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Communicating Sea Level Rise

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Summary and Keywords

Three quarters of the world's large cities are located on coasts. As climate change causes oceans to warm and expand, and triggers vast influxes of water from melting ice sheets and glaciers, by the end of the 21st century, as many as 650 million people globally may be below sea levels or subject to recurrent flooding. Human beings have always faced threats from coastal storms and flooding, but never have so many of us and so much of our societal infrastructure been in harm's way. With entire nations facing forced emigration, international online media are framing sea-level rise as a human rights concern. Yet sea-level rise suffers from generally low media attention and salience as a public issue. Coastal communities tasked with developing adaptation strategies are approaching engagement through new forms of risk visualization and models of environmental decision making. As a subfield of climate communication that addresses a variety of other anthropogenic and natural phenomena, sea-level rise communication also calls upon the less politicized field of natural hazards risk communication. This review explores media analyses, audience research, and evaluation of communication outreach and engagement, finding many remaining gaps in our understanding of sea-level rise communication.

Keywords: Sea-level rise, flooding, visualization, participatory mapping, vulnerability and risk assessment, public opinion, media coverage, engagement models

Introduction

Globally, between 147 and 216 million people live in areas that are likely to be regularly flooded or inundated by the end of the century as a result of sea-level rise, with the potential for even up to 650 million at risk (Climate Central, 2014). Scientific discourses on anthropogenic climate change and sea-level rise have unfolded together over the decades due to the significant responses of the oceans and land-based ice to warming within the climatic system (Weart, 2003). Internationally, the science of sea-level rise projections has generated some of the most heated controversies (Church et al., 2013B; Englander, 2012), and calls from small island states to adhere to lower emissions targets to save their countries from inundation (Ashe, Van Lierop, & Cherian, 1999). However, the initial focus within climate policy on reducing greenhouse gas emissions largely forestalled decisions —and public communication—on how to respond to the effects of climate change, including sea-level rise, particularly in the United States (Moser & Luers, 2008; Pielke, Prins, Rayner, & Sarewitz, 2007).

Internationally, sea-level rise may be becoming a more prominent public issue, especially in countries most at risk (UNF, 2013). In reviewing U.S. media coverage since 2001 and recent public opinion surveys, we conclude that sea-level rise in the United States remains low in issue salience and coverage, even as the federal government and many states and localities place new emphasis on the importance of protecting vulnerable communities from the impacts of climate change (Exec. Order No. 13653, 2013; Exec. Order No. 13690, 2015; Moser et al., 2014). Numerous small-scale, localized models for engaging the public and stakeholders in assessing coastal risks and considering community responses have emerged, largely driven by nonprofit and governmental organizations. Understanding how people perceive the threat and potential response measures are important for public and stakeholder communication, both to reduce exposure to coastal risks and lessen the emissions that will continue to drive warming and expansion of the seas.

Small Island States Push for Lower Emissions to Stave Losses

In December 2015 negotiators from across the globe gathered in Paris for the 21st Conference of Parties to the United Nations Framework Convention on Climate Change (COP21). The goal was to achieve a binding agreement on climate from all of the world’s nations. The subsequent Paris Agreement set goals for 195 nations for the reduction of greenhouse gasses and targets for CO_2 emissions (UNFCCC, 2015). One influential group was the Alliance of Small Island States (AOSIS) as they pled for lower temperature targets to abate sea-level rise and the resultant flooding of their islands (Mooney & Warrick, 2015). Many of these islands are a few perilous meters above sea level; and

although they have contributed little to the problem, they are the ones with the most to lose from rising seas (Ashe et al., 1999).

AOSIS is an ad hoc group organized in 1990 to represent the interest of small island states in international climate discussions (Betzold, 2010). Through their past efforts, many of the previous discourses in international climate negotiations shifted from mechanics to morality (Águeda Corneloup & Mol, 2013), and the group has been successful in bringing a strong voice to small nations (Betzold, 2010). The communication impact of AOSIS at COP21 was equally influential, exemplified by a poster developed by their Caribbean members displayed at the Wider Caribbean Pavilion showing a woman up to her neck in ocean water with her feet on the former beach with a sign that reads "1.5 TO STAY ALIVE." The number refers to how many degrees Celsius to limit global warming above preindustrial levels. According to AOSIS and their allies, 2.0° C would be too much, and their islands would be lost. The agreement settled on 2.0° C, but the small island nations —and nearly all but the largest of CO_2 emitters—pushed to include a statement "to pursue efforts to limit the temperature increase to 1.5 °C" (UNFCCC, 2015).

The largest numbers of people who will be affected by climate change live in Asia along the Pacific Ocean—location of many of the small island states—but also highly populated nations such as China, Vietnam, Japan, India, Bangladesh, Indonesia, and Thailand (Climate Central, 2014). Research on climate change communication has been slower to develop in non-Western nations (Capstick, Whitmarsh, Poortinga, Pidgeon, & Upham, 2015; Moser, 2014; Schmidt, Ivanova, & Schäfer, 2013). This is no less true for sea-level rise. We will highlight some international studies but focus on communication and stakeholder strategies taken from the United States with many of our case examples from the mid-Atlantic region, one of the global "hot spots" of sea-level rise acceleration (Sallenger, Doran, & Howd, 2012). In sheer numbers of exposed populations to sea-level rise flooding and inundation, the United States ranks eleventh (Climate Central, 2014). Though there are region- and case-specific limits to the U.S.-based research, as we emphasize, there are several insights that are generalizable across geographic and national contexts. However, in this regard, more evaluative work is needed, especially as applied to developing countries.

Sea Level Rise and Climate Communication: Related but Different Challenges

Sea level rise and climate change represent related, but distinct, phenomena. Projections for global sea-level rise rely on emissions scenarios and associated estimated rates of warming and are tied to their uncertainties (Church et al., 2013A). But at local and regional scales, other anthropogenic and geologic processes can also have significant effects (Stammer, Cazenave, Ponte, & Tamisiea, 2013; Williams, 2013). Relative sea level refers to the position of the ocean in relation to the land surface and is the defining measure of local vulnerability for flooding and inundation planning purposes. As a result, both

movement of sea and land determine how wet coastal regions will get. Sea levels are influenced through hydrological cycles by groundwater depletion, irrigation, and impoundment in dams and reservoirs. The height of the land relative to the earth's core is affected by forces such as tectonic displacement, adjustments in the earth's crust from the last glacial retreat, soil compaction in river deltas, and extraction of groundwater, oil, and gas.

For example, in New Orleans the local rate of sea-level rise is four times that of the global average (Zervas, 2009) primarily due to sediment compaction of the Mississippi River delta plain (Penland & Ramsey, 1990). In the U.S. mid-Atlantic region, slowing of deep ocean currents within the Atlantic Meridional Overturning Circulation, likely due to climate change, has been tied to higher rates of sea-level rise acceleration (Ezer, Atkinson, Corlett, & Blanco, 2013; Sallenger et al., 2012). And in Chesapeake Bay, land subsidence contributes half of the rate of sea-level rise, largely due to lowering of the land as a forebulge caused by the Laurentide Ice Sheet continues to collapse (DeJong et al., 2015).

Communication—including on science and policy topics such as sea-level rise—enables individuals to effectively accomplish their own goals within social contexts, to bond with others, and to act in coordination for the accomplishment of collective objectives (Shuai & Gong, 2014; Wilson, 2012). Some researchers argue for multilevel evolutionary selection in which communication predominantly figures as an emergent group property guiding behaviors that allow for the functional success of societies (Shuai & Gong, 2014). These processes operate across multiple levels: an individual's development and receipt of messages; conversations within dyads; group-level discourses; mass communication; and the overarching generative interplay between culture and communication (Littlejohn & Foss, 2008). Drawing on these insights, structure of this article also reflects this multidimensionality, first describing the scientific and political context for sea-level rise, then addressing mass media, individual-level cognitions, and small-group engagement.

Experiencing Sea-level Rise and Coastal Flooding

Due to the global trend toward densely populated coastal development, as sea levels rise, national economies and human lives will face an ever-increasing threat, yet the types of impacts, awareness of these risks, and adaptive capacity are unevenly distributed (Brown et al., 2013). Brown and colleagues succinctly summarize some of these global differences: “Small islands are vulnerable due to their remoteness (particularly those at low elevation), Africa and other parts of the developing world are vulnerable due to a lack of financial capacity to adapt, and south, south-east and east Asia due to high population densities in subsiding deltas” (p. 143).

People in U.S. coastal areas are already experiencing the effects of sea-level rise: primarily inundation of land, erosion of shorelines, and more frequent flooding due to higher tides and the failure of drainage systems (Moser et al., 2014). Just as the manifestations of climate change vary from place to place, so do the effects of sea-level rise. As detailed in the National Climate Assessment (p. 585), in Hawaii and the Pacific Islands, sea-level rise threatens shallow coral reefs, in Chesapeake Bay sea-level rise aggravates already significantly degraded coastal ecosystems, in Louisiana and Florida saltwater intrusion poses a threat, and along the Gulf Coast the combination of land subsidence, sea-level rise, and hurricanes place communities at great risk from storm surges and loss of land.

Differences in Messages and Framing from Climate Change

Because sea-level rise is most frequently directly experienced as flooding or other coastal processes such as erosion that can be attributed to local and regional forces or extreme weather events that are not associated directly with climate change or easily attributable, it is often framed differently than climate change. As a result, it may share more in common with natural hazards risk communication than with climate change communication (Ezer & Atkinson, 2014). For example, in Maryland, key messages developed by the Climate Communication Consortium of Maryland in collaboration with Maryland Department of Natural Resources emphasized preparation for storms and sea-level risestorm surge associated with sea-level rise, maintenance and restoration of natural areas as a buffer against rising seas, and local adoption of state construction guidelines for new infrastructure (Strobridge, Nackerman, & Gentile, 2014) (see Figure 1).

Click to view larger

Figure 1. Social media graphics developed for the Climate Communication Consortium of Maryland (2014) emphasize the protective benefits of natural ecosystems in buffering against storms and the need to develop new guidelines for coastal infrastructure.

This focus also opens the space for new messengers not as frequently associated with climate change, such as emergency responders, floodplain managers, landscape architects, green infrastructure specialists, real estate professionals, coastal businesses, insurance companies, developers, and local governments (Recurrent Flooding Sub-panel, 2014; Wamsler et al., 2016).

Goals of Sea-level Rise Communication

Sea-level rise communication both focuses on the interaction between scientists, policymakers, and other stakeholders for the purposes of planning, and the wider inclusion of the public in outreach and environmental decision making. Studies that take a risk communication approach have proposed that sea-level rise communication between scientists and planners should be a dialogue (Lehtonen & Peltonen, 2006) and that careful consideration of audience knowledge, attitudes, and perceptions should be taken into account when designing communication (Covi & Kain, 2016).

The goals of communicating sea-level rise are twofold: (1) prepare coastal populations for flooding, inundation, and increased storm surge during extreme weather events; and (2) to reduce the greenhouse gas emissions that will continue to warm ocean waters, causing them to expand, and melt the waters in the world's glaciers and ice sheets (Nicholls & Cazenave, 2010). Yet, as we will explore, these conversations do not necessarily occur synonymously, and have begun more recently than communication about climate change generally. The development of social science research in support of sea-level rise communication has similarly lagged.

Critical Junctures in Communicating Global Sea-level Rise Science and Policy

In 1950 one of America's most widely read magazines, the *Saturday Evening Post*, noted that sea levels had increased in the previous quarter century due to melting ice sheets and glaciers: the *Post* ominously asked, "Can all this freed water cause another deluge, such as the catastrophe recorded in the Bible and in the myths and legends of all human races?" (Abarbanel & McClusky, 1950). Climatologists have long known that the

progression of changes in the earth's temperatures through the glacial and interglacial periods highly correlate with global sea levels: as temperatures go up, the ice sheets and glaciers melt and oceans rise (Dutton et al., 2015). Scientists' warnings about the effects of anthropogenic climate change on sea-level rise and coastal flooding had reached the halls of private foundations and the White House by the 1960s (President's Science Advisory Committee, 1965; The Conservation Foundation, 1963). Notably, Richard Nixon's science advisory committee pointed to the possible melting of the Antarctic ice cap as one of the primary concerns from increased atmospheric carbon dioxide with potentially 100 times the rate of present sea-level rise (p. 123).

Slow Rise or Abrupt Tipping Point?

Until the early 1980s, glaciologists focused primarily on the effects of anthropogenic warming on the melting and stability of ice sheets, especially those of the West Antarctic and Greenland (Weart, 2003). Potential abrupt loss of the West Antarctic Ice Sheet, sliding from over bedrock into the ocean, represents a severe climatic tipping point as it could alone precipitate a rise of sea level between three to five meters (Hein et al., 2016); the Greenland Ice Sheet could release another seven meters (Vasskog, Langebroek, Andrews, Nilsen, & Nesje, 2015). Yet by 1982, estimates of global sea-level rise attributed the greatest contributions to the thermal expansion of the ocean due to warming (Gornitz, Lebedeff, & Hansen, 1982). Within five years, a National Research Council report warned of the need to begin looking at engineering responses to the coming threat (1987). Melting of the Antarctic and Greenland ice sheets increased in the 1990s, but 75% of current sea-level rise is thought to be from thermal expansion and the melting of glaciers (Church et al., 2013A). Indeed, most of the heat energy from global warming between 1971 and 2100 has been captured in the upper oceans (IPCC, 2014).

Scientific Controversies over Sea-level Rise Estimates

The sea level rise projections of the Intergovernmental Panel on Climate Change's (IPCC) 2007 report have been described as its most controversial finding, with scientists accusing the range to be lower than anticipated due to the exclusion of ice sheet dynamics, which are difficult to model (Rahmstorf, 2013). The subsequent report in 2013 was expected to address these concerns, and indeed did raise the range of projections upward, but again was accused of taking a "moderate" approach (Kerr, 2013). Authors of the report retorted that it was being misinterpreted by media (see the discussion on media later in this article), and said that there was a third of a chance that sea levels would be higher than the 2013 projected range, but only if sections of the Antarctic Ice Sheet collapse, for which the scientific evidence is not currently well-established.

In its fifth assessment, the IPCC concluded that global mean sea level rose by 0.19 meters between 1901 and 2010, and that it is likely to rise between 0.26 and 0.82 meters by 2081 to 2100 (relative to 1986–2005), depending on the trajectory of greenhouse gas emissions. Similarly, the National Climate Assessment estimated that sea levels would rise between 0.30 and 1.22 meters (1 to 4 feet) by 2100, with outer bounds of between 0.20 to 2.01 meters (Melillo, Richmond, & Yohe, 2014) (see Figure 2).

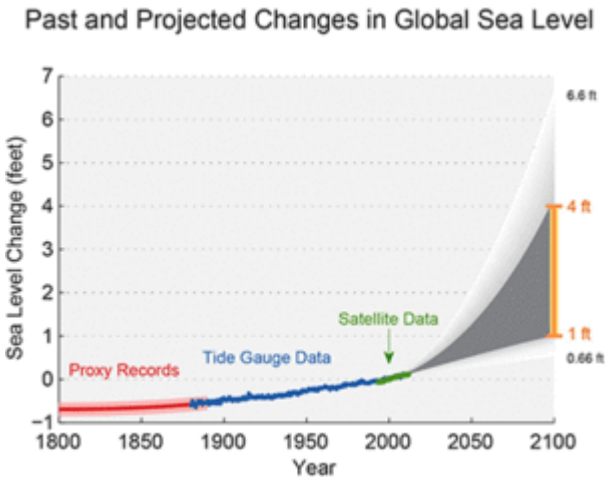

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Figure 2. Projections for sea level change by 2100 differ by a meter or more (Melillo et al., 2014).

Betting on a Number: Communicating the Extent of Sea-level Rise for Policy Planning

Incorporating estimates of future sea-level rise into long-term planning has been challenging for those in charge of some of the world's most at-risk and economically critical infrastructure. Seaports are on the front lines, putting them and 80% of global trade (by volume) directly in harm's way (Becker et al., 2013). A 2009 international survey of administrators at port authorities found a wide range of estimates of changes in the waterline by 2100: from decreases in ports located in the Great Lakes to increases of greater than two meters (Becker, Inoue, Fischer, & Schwegler, 2011). Two-thirds (66%) said that they felt uninformed about climate change, and about the same percent (69%) believed that their port would be able to handle the expected rise by 2100 without any additional protection.

Differences in culture and power can affect the rate at which people discount future versus near term risk (Gong et al., 2014; Joshi & Fast, 2013). Thus, the future orientation of sea-level rise adaptation poses barriers to engaging communities in planning and implementation (Fincher et al., 2015). Long-range projections and planning target dates—such as 2100, emphasized by the IPCC, climate scientists, and state governments—represent valuation of future risks over current risks in ways that can conflict with the present interests and "time stories," of local governments and residents (Fincher et al., 2014). A study in Gippsland East, Australia, found that local residents were more concerned about potentially abrupt policy shifts due to climate change that harmed local development, social relationships, and their town's amenities than future risks posed by climate change itself.

Municipalities in Australia have been using sea-level rise projections in their planning for more than 15 years with vulnerability assessments that include a 100-year planning horizon (Walsh et al., 2004). At the start of the planning process a generalized projection for the continent was used but was found to be insufficiently conservative. Over the years, regions have conducted more granular risk assessments. The government of Australia communicates projections as estimates of the increase in the spatial explicit frequency of extreme weather events (Commonwealth of Australia, 2009, 2011). While the need to address uncertainty in future projections is a challenge for planning in Australia (as it is around the world) local practice has been to pick a precautionary value, informed by the high-end range of projections (McInnes et al., 2015).

As in Australia, U.S. coastal states, cities, and regions have initiated local risk assessments and have requested guidance from scientists in determining a projection of future sea level for planning, preparedness, and engineering purposes. Federal efforts including the U.S. Army Corps of Engineers guidance documents (USACE, 2013) and the National Climate Assessment (Melillo et al., 2014) have taken a semi-empirical, emissions

scenario-based approach to projections, which local efforts have adopted. Some state projections, including the tactic taken in Virginia, adjust national scenario projections by adding estimates of localized vertical land movement (Mitchell, Hershner, Herman, Schatt, & Eggington, 2013). Alternatively, the National Research Council has taken a process-based approach that considers each of the contributing factors to sea-level rise, such as thermal expansion and vertical land movement. This probabilistic methodology, which Maryland has adopted for their state sea-level rise projections, results in a better distinction between the likelihood of different projections (Boesch et al., 2013). These projections are usually communicated as a series of three or four curves on a line graph indicating the range of sea-level rise from present time to the year 2100. Scientists are conservative in their projections (Brysse, Oreskes, O'Reilly, & Oppenheimer, 2013), therefore prefer to communicate sea-level rise projections as ranges. In contrast, planners and engineers need specific guidance to accommodate water level changes in designs and want a specific number or narrow range. As states and regions create sea-level rise planning policies and work with these technical audiences and the public, experts downscaling projections are often asked for simple guidance or a single number to communicate future water levels (Lindeman et al., 2015).

Estimating Economic and Societal Impacts

Added to the complication of selecting one number, or narrow range, of future sea-level rise for planning purposes is assessing and communicating economic and societal damages. Though some see adaptation to sea-level rise as just another opportunity for urban innovation (Kahn, 2016), numerous reports have suggested that the costs of protecting coastal development will be high (Darwin & Tol, 2001; Gordon, 2014; Pycroft, Abrell, & Ciscar, 2016). Three-quarters of the world's largest cities are located on coasts (UNEP & UN HABITAT, 2005). In the United States, coastal counties account for 13% of land area but more than half of the population and per capita income (Rappaport & Sachs, 2003). The current rate of sea-level rise is faster than observed among the last 2,700 years (Kopp et al., 2016), with damages expected to accrue more quickly than the rise itself (Boettle, Rybski, & Kropp, 2016). The *Risky Business* report estimated that by 2100, U.S. coastal property worth more than $701 billion will be below mean sea levels (Gordon, 2014). Average annual losses from storms along the Gulf Coast and eastern seaboard add another $42 billion. The considerable uncertainties across both sea-level rise projections and societal and economic consequences raise legal concerns about communication and policies that either do not sufficiently alert and protect citizens, and private and public property, or alternately, those that do so too aggressively (Abel et al., 2011; Measham et al., 2011).

The significant projected costs are causing some governments to reverse long-standing policies of coastal protection with immediate implications to the economic and societal welfare of these communities. For example, in the United Kingdom, funding of engineered defenses along the north Norfolk coastline since the 1950s led to perceptions of a stable shoreline that guided regional development (Day et al., 2015). A policy shift within the Department for Environment, Food, and Rural Affairs in 2005 to promoting natural coastal systems, including allowing dynamic shoreline changes through flooding and erosion, was interpreted within Norfolk's shoreline management plans as reversing support for hard defenses. As these failed, communities such as Happisburgh began to lose land and built properties to storms and erosion, threatening their continued existence and causing declines in already socially and physically vulnerable areas. The United Kingdom's Coastal Change Pathfinder projects have sought to identify and mediate some of these immediate and near-term costs.

Mainstreaming Sea-level Rise Discourses to Facilitate Policy Processes in the United States

Policy responses to sea-level rise—for example, requirements to take future water level into account when planning new federally funded infrastructure—exist at many different levels of governance with different, but mostly complementary, objectives (Ostrom, 2012). While climate adaptation planning activity is growing in the United States at federal,

state, and local/regional levels, some argue that few policies have been implemented with little aggregate meaningful impact (Bierbaum et al., 2013). In U.S. regions with significant political opposition to climate change planning discussions, mainstreaming adaptation into existing relevant policy areas such as emergency management and land use planning has been a successful way to sidestep political challenges (Kok & de Coninck, 2007). The process of mainstreaming involves careful attention to communication framing, often focusing on the climate impact without explicit mention of climate change (Haywood, Brennan, Dow, Kettle, & Lackstrom, 2014). Sea-level rise communication, especially in practitioner literatures, typically focuses on risks, vulnerabilities, and responses rather than causes related to climate change.

U.S. State Controversies in Communicating Sea Level Rise Policies

Not all states have avoided the politicization of climate change in advancing sea-level rise adaptation policies. Sea-level rise science and policy have become political issues in states such as North Carolina (Gannon, 2012) and Virginia (Fears, 2011; Harper, 2012), and even a centerpiece of presidential election politics at the 2012 Republican National Convention (Broder, 2012). The development of a statewide policy to encourage municipalities to plan for sea-level rise in North Carolina stalled in 2012 due to action by the state legislature. Driven by concerns expressed by scientists and managers about the threat of sea-level rise (Poulter et al., 2009), a panel of scientists, selected by the appointed state commission that oversees coastal resources, released a report recommending that an anticipated rise of one meter should be used for planning in the state (North Carolina Coastal Resources Commission, 2010). NC-20, a group formed by politically active real estate developers, targeted the report and the scientists with press statements, lobbied elected officials, and sponsored a symposium featuring speakers skeptical of climate change (NC-20, N.D.). NC-20 efforts resulted in the successful passage of a law imposing a two-year moratorium on determination of sea-level rise rates, and with new rules specifying how sea-level rise rates may be determined and applied (North Carolina, 2012). An earlier draft of the bill prohibited the use of scientific models to estimate future sea level change and drew attention from the national news media for the repression of scientific information (Huler, 2012).

Shortly after North Carolina’s experience, Virginia asked scientists to address similar planning issues by focusing on flooding. In 2012 scientists at Virginia Institute of Marine Science were charged with an examination of the issue of “recurrent flooding” (Mitchell et al., 2013). By placing sea-level rise response within the realm of public safety and choosing phrases such as “recurrent flooding,” instead of climate change and sea-level rise, Virginia was able to sidestep much of the controversy. Divisions persist between Democrats and Republican legislators about sea-level rise as a priority in Virginia (Yusuf, Iii, & Ash, 2014); however, in 2015, Senate bill 1443 passed requiring localities in the vulnerable Hampton Roads region to include sea-level rise projections in their

comprehensive plans in a Republican-controlled general assembly (General Assembly of Virginia, 2015).

Media Reporting on Sea-level Rise

Media coverage plays an important role in the evolution of public and policymaker attention to environmental issues such as sea-level rise (Brulle, Carmichael, & Jenkins, 2012; Downs, 1972). While there is evidence that people can recognize long-term environmental change (Akerlof, Maibach, Fitzgerald, Cedeno, & Neuman, 2013; McDonald, Chai, & Newell, 2015), and that they believe they can identify the signs of sea-level rise (Responsive Management, 2014), much of people's experience of their environment is mediated through societal channels of communication (Lippmann, 2007). As a result of news attention, previously unobtrusive environmental issues become more salient to the public (Ader, 1995), and new discourses arise that imbue physical reality with social meaning (Gamson & Modigliani, 1989; Goffman, 1974).

While an early study found the quality of sea-level rise coverage to be good, whether reporting is sufficiently informing public discourse remains in question. Rick and colleagues assessed two decades of newspaper coverage of sea-level rise projections (1989–2009), and compared them to IPCC documents and scientific literature (2011). Although scientists perceived inaccuracies in communication on sea-level rise projections (per earlier discussion in this article), the authors found that newspaper coverage was consistent with the scientific literature, and moreover appeared to be on the rise by 2009. However, in a study in the United Kingdom, researchers found that media communication about sea-level rise, a relatively unknown hazard, contributed little to public understanding (Harvatt et al., 2011).

Sea-level Rise Receives Little Press—or Academic—Attention

Few academic media studies focus solely on sea-level rise or related adaptation planning and implementation; in content analyses of news stories it is often coded as one of the many impacts of climate change (Hart & Feldman, 2014; Liu, Vedlitz, & Alston, 2008) or among numerous categories of adaptation activities (Boykoff, Ghosh, & Venkateswaran, 2013; Moser, 2009). Until about 2009, sea-level rise infrequently occurs in media communication on climate change impacts, even within three countries—India, China, and Bangladesh—that are among the top-five countries at risk by population size (Climate Central, 2014). A review of four major English-language newspapers in India from 2002 to 2007 cites sea-level rise as one of the threats to low-lying coastal metropolises. But declines in agriculture, changes in the monsoon, and glacial retreat are the most frequently coded climate impacts within these publications (Billett, 2009). Until 2006 national media reporting on regional effects of climate change in China accounted for

only an estimated 10% of coverage with majority (90%) representing translated scientific or news stories from the West (Tolan, 2007). Sea-level rise is not mentioned specifically in the report, though examples of regional effects included potential inundation of Hainan Island. Finally, a climate change content analysis of Bangladesh's three most popular newspapers from 2006 to 2009 did not address sea-level rise, finding most of the stories addressed natural disasters (Miah, Kabir, Koike, & Akther, 2011).

Notably, these three studies were all conducted prior to 2010. A 2013 analysis of climate change in online international media—including formal news outlets, blogs, and social media—suggests that attention may since have increased, particularly in the Pacific-Asian region (UNF, 2013). While the variability of sea levels across earth's geologic record were cited online in Brazil, the United Kingdom, and Australia as an argument *against* concern for anthropogenic climate change, alarm about current and incipient effects of coastal flooding and sea-level rise appeared frequently in online postings by Chinese, Japanese, and Indian citizens. Moreover, according to the United Nations Foundation (UNF) report, sea-level rise has become framed internationally as a human rights issue due to the displacement of disenfranchised populations as entire nations disappear underwater (Barnett & Adger, 2003; UNF, 2013, p. 35). The online media analysis covering 14 European, Asian-Pacific, North and South American, and African countries found that the plight of the small island nation of Kiribati, which faces relocation of its entire population, has received the most attention and "shares" of any climate migration story. Stories of potentially large migrations due to sea-level rise in Bangladesh, India, and the Carteret Islands in Papua New Guinea also appear within this frame.

Indeed, one of the few issue-specific media analyses focuses on the depiction of Tuvalu—a small island state under threat from sea-level rise and forced emigration—within the newspaper accounts of Australia's *Sydney Morning Herald* between 1990 and 2005 (Farbotko, 2005). The author argues that superficially the media coverage could be seen as raising awareness. The study's conclusion, however, is that the focus on vulnerability within the newspaper's coverage reinforces stereotypes of islanders as disempowered and marginal populations within negative governmental discourses on migration.

Quantifying Sea-level Rise Coverage in U.S. Newspapers

A study of sea-level rise newspaper reporting in the United States from 2001 to 2015 further supports evidence that attention to the issue has been on the rise, and moreover, that some local publications are dedicating a larger share of their climate change coverage to it (Akerlof, 2016). The analysis includes both national prestige newspapers—*Washington Post, New York Times, Los Angeles Times*, and *The Wall Street Journal*—and local publications in areas at high sea-level rise risk, *Miami Herald*, Norfolk/Virginia Beach's *Virginian-Pilot*, Jacksonville's *Florida Times-Union*, and *Tampa Tribune*.

Since the early 2000s media attention to sea-level rise has been substantially lower than for climate change in all eight local and national prestige newspapers included in the analysis (Figure 3).

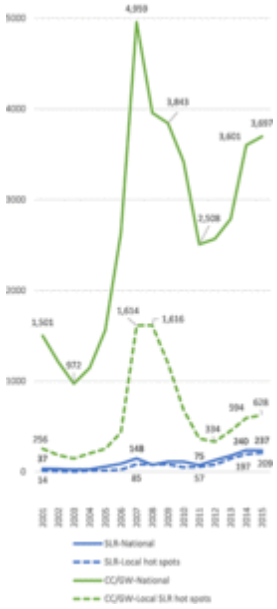

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Figure 3. Comparing aggregate prestige national and local coastal newspaper attention to climate change (CC) and sea-level rise (SLR) across the eight publications analyzed. Data for *The Virginian-Pilot* are unavailable from 2014–2015.

In the national prestige papers, climate change appeared in 4,959 texts in 2007 and was climbing again in 2014 with 3,601. Local newspapers in areas at high risk from coastal waters demonstrated considerably lower rates of climate coverage than their higher circulation brethren, peaking at 1,614 and 1,616 texts that mention the phenomenon in 2007 and 2008. However, they maintained approximately the same levels of sea-level rise attention as the prestige publications over the 15-year period with a low of four articles among all four publications in 2003 but more than 200 by 2015.

Until 2012, 5% or fewer of prestige national newspaper texts that addressed climate change also mentioned sea-level rise, and this percent did not exceed 9% across all 15 years with the exception of the *Washington Post* in 2015 (see Figure 4).

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Figure 4. Percent of sea-level rise coverage that co-occurs with mentions of climate change/global warming in prestige national newspapers.

The 2015 increase in the ratio of sea-level rise to climate change coverage to 30% by the *Washington Post* does not reflect a surge in sea-level rise attention but rather a relatively smaller number of climate change stories in 2015. In the local Virginia and Florida newspapers, rates of sea-level rise mention within texts that address climate change reach higher rates than in national prestige publications, but the ratio is also more variable (see Figure 5).

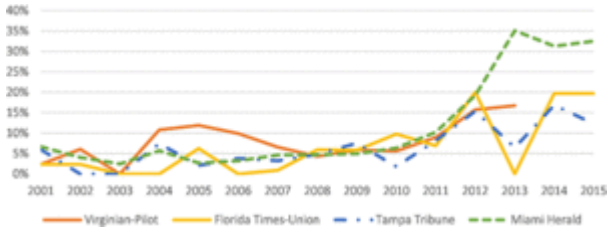

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Figure 5. Percent of sea-level rise coverage that co-occurs with mentions of climate change/global warming in local coastal newspapers. Data for *The Virginian-Pilot* are unavailable from 2014–2015.

Within these local publications there appears to be an upwards trend toward higher percentages of sea-level rise discussion within the same discourses as climate change. Since 2012 all have mentioned sea-level rise within climate change coverage more than 10% of the time, though not consistently.

Conclusion

Few media studies explicitly address sea-level rise coverage; this impact of climate change has been subsumed as one of many environmental consequences and related adaptation approaches. It appears from albeit limited evidence that media attention to sea-level rise has been increasing, especially in the Pacific-Asian region, an area of particular risk. In the United States, newspaper coverage of sea-level rise is low, even in some of the most affected cities in the United States, and is largely co-occurring within climate change discourses. Yet, increasing percentages of reporting on climate change are addressing sea-level rise within regional publications located in sea-level rise "hot spot" areas of the country, indicating localization of media attention.

Public Opinion on Sea-level Rise

"Understand your audience" is an oft-cited communication truism and is particularly important in developing effective public campaigns and messaging (Lefebvre et al., 1995; Rice & Atkin, 2012). With relatively low levels of media coverage, we would anticipate that audiences would largely remain uninformed about sea-level rise. Since the late 1980s polling firms have been asking members of the public, particularly those in Western developed nations, about their perceptions of global warming and climate change (Capstick et al., 2015; Nisbet & Myers, 2007). Questions about sea-level rise in climate change surveys rarely appear, if only gauge public perceptions of the types and timing of impacts, or as an indicator of general environmental risk perceptions (Leiserowitz, Maibach, Roser-Renouf, & Smith, 2011; *Washington Post*, 2007).

Other Climate Change Impacts are of Higher Global Concern than Sea-level Rise

A question from a 2015 study is illustrative of global risk perceptions regarding sea-level rise. A survey of climate change attitudes in 40 nations asked respondents which ones most concern them: droughts or water shortages, severe weather, long periods of unusually hot weather, or rising sea levels (Stokes, Wike, & Carle, 2015). Only 6% cited sea-level rise, compared to 44% of respondents that said drought, 25% severe weather, and 14% hot weather (p. 7). The five countries with the highest levels of sea-level rise concern included France (31%), the U.K. (30%), Japan (23%), South Korea (19%), and Australia (19%); yet, sea-level rise was not the foremost climate concern of any (p. 21). The first four countries are among those worldwide with the highest numbers of people who currently live on land projected to be below sea level or regular flood levels by 2100 (Climate Central, 2014). France ranks 15th among the greatest number of susceptible citizens; the United Kingdom is 12th, Japan is 3rd, and South Korea is 18th.

Sea-level rise poses a threat to Australia's extensive coastal urban development and natural habitats (Cooper & Lemckert, 2012; Krauss et al., 2014), and considerable research on community-level sea-level rise adaptation has been conducted in the country (Barnett, Waters, Pendergast, & Puleston, 2013). It is not, however, among the top-20 nations in the number of its citizens who will face inundation or regular flooding. In a 2014 climate change survey of more than 5,000 Australians, sea-level rise and flooding were among the least likely anticipated environmental changes, with respectively 41% and 39% anticipating they would not occur (Leviston, Greenhill, & Walker, 2015, p. 33). Most thought they would also be able to cope with its effects—only 14% said they would not be able to (p. 37).

U.S. State Surveys Demonstrate Low Issue Salience

In-depth survey measures of sea-level rise public risk perceptions and adaptation policy preferences arose decades after organizations first began to poll on climate change and largely have remained outside of the academic literature. They are often used to promote issue awareness, or as a part of the public consultation process by governments. In one of the earliest examples in the United States, the state of Delaware conducted a public opinion survey of approximately 1,500 residents in December 2009 (Responsive Management, 2010). According to one of the planners who led the study, the results have been helpful in subsequent policy planning conversations (personal communication, Susan Love, Delaware Coastal Programs).

Delaware conducted a follow-on survey in 2014, the same year as a similar study conducted in Maryland. The questionnaires for both mid-Atlantic coastal states included measures of sea-level rise as a comparative issue priority, whether it is happening, its

causes, and timing of expected harms (Akerlof & Maibach, 2014; Responsive Management, 2014). Their results support international findings that the public views other risks as more concerning:

- Sea-level rise is a concern, but other priorities rank higher. In Delaware, 66% said that sea-level rise was an issue that somewhat or very much concerned them, but the economy topped the list at 96%. Similarly, in Maryland, 55% said that protecting Maryland's coastal areas from sea-level rise should be a high or very high priority for the governor and general assembly, but creating jobs was first at 89%.
- Residents of Delaware and Maryland were more likely to be sure that climate change was occurring than sea-level rise. In Delaware, 46% were completely convinced of climate change but only 39% of sea-level rise; in Maryland, 44% were very or extremely sure that climate change was happening but only 18% on sea-level rise.
- Most people in these states understand that climate change is a cause of sea-level rise (DE, 79%; MD, 61%). But only a third of Marylanders said that climate change contributes "a lot" to sea-level rise (34%), and just 28% of Marylanders said that sea-level rise is entirely or mostly the result of human activities.
- Sea-level rise is perceived as a more temporally remote problem than climate change. While 53% of residents in Delaware say climate change is either having impacts now where they live, or will within the next five years, only 30% say the same for sea-level rise. Aggregate majorities in both Delaware and Maryland similarly said that effects will manifest sometime within the next 25 years (DE, 60%; MD, 57%).

Conclusion

Public opinion on sea-level rise is still in an early stage of development across the globe. It ranks as of lesser concern than other climate change impacts, even in some of the most affected parts of the world such as Japan (Stokes et al., 2015). In two U.S. Atlantic coastal states, people are less sure sea-level rise is occurring than climate change. Moreover, encroaching coastal waters are viewed as something that will happen in the future (next few decades), and that ranks comparatively low as an issue priority.

Understanding Stakeholder and Public Mental Models of Sea-level Rise

If many people do not have strong notions of what sea-level rise means, how are they thinking about it, if at all? Sea-level rise writ large can be grouped with climate change as an unfamiliar threat that suggests to the public that they have low efficacy to respond

given the vast scope of the problem (Harvatt et al., 2011). Yet specific impacts—like flooding and erosion—may feel more familiar and controllable. Research in Germany and Denmark has found that flooding experiences predict proactive measures to adapt to sea-level rise (Koerth, Vafeidis, Hinkel, & Sterr, 2013).

One study found that the public's association between climate change and sea-level rise/flooding may have actually decreased. In the United States, a longitudinal study of freely associated climate change imagery in the general public found that flooding and sea-level rise were among the top nine categories of visuals recalled as representative of climate change but that the association decreased in public salience over time (Smith & Leiserowitz, 2012). In 2003 it comprised approximately 10% of all affective images but fell to 5% or less in subsequent years (2007, 2008, 2010). On average, ice melt, heat, alarmism, and naysayers ranked as the top four categories over the seven years. Other studies have found that the experience of living near the coast or in a floodplain increases the salience of perceived climate change risk (Akerlof, Delamater, Boules, Upperman, & Mitchell, 2015; Brody, Zahran, Vedlitz, & Grover, 2008), but counterintuitively, coastal proximity may also decrease support for climate change policies (Zahran, Brody, Grover, & Vedlitz, 2006).

As a popular social science methodology, focus groups can provide insight into complex issues by promoting conversations among participants on the topic (Morgan, 1997). In a series of focus groups conducted with coastal homeowners in the Monterey Bay region of California, Moser (2013) looked to identify the groups' emotional response to global warming; their understanding of the causes of sea-level rise problems and possible solutions; and finally, what their vision of successful adaptation looked like. Of the many themes that came out of her study, one of the most unifying for sea-level rise communication was that emotional attachment to the location—termed "place identity"—is a key element in the desire to protect that place. The groups' vision of adaptation success was also telling: putting aside self-interest to plan for a future in which the beauty of the resource is protected for the larger, common interest. The results of focus groups such as these can provide ideas for engagement strategies based on emergent concepts that arise from discussion (Morgan, 1997).

As an additional qualitative tool to understand how people think about complex topics, mental models can be used to help researchers identify conceptual relationships and ideas of risks (Morgan, Atman, & Bostrom, 2001). People filter their acquisition of new information through existing schema, using their personal knowledge and experience to create a representative model of how concepts fit together (Morgan et al., 2001; Tversky & Kahneman, 1980). These mental models, in turn, help them to reduce uncertainties and make decisions about actions (Morgan et al., 2001). However, under conditions of information complexity and uncertainty, the mental model may include spurious inferences and connections. This can lead to misinterpretation of the risk and what actions a person chooses to take (Slovic, Finucane, Peters, & MacGregor, 2002; Sunstein, 2002; Tversky & Kahneman, 1980). Mental models studies explore how nonexperts interpret

an issue and, specifically, what knowledge gaps exist. To create effective communication about topics such as sea-level rise, using a mental model approach can identify what information the public needs in order to make sound decisions (Morgan et al., 2001).

Carlton and Jacobson (2016) used this approach to compare the coastal environmental concerns of local decision-makers in Crystal River, Florida, to experts. By mapping differences in the schema between the two groups, they discovered that the nonexpert and expert mental models of climate change impacts were largely similar but not those of the causes of climate change. Moreover, among nonexperts, climate change causes and impacts were secondary to local, environmental risks focusing on water quality, coastal storms, and economic impacts. Of the eight nonexperts involved in the study only two mentioned sea-level rise without prompting.

A similar study was done to understand public perception of sea-level rise on the Severn Estuary, an ecologically sensitive area in the United Kingdom. (Thomas, Pidgeon, Whitmarsh, & Ballinger, 2015). The nonexpert mental models aligned with the expert models in many areas, but some key gaps emerged. Nonexperts did not express high concern about sea-level rise but did believe it would lead to more severe flooding in the estuary and that the government should be responsible.

By comparing the mental models of the nonexperts to those of experts the researchers were able to find areas in which to focus future communication efforts (Carlton & Jacobson, 2016; Thomas et al., 2015). By building on the existing schema of nonexperts, communication professionals can target missing or incorrect information to address the uncertainty and complexity of issues such as sea-level rise (Morgan et al., 2001).

Charting a New Course: Engaging Stakeholders and the Public

Public engagement has been recognized internationally as a vital component of environmental assessment and decision making over the past 40 years (Akerlof, 2017), with involvement said to increase the quality and legitimacy of decisions (National Research Council, 2008). Stakeholders are often invited to participate in sea-level rise adaptation planning, sometimes triggered by hazard events such as in San Francisco, California (Cheong, 2014). These efforts are still experimental, and adequate science communication to empower stakeholder participation in decision making remains a challenge (Gramberger, Zellmer, Kok, & Metzger, 2015). Public engagement models for sea-level rise have developed in response to the needs of local governance and have the following characteristics: (1) they employ a range of visualization tools, frequently with geographic information system mapping; (2) they draw a small—or wide—circle around who participates from select stakeholders to the wider public; (3) they create means for identifying relevant data and information for the discourse; and (4) they have varying

levels of connectivity to policymaking processes. We review a series of modalities for sea-level rise engagement that can be used together or individually, from visualization methods to collaborative vulnerability and risk assessments to public-oriented deliberative dialogues.

Visualization

Much of the information on climate change projections and impacts—including sea-level rise—is highly technical and may be difficult for members of the public to incorporate into their own experiences (Weber, 2006). Moreover, for planning purposes risk information must be situated geographically and overlain with other variables to determine vulnerabilities (Preston, Yuen, & Westaway, 2011), such as the location of critical public infrastructure, commercial and residential districts, and natural ecosystems. For public engagement, one solution used increasingly with populations that are currently experiencing the effects of sea-level rise is engagement through photography (see Box 1). The use of images taken by local residents recognizes local environmental knowledge and facilitates public participation in identifying changes in physical and social conditions. These efforts range from online platforms for collecting images of flooding and erosion contributed by members of the public, to social science techniques that send participants out to photograph—and voice—their realities. Sea-level rise mapping using geographic information system data is another approach that has been primarily used by planners but is increasingly available as a public communication tool through participatory mapping approaches and sea-level rise viewers at a range of local to global scales, available to all on the Internet.

Box 1. Communicating sea-level rise with photography

King Tides Project. Starting in 2009 in Australia, and now also underway in the United States and Canada, the King Tides Project (kingtides.net) takes advantage of the public's ability to easily photograph and upload online images of coastal flooding events with the proliferation of camera phones and Internet accessibility ("King Tides Project," 2014). The project has been adopted by both governmental and non-governmental organizations as a means of documenting the effects of extremely high tides, with the expectation that they may become the new normal (tagline "Snap the shore: See the future"). During high tide events, coastal residents and visitors are encouraged to take photos of flooding and erosion, especially of local landmarks, and submit them online.

Photovoice. Photovoice was established as a technique within participatory assessments of public health conditions in the late 1990s (Wang & Burris, 1997). Increasingly, it is being used within communities for bottom-up socioecological assessments and to spur discussion and policy change (Berbés-Blázquez, 2012; Castleden, Garvin, & Nation, 2009), including with coastal communities at risk from sea-level rise (Baldwin & Chandler, 2010; Bennett & Dearden, 2013). Reviews of the technique within public health find that it can effectively identify community priorities and empower participants (Hergenrather, Rhodes, Cowan, Bardhoshi, & Pula, 2009), leading to better research outcomes and increased advocacy by residents (Catalani & Minkler, 2010). Photovoice projects range in their emphasis on information gathering to empowerment and activism. In one study comparing participatory visual methods for information provision and discussion, photovoice was rated less effective by participants than 3D scenarios and flood risk maps (Grant, Baldwin, Lieske, & Martin, 2015). Photovoice is typically conducted through in-person workshops and interviews with participants, but web-based methods may allow for easier—and more removed—implementation (Strack et al., 2015).

Sea-level Rise Viewers

Federal and state governments, private sector businesses, and nongovernmental organizations have developed interactive sea-level rise viewers as a way of communicating the potential impacts of sea-level rise to both public and decision-maker audiences. These include the NOAA sea-level rise viewer, Climate Central's Surging Seas maps, NJ Flood Mapper, and California's Cal-Adapt. Interactive sea-level rise viewers allow audiences to explore flooding and inundation projections over a range of time periods and emission trajectories. These viewers may be particularly appealing in that they allow users to choose sea-level rise scenarios and avoid the determinism of a static vulnerability map.

Within four levels of design—data, visual representation, annotation, and interactivity—Stephens, DeLorme, and Hagen (2014) investigated six narrative-building features of a sample of 20 interactive sea-level rise viewers: (1) technical and conceptual support, (2) uncertainty and risk, (3) realism, (4) interaction structure, (5) local impacts and/or a global perspective, and (6) features for user self-efficacy. They found that representation of uncertainty and risk varied across the viewers, as did emotionally evocative language. They recommended that while for scientific data dissemination purposes a storytelling approach would be inappropriate, for many less technical audiences it may increase the viewer's communicative capacity.

Increasingly social science researchers are testing how audiences use sea-level rise viewers and what effects they have on user decision making. These can range from usability studies (Richards, 2015; Stephens, DeLorme, & Hagen, 2015) to exploration of the persuasiveness of contextual information on coastal location decisions (Wong-Parodi, Fischhoff, & Strauss, 2014). In contradiction to other studies (Spence, Poortinga, & Pidgeon, 2012), Wong-Parodi and colleagues found that the time horizon for coastal flooding (2020, 2050, 2100) did not affect viewer responses and that information about government policies to prepare for the risks influenced decisions whether to move to the locality.

Participatory Mapping

Participatory mapping integrates scientific information and local knowledge that engages stakeholders in the assessment of flood risk and climate change vulnerability (Preston et al., 2011; Tran, Shaw, Chantry, & Norton, 2009; White, Kingston, & Barker, 2010), transitioning from visual depictions of the spatial extent of future sea-level rise to the realm of risk assessment. Mapping and visualization tools can be used to allow stakeholders to test options for planning, develop scenarios, and contemplate futures (Sheppard et al., 2011). Geographic information systems (GIS)—with interfaces that allow for many classes of spatial data to be displayed simultaneously—enable risk communication, access to data, and decision support. A GIS can be coupled with technologies that facilitate stakeholder interaction including the manipulation and annotation of maps. Interactive technologies are a powerful way to help stakeholders understand and engage in planning and environmental decisions (Jankowski, 2009).

The weTable and the CHARM model are a paired technology that have facilitated stakeholder engagement with data and allowed interactive exploration of the spatial dimensions of sea-level rise impacts (Schatz et al., 2013). The weTable’s computer interface and projection capability onto a table allows interaction with data and images. Stakeholders can explore maps and participate in data collection through annotating maps within the GIS. The Community Health and Resources Management (CHARM) application allows stakeholders to share their knowledge of community resources as well as their values and priorities for planning. The CHARM model contains a library of information about urbanization, storm surge risk, conservation areas, public facilities, and other coastal resources that context to the participatory process. During a workshop, CHARM helps local officials, citizens, and a variety of stakeholders understand how planning decisions can affect the environment and the community. Each workshop uses scenarios of future populations within a time frame. Participants are able to manipulate planning decision scenarios based on differing values and priorities and then visualize the future impacts of those planning decisions.

Vulnerability and Risk Assessment

In determining areas of local risk, planners must integrate multiple streams of information from across different levels of governance and external stakeholders, such as elected officials, the scientific community, city or county managers, local businesses, and involved public (Kettle et al., 2014). These collaborative efforts require cross-organizational communication. Vulnerability, Consequences, and Adaptation Planning Scenarios (VCAPS) is a notable success in the use of interactive, risk-based, assessment tools. Developed jointly by the Social and Environmental Research Institute, the Carolinas Integrated Sciences and Assessments Program, and NOAA Sea Grant, the VCAPS tool integrates coastal science, risk management, and community knowledge to help local decision makers plan for a more resilient future. Based on theories of collaborative learning and mediated modeling (Kettle et al., 2014; Metcalf, Wheeler, BenDor, Lubinski, & Hannon, 2010), VCAPS combines analytic deliberation with local knowledge to create a shared learning environment for the participants. The goal of the process is to combine scientific evidence-based and value-laden information about climate risk for decision makers (Fineberg & Stern, 1996; Webler, Tuler, Dow, Whitehead, & Kettle, 2014).

The facilitated process generally is held over several meetings with participants including elected officials, local and state government representatives, local and regional planners, local business leaders, and any community members interested in being involved. The process begins with a briefing from scientists with climate and natural resource expertise in the region. This is followed by a question and answer period to clarify participants understanding and assumptions of potential impacts to their communities. A facilitated discussion leads to the creation of a diagram identifying stressors, outcomes, consequences, any relevant contextual factors and the public and private actions that can be taken to mitigate or adapt to the stressors and create a more resilient community.

VCAPS has been used in U.S. communities throughout the northeast, southeast, and Gulf of Mexico. The town of Plymouth, North Carolina, worked with North Carolina Sea Grant researchers and extension staff to determine its vulnerability to sea-level rise (Covi, 2012). The team used the VCAPS process to develop different response strategies to balance community security and safety with cost of the approaches. The Town of Plymouth received a Coastal and Ocean Resource Management award for excellence in local government in recognition of this effort (National Oceanic and Atmospheric Administration, 2012).

Regional Boundary-crossing Fora

The Hampton Roads Sea-level rise/Flooding Adaptation Forum was designed to promote adaptation to rising sea levels and to help overcome the challenges that local governments face in confronting this difficult planning and preparedness issue such as uncertainties, political sensitivities, and a lack of resources and state support (Old

Dominion University, 2015). Using a model of integrating scientific and local knowledge within an analytic-deliberative context (Dietz, 2013; Kettle et al., 2014), the forum provides a regular, informal setting in which local governmental staff and other stakeholders can access and discuss research or policy initiatives occurring at universities and federal agencies with experts across sectors and municipal boundaries. Each one-day meeting focuses on an adaptation topic and both local and national experts are invited to share their research findings followed by discussion and informal networking. Often a panel of local practitioners working in the topic area will share their practices and processes. Several university-community partnerships have developed from this process and an informal, cross-sector community of practice has emerged. This process has been particularly successful in a region with a complex, diverse and densely populated set of independent municipalities, some of which are acutely vulnerable to sea-level rise impacts and already experiencing increased flooding (Michelle Covi, personal communication).

The major features of the Hampton Roads model are: (1) a partnership between a local government and university/boundary organization (Virginia Sea Grant, Old Dominion University, and the Hampton Roads Planning District Commission); (2) regular meetings that address emerging issues in adaptation in a social learning context; and (3) an informal setting that allows for both group and individual discussion, networking, and the emergence of new ideas and approaches. The forum conducted ten meetings between November 2012 and October 2015 with 60 to 80 participants, with a core group that attended each meeting consisting of six municipalities, five private sector companies, three federal agencies, two universities, and one NGO. At the tenth meeting, 82% of the participants reported that they were involved in sea-level rise adaptation plans or projects that ranged from updating statewide flood protection plans to designing flood proofing strategies for buildings.

Public Deliberative Dialogues

Morrell classifies collective deliberation as falling into three categories: civic dialogue, deliberative discussion, and deliberative decision making (Morrell, 2005). Whereas the purpose of civic dialogues is to bring together members of the community to foster a better understanding of different perspectives, deliberative discussions focus on the thorough evaluation of relevant information by participants. Deliberative decision making furthermore requires the group to make a collective choice. Two examples of deliberative discussions on sea-level rise demonstrate that this technique can have different effects, depending on how it is conducted, but that it can also promote changes in attitudes and policy support even among those most skeptical of climate science (see Box 2). The examples take different approaches, with the first—FutureCoast—focusing on adaptation strategies for a local community (Akerlof et al., IN PRESS; Akerlof, Batten, Rajasekar, & Cutshall, 2013), while the second—Citizen Dialogues on Sea-level rise—broadly addresses

both adaptation to sea-level rise and climate change mitigation (Furth & Gantwerk, 2013). Both were also small scale, with sample sizes of 40 or less per event; as a result, their findings may be considered suggestive, instead of conclusive.

Box 2. Examples of public deliberation on sea-level rise

FutureCoast. In spring 2012, 40 residents from Anne Arundel County in Maryland spent a day learning about coastal flooding and sea-level rise, reviewing sea-level rise local impacts information, hearing from a group of expert panel members, including scientists and policymakers, and discussing the issue with small groups of fellow community members and trained facilitators (Akerlof, Batten, et al., 2013). Even with the small sample size, there were statistically significant increases in topic knowledge, the number of cited local impacts of most concern, the belief that coastal flooding has become more of a problem in recent years, and that sea-level rise is occurring (Akerlof et al., IN PRESS).

When the participants in the Citizens' Discussion were further broken down in the analysis into groups of similar worldviews and assessed for changes between the pre- and post- surveys, those most likely to have low environmental risk perceptions—the "hierarchical individualists"—were more likely to show statistically significant change on measures of impact concern, problem identification, and whether sea-level rise is occurring than the "egalitarian solidarists," who typically have high environmental risk perceptions. Moreover, the direction was toward higher levels of problem identification and concern, at times even superseding that of egalitarian solidarists.

Citizen Dialogues on Sea-level rise. In spring 2013, two public dialogues were conducted with samples of 35-40 residents of Richmond, Virginia, and Tampa, Florida on sea-level rise and climate change on behalf of the Union of Concerned Scientists (UCS) (Furth & Gantwerk, 2013). During the eight-hour sessions, citizens were provided with information on sea-level rise and climate change compiled by UCS and discussed a series of scenarios; questionnaires were delivered at the start and completion of the event. Few participants' opinions about the causes of sea-level rise and climate change changed as a result of the event, but the discussions swiftly moved to the merits of cutting carbon in light of the complexities of adaptation. The organizers concluded that the dialogues were unlikely to change people's understanding of the science, but were apt to move individuals toward agreement about the need to take action, including curbing carbon emissions. The largest increase in mean scores for the two groups combined was for responding to sea-level rise as it happens (1=totally negative to 10=totally positive; M_1=2.9, M_3=3.9), however it was the least-favored approach. The most favored policy was creating incentives to prepare for sea-level rise and address its root causes (M_3=7.1). It shifted 0.5 points upwards between pre- and post-testing. The study report does not provide statistical significance assessments for these shifts.

Conclusion

With the notable exception of VCAPS and deliberative dialogues, the sea-level rise stakeholder and public engagement tools and models have not necessarily developed with the benefit of social science theory, or formative and evaluative research. This is changing as studies begin to assess tools such as the sea-level rise viewers, and the social science of sea-level rise communication broadens through qualitative and quantitative research. Public and stakeholder participation in environmental decision making has long faced problems of inclusion and how to define what constitutes knowledge and integrate these processes into policy formation (Dietz, 2013; Dietz & Stern, 2008). These remain critical issues in sea-level rise public engagement.

The difficulties of incorporating quantitative data modeling with qualitative scenarios developed by groups of stakeholders present opportunities for new tools to rise to the fore. One of those that holds promise is Fuzzy Cognitive Maps (van Vliet et al., 2010). This form of cognitive mapping graphically and mathematically represents causal relationships that are expressed in stakeholder elicited scenarios. During the process, assumptions, system characteristics, and anticipated results from these storylines are clarified so that scenarios can easily be compared to quantitative models and reciprocal learning between stakeholders and modelers can transpire.

Engagement of stakeholders in climate adaptation can also be a challenge in research contexts. In the European Stakeholder Integrated Research (STIR) project, stakeholders are part of the research team, reducing communications challenges associated with science translation (Gramberger et al., 2015). They develop storylines and produce qualitative data which then can be validated with quantitative data collected by the scientists. The STIR approach has been successful enabling stakeholders to make an active contribution to the research and maintain their interest throughout the project.

Discussion and Conclusion

In assessing the progress of communication science on sea-level rise, this subfield of climate change communication remains in its early stages. While social scientists have made the jump from climate mitigation to adaptation studies, sea-level rise communication has not attained a status unto itself. Media attention internationally and in the United States appears to be on the rise, but public opinion is largely unformed, even compared to climate change. The bright spots are in public engagement through organic communication models that bring disparate audiences together to share knowledge and assess risk using diverse mapping and other visualization techniques (Old Dominion University, 2015; Schatz et al., 2013; Webler et al., 2014). With the exception of some of the online tools, these techniques are necessarily small scale, time consuming,

and expensive. New models will need to be able to scale to reach larger audiences with higher frequency.

In the United States, the political fracture lines on climate change have often carried over to sea-level rise science and policy debates (Broder, 2012; Gannon, 2012). Internationally, local resistance to governmental adaptation strategies—such as the abandonment of coastal defenses based on long-term sea-level rise projections—is being viewed more holistically (Day et al., 2015; Fincher et al., 2014). Lessons from U.K. and Australian studies on the necessity of acknowledging cultural differences between the local populace and experts in establishing time horizons for risk and weighing near-term versus future costs may be instructional for those in other countries.

Media

As the field of climate change media analysis has evolved, sea-level rise has remained of interest primarily as a subset of its impacts and related adaptation policies. Little work has been done to explore the ways in which international discussions of sea-level-rise-driven emigration are evolving, or identifying regional cultural differences in recognition, naming, temporalities, and problem-solving approaches. Internationally, sea-level rise occupies an important part of climate change human rights discourses; concerns are especially being voiced by citizens in the high-risk Pacific-Asian region (UNF, 2013).

Climate change remains considerably better covered than sea-level rise in both U.S. national prestige publications (the *New York Times*, *Wall Street Journal*, *Los Angeles Times*, and *Washington Post*) and local sea-level rise "hot spot" newspapers (*Miami Herald*, *Tampa Tribune*, *Florida Times-Union, Virginian-Pilot*) (Akerlof, 2016). Given the dearth of climate change coverage itself (Boykoff, 2011), this finding is significant. Differences in reporting between national and local "hot spot" newspapers were also apparent, with these latter publications increasing their reporting on sea-level rise within climate change coverage at higher levels than national publications—more than 30% of articles for the *Miami Herald* in 2012–2015.

Public Opinion

The study of public opinion on sea-level rise impacts and adaptation is beginning to develop as a field in its own right with the emergence of state and regional issue-specific surveys (Akerlof et al., 2016; Responsive Management, 2014). However, most information on the status of public opinion is from measures within larger climate change surveys. In a study of 40 nations across the globe, none cite sea-level rise as a primary concern from climate change (Stokes et al., 2015). In U.S. states such as Maryland and Delaware with substantial populations at risk, more people remain unsure that sea-level rise is currently happening than that the climate is changing (Akerlof & Maibach, 2014; Responsive

Management, 2014). In regions where discourses have evolved about flooding instead of sea-level rise, this may be particularly true.

Mental Models

Few empirical studies have been done about public understanding of sea-level rise risk and uncertainty (Carlton & Jacobson, 2016; Moser, 2013; Thomas et al., 2015). As a result, communication professionals must be cautious in developing their messages until this field further matures. By using focus groups and mental models, researchers can compare the gaps between expert and nonexpert knowledge of sea-level rise and analyze in-depth conversations to build a better representation of the public's understanding of sea-level rise. Practitioners and communicators require this base of knowledge to create more strategic communication that will better inform those making decisions and taking action on sea-level rise.

Engagement Models

Finally, a diversity of engagement models and tools have been developed by agencies, nonprofit organizations and university boundary organizations to fill a gap in stakeholder and public engagement. Stakeholder participation has long been recognized as vitally important to climate adaption in major international policies, yet making certain that the engagement process used are meaningful and active has been an enduring challenge (Few, Brown, & Tompkins, 2007). Meaningful inclusion of a variety of stakeholders in the adaptation process can help to engender fairness in climate adaptation and reflect the diversity of values that have been found within a community (Graham, Barnett, Fincher, Mortreux, & Hurlimann, 2015). Coastal communities do not have the communication and engagement tools available to help their residents understand the threat of sea-level rise and often find that public audiences are uncertain and apathetic when they lack personal experience of sea-level rise-associated impacts. These engagement models allow for social learning, which broadens individual experience.

Visualizations and interactive mapping help residents to "experience" possible futures (Sheppard et al., 2011; Stephens et al., 2014). Deliberative dialogues and participatory mapping allow participants to share personal experiences that become part of the collective experience that can then drive decisions about how communities respond to sea-level rise (Akerlof et al., 2016; Schatz et al., 2013). Stakeholder fora allow sharing of best practices that can drive better adaptation decisions and regional cooperation (Old Dominion University, 2015). These engagement and communications modes have the potential to affect mental models, alter public opinion, and increase the salience of sea-level rise.

Conclusion

Within sea-level rise communication, there is a dearth of information on how it is being communicated and what models of engagement are demonstrably successful. This article is a call for additional social science research to address what is admittedly an enormous risk with the potential to affect millions in the United States alone. The true test of adaptation—and of sea-level rise communication—will be in those nations where inundation is most imminent and the size of the populations most vast (e.g., in the small island states and Asia). A wealth of new cross-cultural studies-partnered with practitioners—are needed to meet the challenge.

In conclusion, we also raise a note of caution. Most sea-level rise communication is predicated on the flow of information from science-based imagined futures to policy decisions for managing the long-term risk. Yet, the wide range of sea-level rise projections can be problematic for planning and implementation (Boesch et al., 2013), and future estimates of risk may be difficult for audiences to balance against current vulnerabilities, some of which may be aggravated by changes in coastal policies to accommodate rising waters (Day et al., 2015; Fincher et al., 2014).

The uncertainties around sea-level rise projections make it a prime example of “post-normal science” in which wider stakeholder communities must participate in decision making (Funtowicz & Ravetz, 1993), placing communication at the forefront. As has been suggested for climate change, communities may wish to first decide upon general guiding principles that prioritize people and ecological functioning as means to open up wider ranges of discourse over policy options that increase both near- and long-term resilience (Sarewitz, 2011). Other policy areas may be instructional, such as public health and national security, as they have already learned to choose policies best suited to a wide range of potential futures, and not become tied to the need for narrow predictions (Dessai, Hulme, Lempert, & Pielke, 2009).

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