Cooperation without Consensus: Brokering Resiliency with Boundary Objects

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ABSTRACT: This paper presents a case study of how boundary objects were deployed to support a collaborative knowledge production process that resulted in the creation of climate change knowledge usable to municipal governments in the New Jersey shore region. In doing so, a case is made that boundary objects are useful throughout the collaborative process in overcoming ambiguity and disagreement. This points to boundary objects possessing a wider array of capabilities than is frequently theorized in the climate policy literature. Effectively designing and using boundary objects, however, requires carefully considering how they interface and interact with one another.

SIGNIFICANCE STATEMENT: This article contributes to a number of ongoing developments in the scientific literature on this topic. First, it provides an empirical (i.e., hands-on experience) account of how boundary objects (i.e., tools that allow different communities of practice to collaborate without precise agreement about the goals and purpose of working together) are used to create usable information. While boundary objects are frequently called for in the literature, there still remain few empirical examples. Second, the article argues that boundary objects provide a wider range of capabilities than is typically theorized in the climate change policy literature, which tends to focus on how boundary objects can help during the actual moments of collaboration between different communities of practice. Third, the article should be of value to practitioners and decision-makers in a wide range of geographical and political contexts beyond the New Jersey shore region who want to generate and apply usable climate change information.

KEYWORDS: North America; Adaptation; Climate services; Decision support

1. Introduction: Closing the gap

In light of the persistent gap between, on the one hand, the knowledge about the causes and consequences of climate change and, on the other hand, the lack of effective actions taken to address climate change (Lemos et al. 2012; Moser and Dilling 2011; O'Brien 2012), scholars have called for collaborative knowledge production practices that bridge the social worlds of science and policy to create usable, tailored climate change information (Dilling and Lemos 2011; Hegger and Dieperink 2014; Kirchhoff et al. 2013; Lemos and Morehouse 2005; Lemos et al. 2012, 2019). Implementing collaborative knowledge production programs, though, requires overcoming the challenges of irreducible ambiguity and disagreement between different communities of practice (Brugnach and Ingram 2012; Eriksen et al. 2015; Flagg and Kirchhoff 2018; Porter and Dessai 2017) as well as frequently high financial and opportunity costs (Harvey et al. 2019; Lemos et al. 2019). To navigate such factors, researchers have called for designing and employing "boundary objects" within collaborations (i.e., Cash et al. 2006; Guston 2001; Kalafatis et al. 2019; Kirchhoff et al. 2013). Boundary objects are tools for facilitating cooperation in situations lacking consensus by bridging multiple social worlds and supporting collaboration between actors with divergent goals and worldviews (Star 2010; Star and Griesemer 1989). However, there exists limited theoretical and empirical engagement on boundary objects within the climate change vulnerability, risks, and adaptation literature [exceptions include Kalafatis et al. (2019), Meyer et al. (2015), and van Pelt et al. (2015)]. Additionally, the concept is often used in a loose sense in which some specific qualities of boundary objects are overlooked or excluded [see Star (2010) for an overview of the misuses of the concept].

In this article, I demonstrate how boundary objects facilitated cooperation in a situation in which ambiguity and debate prevailed with regard to the implications of climate change as well as how to best address plausible impacts. I use examples from a case study of an effort led by the Jacques Cousteau National Estuarine Research Reserve (JCNERR) to collaborate with municipal government staff and officials to produce usable, tailored climate information. The staff of the JCNERR used a collection of boundary objects that worked together to entice participation, help foster cooperation from diverse actors, and produce tailored climate information and policy recommendations. In doing so, the paper makes two important empirical observations about how boundary objects can foster collaboration. First, I demonstrate that boundary objects can bridge a diverse array of social worlds—including between science and policy as well as within the multiple goals, knowledges, and practices within the policy realm. Second, I show how different boundary objects interact with each over the course of a project so that they gain a more specific and coherent identity that allows for more effective collaboration.

Section 2 begins with a brief summary of the concept of "boundary objects" that includes a discussion of its origins in the field of science and technology studies. Next, I provide a short review of the climate change policy scholarship exploring

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the factors theorized to inhibit and enhance knowledge collaboration as well as the as well as how boundary objects have been suggested as fostering effective collaboration. Following this, section 3 introduces the case study of the JCNERR's effort to generate tailored climate risk information with municipal actors within the New Jersey shore region. I then move in section 4 to describe how boundary objects aided in the convening and facilitating of a collaborative process that resulted in the generation of tailored climate risk information and policy options. The aim of this analysis is to explore the multiple roles of boundary objects in facilitating cooperation in situations in which consensus is lacking as well as fostering a shared understanding of climate hazards and possible solutions. I conclude in section 5 by highlighting three key lessons that can be applied to other efforts to foster collaboration.

2. Using boundary objects to overcome barriers to collaborative knowledge practices

Within this section, I summarize the scholarship on boundary objects as well as on the factors that inhibit or enhance the process of collaboratively producing usable climate information. Neither one of these overviews aims to provide an exhaustive analysis of these diverse fields. Instead, I aim to highlight areas in which a fuller engagement with the concept of boundary objects can help achieve the theorized design principles for collaboratively producing usable climate information and services. In providing an overview of how the concept of boundary objects has been developed and deployed in the science and technology studies literature, I summarize the work of S. L. Star and her colleagues (i.e., Bowker and Star 1999; Star 2002, 2010; Star and Griesemer 1989) who developed the concept to initially explain how scientific collaboration occurs despite irreducible ambiguity and refined the concept over three decades to apply to other social processes. To identify how boundary objects have been theorized to enhance collaboration and overcome inhibiting factors, key articles reviewing the state of the literature on collaborative climate knowledge processes (i.e., Cvitanovic et al. 2016; Fazey et al. 2014; Harvey et al. 2019; Hegger and Dieperink 2014; Kirchhoff et al. 2013; McNie 2013; Meadow et al. 2015; Vincent et al. 2018; Wall et al. 2017) were identified and analyzed.

a. The conceptual origins of boundary objects

The concept of boundary objects emerged in the late 1980s within the field of science and technology studies (STS) to explain how scientific work can unfold and succeed even though collaborators frequently have different understandings of a problem and objectives in addressing it (Star and Griesemer 1989). Indeed, at the time the concept of boundary objects was being developed, a central problem with the field of STS was explaining how scientific collaboration could occur when consensus was often only achieved at the conclusion of a successful collaboration (Latour 1987). Thus, a boundary object is something allows different communities of practice to collaborate without precise agreement about the goals and purpose of working together (Star 2010; Star and Griesemer 1989). There are three crucial dynamics that determine whether something acts as a boundary object (Star 2010). First, they reside between multiple communities of practice and maintain a common, ill-structured identity within all such worlds—this allows for multi- and transdisciplinary work. In other words, all participating actors share a common, though general, understanding of a boundary object around which collaboration unfolds. Second, when being used by a particular community of practice, a boundary object gains a more tailored identity that allows for specialized work. Third, cooperating groups can tack back and forth between ill-structured and tailored forms of a boundary object. This tacking back between two forms is how boundary objects support cooperation without consensus (Star 2010). Consequently, assessing whether something is a boundary object requires a constructivist approach in which what matters is less the inherent qualities of a thing and more whether it meets a variety of actors' specific work and informational needs while maintaining a shared identity.

As Star (2010) acknowledges, almost anything can be a boundary object—including physical objects, repositories, concepts, and geographic areas. Indeed, in Star and Griesemer's (1989) initial article introducing the concept, they found that a collection of boundary objects of various types worked together to facilitate collaboration that resulted in the creation of a museum in California during the early twentieth century. In this case, the state of California, the museum itself, forms that standardized collection protocols, and the idea of "species" all acted as boundary objects that allowed scientists, funders, and specimen collectors to work together in creating the museum. Crucially, this case highlights that individual boundary objects frequently operate in a broader context that connects them to other boundary objects—a point that will be demonstrated in section 4. This multifaceted nature of boundary objects has been underexplored within the climate change policy literature, although it is implicitly explored in some papers (e.g., Kalafatis et al. 2019). A simple example of a boundary object relevant to climate change knowledge collaborations would be a map of projected tidal flooding in the year 2050. Such a map can possess a common, ill-structured identity between a range of relevant communities of practice, such as hydrologists, ecologists, coastal engineers, urban planners, elected officials, and homeowners. Assuming an agreement that the map is legitimate, all of these communities of practice can look at the map and likely agree that it shows what flooding might be like in 2050. However, each community of practice is likely to also see the relevancy, salience, and value of the map differently. The ability of the flood map to act as a boundary object within a collaborative knowledge production process would require that actors from each community of practice be able to continue to apply the map to their specialized needs and interests while tacking back to the common identity of the map.

b. The value of boundary objects within collaborative knowledge production

The ability of boundary objects to support collaborations has been highlighted within the climate change adaptation literature as particularly useful because of the need for and challenges associated with including multiple communities of

practice with divergent needs, knowledges, and goals (Cash et al. 2006; Guston 2001; Harvey et al. 2019; Hegger et al. 2012; Kirchhoff et al. 2013; Lemos et al. 2012; Tribbia and Moser 2008). Three broad ways boundary objects have been highlighted as enhancing collaboration are (i) helping secure buy-in from key actors by presenting a flexible concept that different actors can interpret and value differently, (ii) reducing ambiguity and disagreement by providing shared ideas and/or materials around which negotiation can unfold, and (iii) lessening financial and opportunity costs by facilitating more mediated forms of collaboration, such as through boundary organizations and knowledge brokerage.

1) Securing buy-in through interpretive flexibility

Research in the past two decades has frequently capacity of boundary objects to help to generate and secure buy-in from crucial actors from both sides of the science–policy interface (Cash et al. 2006; Guston 2001; Meyer et al. 2015). Because boundary objects possess a high degree of interpretive flexibility, different actors can view and value them in ways that they see as positive. For instance, the concept of resilience has been highlighted as boundary object that many different communities of practice see as a positive goal to work toward (Baggio et al. 2015; Brand and Jax 2007; Meerow et al. 2016; Meerow and Newell 2016). Thus, by framing collaboration as unfolding around a flexible concept that can be understood as desirable by multiple communities of practice, it is possible to secure commitment to participate from a wide range of participants. However, at the same time, having too much interpretive flexibility could also hinder effective collaboration.

For instance, Brand and Jax (2007) argue that the concept of resilience can act as a boundary object because it both is ''increasingly viewed in a rather vague and malleable'' fashion and spans multiple disciplines (p. 8), Yet, they warn that the malleability of resilience could hinder scientific progress because if the term becomes diluted and unclear, then that could lead people to believe the concept of resilience is arbitrary and, ultimately, prevent collaboration to unfold around the concept. In such a situation, resilience would no longer meet the informational and work requirements of relevant communities of practice, which would preclude the tacking back and forth from an ill-structured form of resilience and a tailored form of resilience. Thus, resilience would fail to meet the definition of a boundary object as it was developed in the STS literature (i.e., Star 2010).

More recently, S. Meerow and colleagues (Meerow et al. 2016; Meerow and Newell 2016) have sought to provide guidance for how resilience can be effectively utilized as a boundary object. They acknowledge that the ambiguity and flexibility of resilience can be a hindrance to collaboration. However, they also see this malleability as potentially ''allowing stakeholders to come together around a common terminology without requiring them to necessarily agree on an exact definition'' (Meerow et al. 2016). They suggest that some degree of consensus be achieved within collaboration by addressing what they refer to as the ''five Ws of resilience'': ''resilience of what, to what, for whom, at what time, and where?'' (Meerow and Newell 2016). In other words, by connecting the concept of ''resilience'' to more specific and concrete issues, a more coherent basis for collaboration can be achieved. As I will argue on the basis of the case study of the New Jersey shore region, one way this coherence can be achieved is by connecting the concept of resilience to other boundary objects that help to foster discussion on these questions.

2) Reducing ambiguity and disagreement

A common challenge to collaboration is that participants tend to have a range of understandings of the problems being addressed and visions for what solutions ought to achieve (Brugnach and Ingram 2012; Kalafatis et al. 2019; Porter and Dessai 2017). Harvey et al. (2019, p. 109) highlight that collaborative knowledge generation is often difficult because ''heterogeneous groups of stakeholders have diverse worldviews, cultural backgrounds, interests, objectives, motivations, relationships, institutional structures, and resources.'' Because of this, disagreement and ambiguity are prevalent (Brugnach and Ingram 2012). Ambiguity is often irreducible within collaborative processes because of ''the fact that in a group of people there are different sensible and valid ways of knowing reality'' (Brugnach and Ingram 2012, p. 61). While ambiguity might not be completely removed, it is possible to acknowledge differences and still productively produce new, usable knowledge through careful practices of collaboration (Brugnach and Ingram 2012; Tengö et al. 2014, 2017). The use of boundary objects has been highlighted as one strategy for addressing ambiguity and disagreement (Meyer et al. 2015; Kalafatis et al. 2019).

Research by Meyer et al. (2015) provides an example of boundary objects reducing ambiguity within an effort to generate tailored, usable knowledge about how to respond to hypoxia and ocean acidification along the western coast of the United States. These two issues were linked by framing ocean acidification as partially being caused by hypoxia, which helped to make the challenge of ocean acidification more tractable to state decision-makers. However, some scientists were uncomfortable with this framing. To reduce the ambiguity and disagreement about how to best frame the problem, the results of two science needs assessments acted as a boundary object that helped different scientists with different goals and concerns to negotiate with each other and decision-makers the ways in which they could both meet their own objectives while gaining a better understanding of the needs of decision-makers; at the same time, decision-makers improved their understanding of what scientists could offer them (Meyer et al. 2015, p. 55). Thus, the combined results of the two science needs assessments successfully acted as a boundary object because they met the work requirements of multiple communities of practices, possessed interpretive flexibility, and facilitated collaboration. Because of this, the ambiguity of how to frame and understand hypoxia and ocean acidification and the potential links between the two was reduced.

3) Lowering the costs of collaboration through mediation and brokerage

Another common factor inhibiting effective collaboration that stems from the need to bring together a diverse array of

communities of practice is the frequently high costs to participants. For instance, in a recent commentary, Lemos et al. (2018, p. 722) highlight that "the costs of co-producing are potentially high, requiring more time, money, facilitation, expertise and personal commitment from participants than conventional modes of knowledge production." In particular, they point toward collaborative efforts frequently taking a long time, the potential for fatigue among stakeholders, and participants not believing they possess the proper training and/or understanding to collaborate with others from different communities of practice. In other words, unresolved ambiguity and disagreement can add to the costs of collaboration by increasing the time, money, and effort necessary. Thus, the capacity of boundary objects to act as resources for reducing ambiguity can also help to reduce the costs of collaboration by lessening the time and effort spent on negotiating disagreements.

Boundary objects can also reduce costs in other ways, such as by lessening the need for direct participation of some communities of practice. For instance, boundary organizations are a type of boundary object that supports collaboration by bridging the social worlds of science and policy, forming lines of accountability to crucial actors on both sides of the science–policy interface, and creating a combined scientific and social order (Guston 2001; Kirchhoff et al. 2013). Boundary organizations typically employ knowledge brokers to facilitate this process. Such strategies have been highlighted recently as having the potential to reduce the costs of collaboration (Harvey et al. 2019; Kirchhoff et al. 2015; Lemos et al. 2019). Van Pelt et al. (2015) provide an empirical case in a simulation game exploring the challenges of sea level rise, precipitation changes, and temperature that was used as a boundary object bridging the worlds of climate science and policy—even though scientists and policy makers did not directly interact. In this case, a simulation game that had been designed by scientists for learning about the interactions between climate change and water management was slightly altered to be used by decision-makers to learn about adaptive management. Through playing the simulation game, decision-makers gained a greater appreciation of the irreducible quality of uncertainty around future climatic conditions and came to understand that more scientific research would be unable to provide accurate projections of the future. This helped decision-makers to appreciate the value of adaptive approaches. Thus, while "scientists were no active part of the game session, they interreacted with the water managers through the game" (van Pelt et al. 2015, p. 48). This highlights the capacity of boundary objects to transport the knowledge and insights from one community of practice to another without direct interaction. In other words, knowledge brokers and boundary organizations can use boundary objects as tools to bridge the social worlds of science and policy while reducing the financial and opportunity costs to actors.

3. The JCNERR and the New Jersey shore region

Municipal governments the New Jersey Shore region are in need of tailored, usable climate risk information (Bates 2016; O'Neill and van Abs 2016). Coastal areas of New Jersey are vulnerable to climate change impacts such as sea level rise, more prevalent flooding events, and potentially more powerful and frequent coastal storms (Strauss et al. 2014). Residential and business development exists along most of the ocean and back bay shorelines—including a number of narrow barrier islands and peninsulas (Mazzagetti 2018). In recent years, multiple powerful storms, such as Superstorm Sandy and Tropical Storm Irene, have caused significant damage to infrastructure and property (Bates 2016; Leichenko et al. 2014; Leichenko and Solecki 2013; O'Neil and van Abs 2016). However, local governments and communities in the region have largely continued to follow existing development and policy trajectories with few signals of transformative change (Bates 2016; Leichenko et al. 2015; van Abs and O'Neill 2016). In response to the continued exposure of the shore region to climate impacts and the persistence of vulnerable development patterns, scholars have called for new approaches to communicating climate risks, developing policies to respond to projected climate impacts, and supporting on-the-ground actions (Bates 2016; Leichenko et al. 2015; van Abs and O'Neill 2016).

Between 2012 and 2018, JCNERR collaborated with municipal governments to tailor climate change projections about sea level rise and coastal flooding to local needs. This initiative, titled "Getting to Resilience" (GTR), entailed JCNERR staff facilitating iterative discussions with municipal government staff about projected coastal hazards as well as potential policy options local governments could pursue to become more resilient. The program was organized around an evaluation tool that was also titled Getting to Resilience that was developed by the New Jersey Department of Environmental Protection. The tool included a questionnaire designed to be completed by municipal government actors. The questionnaire was organized into five sections: risk and vulnerability assessments, planning integration, public engagement, disaster preparedness and recovery, and hazard mitigation implementation. By collectively answering these questions, municipal actors were supposed to gain a better understanding of current strengths and weaknesses of local approaches to coastal management as well as learn about possible strategies for creating more resilient and effective planning and policy pathways. The JCNERR staff facilitated discussions on the basis of this questionnaire with the goal of enabling both (i) mutual learning in which different participants learn about the concerns and perspectives of other municipal actors and (ii) collective learning about recent scientific research on the potential impacts that sea level rise will have in the region. This knowledge was then collected in a collaboratively written recommendations report.

In recruitment and planning material, the concept of resilience is given a broad definition of entailing "the capacity of a system, community, or society potentially exposed to hazards to adapt to stress and change, by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure" (New Jersey Department of Environmental Protection 2011, p. 1). As described in section 2, such a broad definition of resilience risks being overly flexible and incoherent—leading to ineffective collaboration. However, as will be explored in the following section, by connecting the

TABLE 1. Inhibiting factors found in the New Jersey shore region.

Category	Inhibiting factor
Informational fit and interplay	The technical language of scientific work presents a challenge for municipal government actors
	The policy and management requirements of municipal governments do not align with the temporal and spatial scales of climate science
	Scientific information is difficult to integrate into existing knowledge systems used in municipal government decision-making
Institutional and individual capacity	Municipal governments lack the staff and funding necessary to gather and deploy climate information in pursuit of adaptive actions
	It is a challenge to identify and partner with technical experts
External	There is hesitancy to pursue information that might challenge prevailing development patterns

concept of resilience to other boundary objects, the JCNERR staff were able to give it a more coherent identity as the process unfolded.

Materials and methods

Twenty-five semistructured interviews were conducted with municipal actors from nine municipalities that participated. The selected municipalities were Perth Amboy, Atlantic Highlands, Sea Bright, Toms River, Brick, Tuckerton, Little Egg Harbor, Longport, and Atlantic City. Each of these municipalities suffered damage during Superstorm Sandy. Interviews included both elected officials and municipal staff, such as planners, engineers, and floodplain managers. Interviews typically lasted between 40 and 60 min and explored what interviewees learned through participating in the GTR program, what aspects of the program were most helpful, and to what extent the program contributed to adaptive actions. Interviews were transcribed and qualitatively analyzed to identify patterns and trends between responses about the factors perceived as inhibiting and enhancing collaboration, the differences in how various key objects used within the GTR program were understood and valued, and the ways in which those objects interacted with one another during the collaborative process and how those interactions impacted the ways in which each object was understood and used.

4. Getting to resilience with boundary objects

In this section, I describe how the JCNERR staff were able to overcome inhibiting factors by using a set of boundary objects. Before, during, and after the GTR program, no consensus existed among municipal staff and officials as to the exact problems climate change posed or what objectives climate policies ought to seek to achieve. However, the interpretive flexibility of boundary objects allowed collaboration to unfold despite this disagreement and ambiguity. Ultimately, the GTR program resulted in a jointly written report in each of the municipalities where collaboration occurred. Each boundary object used in the GTR provided particular benefits. However, the boundary objects do not operate in isolation. Rather, in this case, the JCNERR facilitators bundled them together to coordinate different communities of practice working together to produce tailored and usable climate change information and potential policy options.

Before detailing how the boundary objects supported collaboration, it is important to highlight the role of skilled facilitators. As will be highlighted throughout this section, interviewees described how the JCNERR staff made the boundary objects relevant and interesting to them. The facilitators possessed a number of attributes that helped to gain the trust and interest of participants—including being from the New Jersey shore region and being employed by Rutgers, the largest state university in New Jersey. Moreover, the facilitators were knowledgeable about the academic literature on climate science and policy. Indeed, the structure of the program was designed through collaboration by academics at Rutgers and other universities. Thus, while the focus of this paper is on the boundary objects used within the GTR program, the people involved are still critical to a successful collaborative process.

Interviewees described three broad factors inhibiting collaboration: problems of information fit and interplay, challenges of institutional and individual capacity, and issues of political will and public support (see Table 1). To overcome these constraints, the JCNERR staff deployed a collection boundary objects that included the concept of ''resilience,'' local level sea level rise maps, the GTR evaluation tool, and a jointly written final report (Table 2). The concept of resilience operated as the central organizing boundary object that influenced how the other boundary objects were used in the GTR program. The other boundary objects, in turn, conditioned how resilience was understood within the collaborative process. In the remainder of this section, I document how this collection of boundary objects supported the convening and stabilizing of the collaborative process as well as the generating of tailored, usable climate risk information collected within a jointly composed recommendations report.

The concept of resilience played a crucial role in convening collaboration by helping to secure buy-in from key municipal officials—who often reported agreeing to participate because they saw resilience as a positive goal. At the time, many municipal governments were seeking guidance in updating planning documents in response to the lingering effects of Superstorm Sandy. As one municipal floodplain manager on a barrier island stated: ''Resiliency gives you direction. The best thing about it is that it is pulling all the different components that we have when it comes to our ordinances, when it comes to planning, [and] when it comes to enforcement. And, hopefully, it'll provide some direction.'' As this suggests, municipal government actors were able to apply the concept of resilience to existing planning and policy objectives and then imagine how it

TABLE 2. Accomplishments of the boundary objects used in the GTR program.

Boundary object	Accomplishment
Concept of resilience	Secured buy-in from stakeholders by meeting divergent visions and values
	Connected municipal actors, state government actors, and scientific actors around a broad concept
Sea level rise maps	Supported the identification of common problems around which collaboration could unfold while allowing specific communities of practice to identify unique problems
	Bridged the social worlds of climate scientists and municipal actors while gaining a unique, tailored identity in both worlds
	Conditioned the concept of resilience to relate to a specific range of issues and challenges
GTR evaluation tool	Organized and coordinated collaboration between communities of practice
	Bridged the social worlds of state government actors and municipal actors
	Conditioned how collaborative efforts to address the challenges of sea level rise and resilience unfolded by focusing discussion
GTR report	Allowed multiple communities of practice to play a role in producing documented knowledge
	Provided multiple communities of practice a concrete resource to pursue new programs

could help them achieve desirable outcomes. This incentivized participation because, in its ill-defined form, most key actors were able to apply the idea of resilience to their needs. However, at this early stage, the concept of resilience was still vague and ambiguous. At this stage of collaboration, the concept of resilience possessed many of the qualities theorized in the literature to both enhance and inhibit collaboration, as described in section 2. Key actors were willing to participate because they viewed resilience as a positive goal toward which to work. Moreover, actors with different responsibilities and goals were able to apply the concept to their particular work requirements. In this sense, the concept of resilience clearly possessed two of the critical qualities of a boundary object—it had an ill-defined, shared identity of being a positive goal to work toward while also possessing more tailored identities that allowed for specialized work. At the same time, the vague and ambiguous shared definition of resilience still presented a challenge to successful collaboration. Without being able to tack back and forth between the tailored and ill-structured definitions, the concept of resilience would fail to properly act as a boundary object and effective collaboration would not occur. Moreover, these discussions about resilience highlighted that the social worlds on both sides of the science–policy interface are diverse and multifaceted, because while engineers, planners, and elected officials all broadly reside within the "policy" realm their goals, knowledge, and practices differ in key ways that contributed to them conceptualizing resilience in distinct ways.

To help to foster collaboration and reduce—while not removing—flexibility, the JCNERR facilitators presented local sea level rise maps during the first meeting. The JCNERR facilitators displayed maps showing a range of plausible sea level rise and coastal flooding scenarios. Because these maps were local in scale, participants were also able to connect them to personal experiences. One member of a municipal environmental commission stated that

> the thing that really got my attention was the projections. One was the projections of what the potential water rise would be [in the future]. Particularly because I spend a lot of time on the water doing fishing, and I've seen the tides be outrageously high consecutively or on a consistent basis. There's one woman on the environmental commission who lives in an area that floods, and she said she's seen nothing like this in the first 30 years [of living here], but, in the last five years, you get flooding every nor'easter. It was only the really severe storms or the super storms once a year. Now it is several times a year. But the other thing that I thought was really informative was the SLOSH models—that opened some eyes, I think. It opened my eyes. Particularly as they rolled them out into the future with sea level rise.

This quotation shows how maps of sea level rise and sea, lake, and overland surge from hurricanes (SLOSH) models not only contain objective information about plausible future climate impacts but also that nonscientists are able to make connections between their personal experiences and the technical and scientific knowledge displayed on the maps.

These maps gave resilience a more coherent shared identity by clarifying some, although not all, of the five Ws of resilience discussed in section 2. In particular, the maps framed resilience as unfolding at the municipal level (i.e., where), in relation to sea level rise and coastal flooding (i.e., to what), and as necessary in the near term (i.e., when). By making these connections, the maps conditioned the ways in which the concept of resilience would be used within the GTR program, which was critical for facilitating the tacking back and forth between its tailored and ill-defined forms. At the same time, while the identity of resilience was conditioned, it still retained significant flexibility, which, as will be explored, allowed different actors to still define resilience to meet their own needs.

Beyond conditioning the ways in which the concept of resilience was used, the maps also acted as boundary objects in two critical ways. First, the maps helped connect the social worlds of climate science and municipal government policy and planning. The maps were created with input from climate change researchers at Rutgers. This allowed the facilitators to present the maps as legitimate and objective data. Thus, even though the scientists whose work informed the maps were not physically present, the maps carried their knowledge into the GTR. However, the JCNERR facilitators also made clear during the GTR meetings that the science behind the maps further deepen climate risk knowledge and play an important role in the development of policy and planning solutions. By acting as an intermediary between actors from the social

worlds of science and policy, the JCNERR facilitators were able to broker and integrate knowledge claims from both sides even through the actors did not directly interact. This again highlights that skillful human actors are still needed to effectively deploy boundary objects.

Second, the maps also helped to define the value of recognizing differences in expertise and perspective. Within a discussion about potential risks and vulnerabilities, JCNERR queried municipal actors on what communities, infrastructures, and spaces they were concerned about due to sea level rise. Municipal actors with different sets of expertise and experience volunteered information about how and why increased sea level rise might impact the local community, infrastructure, and economy. This helped to validate the knowledge claims of some municipal actors. For instance, one municipal engineer relayed: ''When the SLOSH maps were put up and we had a new mayor and administrator, they were like, 'Wow, look at that!' I said, 'No, that is what flooded during Sandy. That is the area that was flooded already.''' Afterward, the engineer reported that they were able to get more support for projects to plan for flooding. Thus, the engineer's existing concerns about coastal flooding gained credibility in part because of the maps. Multiple interviewees conveyed similar stories in which the displaying of maps validated their concerns and arguments for addressing coastal flooding problems both in the short and medium term. Again, this process demonstrates that boundary objects not only bridge the worlds of science and policy, but also bridge the perspectives of different actors within a municipal government. Through such discussions, the JCNERR facilitators brokered and wove together knowledge from both sides of the science–policy interface to elucidate specific risk information with regard to the local context.

After actors collectively identified common problems, the process moved onto a discussion about potential strategies for improving resilience to coastal hazards. The JCNERR facilitated this discussion by using the Getting to Resilience evaluation tool described in section 3. While the evaluation tool questions were structured as a series of yes/no questions, the JCNERR facilitators also worked to spur a conversation about how additional actions could address concerns that participants expressed with regard to coastal resilience. This allowed the facilitators to use questions included within the tool to stimulate further discussion of the five Ws of resilience. For instance, the tool was used to foster conversations around the question of ''resilience for whom?'' through asking questions about whether the municipal government had developed policies to identify which specific communities might be more vulnerable to sea level rise and flooding, such as elderly and low-income populations. Other questions deepened the conversation on the question of ''resilience to what?'' by asking if the municipal government had defined potential hazards and their probabilities, frequency, and magnitude.

These conversations allowed for participants to further apply their specialized knowledge to improving resilience to coastal flooding. Because other participants had the ability to respond and add their own perspective, mutual learning unfolded so that different municipal actors gained an appreciation for how other departments could add to potential solutions. In other words, the GTR questions allowed for a bridging of the various knowledges and practices of different actors around a shared problem. Interviewees frequently stated that the ability of the JCNERR facilitators to skillfully weave together the different perspectives in the room with scientific information about sea level rise and flooding projections increased the value of these conversations. For instance, one planning director of a municipality with development on both a barrier island and on the mainland back bay explained that the JCNERR facilitators were able to describe the differences between flooding dynamics on the ocean and bay coasts in a way that helped people in the room to better understand the challenges of coastal resilience as well as spur conversation on where resilience efforts might be needed.

On the basis of these discussions, the GTR program culminated in the joint creation of a report laying out vulnerabilities to coastal hazards facing the municipality as well as policy and management options to mitigate them. The JCNERR staff composed the initial draft of the report by using the information generated during the facilitated meetings. The draft was then circulated to all participants for comments and revisions. The JCNERR staff coordinated revisions and circulated iterative drafts to participants. The report could not be finalized without agreement from key municipal officials, such as mayors, township administrators, and council members. The writing and approval of the report, therefore, depended on municipal staff and officials seeing it as valuable to their own work as well as the general goals of the local government.

Interviews with municipal staff uncovered four broad benefits from the report: facilitating grant application, acting as external validation, providing new ideas, and collecting institutional knowledge and memory. Municipal staff reported that the ability to draw upon findings and language in the GTR report to apply for grants was extremely helpful. As one borough administrator explained when asked what they gained from the GTR program: ''The main factor is obviously the opening of the door to other grants. The report has helped us get quite a few grants.'' This sentiment was echoed by a planner in another municipal government, who explained

> When the federal government comes out with a grant, they announce it on a Friday and they want it on the following Friday. It is never enough time to amass the information necessary. The report prompted us to make ten affidavits of random projects that essentially have all the information that always is requested in the federal docket. So now when a federal program becomes available, you fill in the one-page application form and attach the application form to it and send it out. So that is something that is really helpful. We've already used it to apply to several grants.

As these sentiments convey, participants saw the report as a valuable tool for securing funding for important projects.

The report was also seen as a source of external validation for their existing concerns and ideas about coastal resilience. One municipal staff member who had worked on floodplain management issues for more than two decades explained that they had been able to point to information contained in the

report to convince individuals on the planning commission to take their long-expressed concern about coastal flooding more seriously. Similarly, both the engineer and planner of the same municipality stated that the report had allowed them to begin to discuss the possibility of pursuing managed retreat from some vulnerable areas. Although this conversation remains extremely preliminary and little to no support from key decision-makers exists for retreat, the report has at least allowed the issue to be raised, whereas in the past it was off limits.

Staff members also found that the report acted as a valuable repository of institutional knowledge and memory. One representative statement of this sentiment came from an assistant planner who stated that

> I think the nice part about the report is having it all written down. Everybody here knew what happened after Sandy and what needed to be done. If something happens next year, we will know what to do. But the new people that come in, they're not going to know what to do and if we all retire or leave these positions than the township won't be prepared. So that was a major thing that stuck in my head: how do you prepare for continuity when we are no longer here or the officials are no longer here.

5. Conclusions

Boundary objects can aid in overcoming factors inhibiting collaboration throughout collaborative knowledge production efforts by helping secure buy-in, generating shared problems, stabilizing a space for collaboration, and supporting the creation of new repositories of knowledge. This potential has been underutilized so far within efforts to bridge the knowledge-action gap. Instead, scholarly attention has focused on the potential of boundary objects once collaboration has commenced. However, as detailed, boundary objects can also play a crucial role in catalyzing collaboration as well as implementing policies. In particular, I highlight three broad lessons that can be taken from this case study and applied to other contexts.

First, boundary objects are valuable in every stage of collaborative knowledge production. Scholarship within the field of climate change policy has so far mostly focused on the capacity of boundary objects to support collaboration between different actors once collaboration begins (i.e., Meyer et al. 2015; van Pelt et al. 2015). In the case of the GTR program, boundary objects did support collaboration. However, boundary objects were also valuable in earlier and later stages of the program. They helped to generate buy-in, stabilized a space for collaboration, and helped to apply the tailored knowledge to unfolding problems. This highlights the potential for boundary objects to help to overcome barriers to collaboration encountered both early and late in the process.

Second, the boundary objects used in the GTR program were effective in each stage of collaboration because of how they connected with and gave additional shape to one another. The concept of resilience was the central, organizing boundary object around which collaboration unfolded. Resilience's interpretive flexibility helped secure buy-in from key municipal decision-makers because it was easy for them to envision the benefits of becoming more resilient. Thus, even though key actors might not have the same aspirations and hopes for the future, they could agree that generally being more resilient would likely be positive. As more boundary objects were brought in, resilience gained a more stable identity. The sea level rise maps connected it more concretely to projections of future flood risks. This conditioned the shared identity of resilience within the GTR program; however, it still retained sufficient degrees of interpretive flexibility to remain a boundary object. Similarly, the concept of resilience shaped how the sea level rise maps were framed and discussed during the GTR program. By being connected to resilience, future sea level rise and coastal flooding were generally seen by participants as problems that could be managed through planning and engineering solutions, including both hard and soft infrastructure projects, insurance programs, and poststorm rescue and recovery strategies. The GTR tool was then used to direct conversations between participants around issues of coastal resilience. The JCNERR facilitators used the tool to open up discussion to include multiple perspectives and concerns while also keeping it on track by focusing on discrete policy and planning questions. The jointly written GTR report collected the collaboratively generated insights in way from which municipal staff could continue to draw insights. In light of this, the design of collaborative efforts ought to consider how individual boundary objects connect to one another throughout the course of a project.

Third, boundary objects did not just bridge the science–policy interface, they also connected the different goals, knowledge, and practices that exist within a municipal government. Thus, boundary objects should not just be seen as only facilitating collaboration between the idealized worlds of "science" and "policy," but rather as also fostering collaboration *within* the differentiated worlds of both science and policy. With the GTR program, a range of actors within municipal governments—including planners, engineers, and elected officials—possessed different sets of values, knowledge, and practices that presented both opportunities and hurdles for effective collaboration. One key difference that was evident within this case was that municipal staff had a tendency to think about problems on a longer time horizon than did elected officials—partially because of the need of such officials to run for reelection every 2–4 years. Throughout the GTR program, the interpretive flexibility of boundary objects allowed for overcoming this difference in temporal prioritization. Therefore, when selecting and using boundary objects within a collaborative project, it is important to consider not only how to bridge the science–policy interface but also how to bridge different actors within the worlds of science and policy.

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