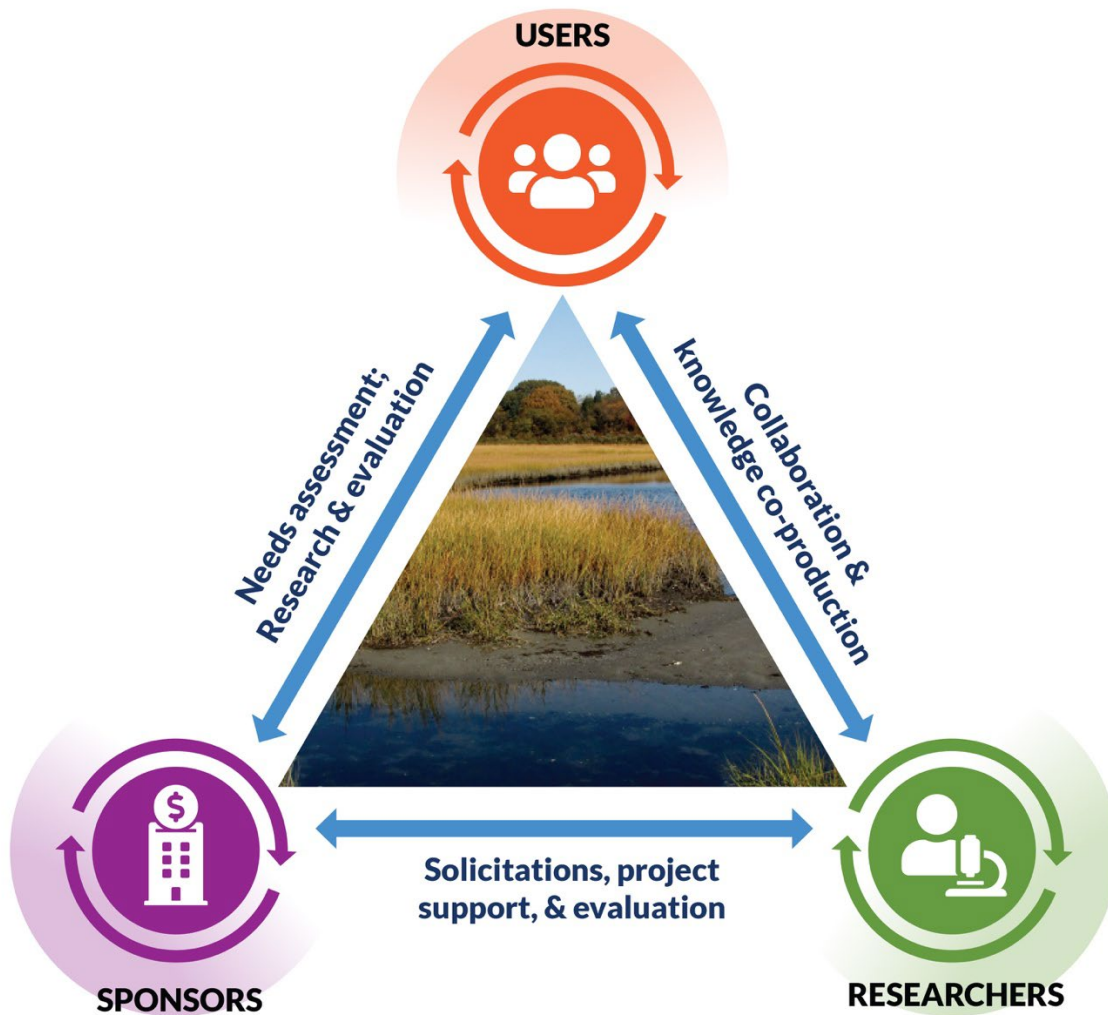


Fig 1. A model for multi-way interaction between researchers, sponsors, and users based on the evolution of extramural funding at NERRS (blue arrows along sides). As interaction occurs between these actors, this leads to internal reflection and change within each of the separate institutional settings (circular arrows surrounding each actor). This approach departs in significant ways from conventional modes of funding where minimal interaction occurs between researchers and users.

References

- Allison, E. H., and H. R. Bassett. 2015. "Climate Change in the Oceans: Human Impacts and Responses." *Science* 350 (6262): 778–82. <https://doi.org/10.1126/science.aac8721>.
- Cash, David W, William C Clark, Frank Alcock, Nancy M Dickson, Noelle Eckley, David H Guston, Jill Jäger, and Ronald B Mitchell. 2003. "Knowledge Systems for Sustainable Development." *Proceedings of the National Academy of Sciences of the United States of America* 100 (14): 8086–91. <https://doi.org/10.1073/pnas.1231332100>.
- DeLorme, Denise E., David Kidwell, Scott C. Hagen, and Sonia H. Stephens. 2016. "Developing and Managing Transdisciplinary and Transformative Research on the Coastal Dynamics of Sea Level Rise: Experiences and Lessons Learned." *Earth's Future* 4 (5): 194–209. <https://doi.org/10.1002/2015EF000346>.
- Ford, James D, Maggie Knight, and Tristan Pearce. 2013. "Assessing the 'Usability' of Climate Change Research for Decision-Making : A Case Study of the Canadian International Polar Year." *Global Environmental Change* 23 (5): 1317–26. <https://doi.org/10.1016/j.gloenvcha.2013.06.001>.
- Leschine, Thomas M., Bridget E. Ferriss, Kathleen P. Bell, Krista K. Bartz, Sarah MacWilliams, Michelle Pico, and Andrew K. Bennett. 2003. "Challenges and Strategies for Better Use of Scientific Information in the Management of Coastal Estuaries." *Estuaries* 26 (4 B): 1189–1204. <https://doi.org/10.1007/BF02803373>.
- Lubchenco, J. 1998. "Entering the Century of the Environment: A New Social Contract for Science." *Science* 279 (5350): 491–97. <https://doi.org/10.1126/science.279.5350.491>.
- Matso, Kalle. 2012. "Producing Science That Gets Used by Coastal Communities: What Funders Should Do to Link More Science with Decisions." University of New Hampshire.
- Matso, Kalle E., and Mimi L. Becker. 2014. "What Can Funders Do to Better Link Science with Decisions? Case Studies of Coastal Communities and Climate Change." *Environmental Management* 54 (6): 1356–71. <https://doi.org/10.1007/s00267-014-0347-2>.
- Matso, Kalle E, Molly O'Donovan Dix, Benjamin Chicoski, Debra L Hernandez, and Jerry R Schubel. 2008. "Establishing a Minimum Standard for Collaborative Research in Federal Environmental Agencies." *Integrated Environmental Assessment and Management* 4 (3): 362–68. https://doi.org/10.1897/IEAM_2007-070.1.
- McNie, Elizabeth C. 2007. "Reconciling the Supply of Scientific Information with User Demands: An Analysis of the Problem and Review of the Literature." *Environmental Science and Policy* 10 (1): 17–38. <https://doi.org/10.1016/j.envsci.2006.10.004>.
- Scavia, D, JC Field, DF Boesch, James Titus, Robert W.G. Buddemeier, Virginia Burkett, Daniel R. Cayan, et al. 2002. "Climate Change Impacts on US Coastal and Marine Ecosystems." *Estuaries* 25 (2): 149–64. <http://link.springer.com/article/10.1007/BF02691304>.
- Steffen, Will, Wendy Broadgate, Lisa Deutsch, Owen Gaffney, and Cornelia Ludwig. 2015. "The Trajectory of the Anthropocene : The Great Acceleration." *The Anthropocene Review*. <https://doi.org/10.1177/2053019614564785>.
- Turner, Elizabeth, and Thomas Jordan. 2017. "Integrating Regional Management Needs into a Mid-Atlantic Shorelines Research Project." *Estuaries and Coasts*. <https://doi.org/10.1007/s12237-017-0261-y>.
- Vano, Julie A, David Behar, Philip W Mote, Daniel B Ferguson, and Raj Pandya. 2017. "Partnerships Drive Science to Action Across the AGU." *Eos* 98 (December): 1–7.