Coastal Management, 43:555–574, 2015

ISSN: 0892-0753 print / 1521-0421 online
DOI: 10.1080/08920753.2015.1075282

Science Needs for Sea-Level Adaptation Planning: Comparisons among Three U.S. Atlantic Coastal Regions

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To identify priority information needs for sea-level rise planning, we conducted workshops in Florida, North Carolina, and Massachusetts in the summer of 2012. Attendees represented professionals from five stakeholder groups: federal and state governments, local governments, universities, businesses, and nongovernmental organizations. Over 100 people attended and 96 participated in breakout groups. Text analysis was used to organize and extract most frequently occurring content from 16 total breakout groups. The most frequent key words/phrases were identified among priority topics within five themes: analytic tools, communications, land use, ecosystem management, and economics. Diverse technical and communication tools were identified to help effectively plan for change. In many communities, planning has not formally begun. Attendees sought advanced prediction tools yet simple messaging for decision-makers facing politically challenging planning questions. High frequency

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key words/phrases involved fine spatial scales and temporal scales of less than 50 years. Many needs involved communications and the phrase "simple messaging" appeared with the highest frequency. There was some evidence of geographic variation among regions. North Carolina breakout groups had a higher frequency of key words/phrases involving land use. The results reflect challenges and tractable opportunities for planning beyond current, geophysically brief, time scales (e.g., election cycles and mortgage periods).

Keywords adaptation, climate, land use, planning, sea-level rise

Introduction

In 2010, 39% of the nation's population lived in coastal shoreline counties with less than 10% of U.S. land area, excluding Alaska. The population density of these counties is over six times greater than corresponding inland counties (NOAA 2013). Sea-level rise projected for the coming decades presents multiple hazards (e.g., property inundation, salt water intrusion) to these concentrations of population, economic production, and static infrastructure (NRC 2010; Melillo, Richmond, and Yohe 2014). Many economic and social systems underlie this continuing phenomenon and reflect local through national geographic drivers such as government subsidies of many types, real estate market trends, and tourism-based local economies (Bagstad, Stapleton, and D'Agostino 2006; McGranahan, Balk, and Anderson 2007; Tebaldi, Strauss, and Zervas 2012). In the face of this continued coastal growth, the complicated processes underpinning sea-level rise projections (Horton et al., 2014) create challenges in attempting to scale and integrate complex information from the geophysical sciences into adaptation planning at community and regional scales.

The literature on adaptation planning is growing rapidly (e.g., Grannis 2011; Rozum and Carr 2013; Gregg et al. 2013; Melillo, Richmond, and Yohe 2014). Planners and researchers have long suggested that continued development in flood zones on Florida's coastline can result in significant long-term challenges to public infrastructure, real estate markets, and natural capital (Estevez 1990; Bush et al. 2004: Parkinson, Harlem, and Meeder 2015). Yet, disjunctions continue among scientific information on sea-level rise, common planning guidelines, and political trends in many coastal communities. Relatively few local governments in Florida have developed or implemented climate or sea-level adaptation plans (Frazier, Wood, and Yarnal 2010; Mozumder, Flugman, and Randhir 2011; SFRCCC 2012); similar patterns are found nationally (Melillo, Richmond, and Yohe 2014). North Carolina, also on the coast of the southern United States, shows a similar absence of formal sea-level rise planning (Poulter et al. 2008; Lackstrom et al. 2014) whereas several northeastern U.S. states have multiple formal coastal climate adaptation initiatives underway (Rubinoff, Vinhatiero, and Piecuch 2008). In both the southeast and northeast United States, the mainstreaming of adaptation activities into existing policies and governance structures at local levels has been documented (Haywood et al. 2014; Hamin, Gurran, and Emlinger 2014).

An expanding literature is examining the communication and behavioral aspects of why effective climate change responses have not been abundant in politics and resource management despite the scientific evidence (e.g., Grothmann and Patt 2005; Kahan et al. 2012; Luers 2013). Climate messaging documents often include extreme events, such as hurricanes and droughts with a relatively smaller percentage of focus on messaging specific to sea-level rise (examples include Flugman, Mozumder, and Randhir 2011; Climate Nexus 2012). These challenges also reflect questions regarding the effectiveness of translating science and its communication into measureable improvements in governance (Funtowicz and Ravetz 1993; Ostrom 2009).

To help identify the most prominent science needs for sea-level adaptation planning on the U.S. Atlantic coast, we conducted workshops in east Florida, North Carolina, and Massachusetts with professionals from stakeholder groups working on science-based sea-level adaptation planning. These professionals are at the complex front lines of response to local citizens and elected officials as they begin to evaluate local adaptation to increasingly dynamic coastal geophysical systems. We used text analysis of notes summarizing discussions in breakout groups to organize and quantify key words/phrases and to identify potential similarities and differences among geographic regions. Applications of these findings to land use planning for sea-level rise were examined with a focus on local through regional adaptation.

Methods

Workshops and Breakout Groups

To identify priorities for science-based adaptation planning to aid local, state, and federal application of sea-level products from a National Oceanic and Atmospheric Administration (NOAA) Climate Program Office grant, we conducted three workshops on the U.S. Atlantic coast in 2012 with multiple stakeholder groups. Based on the theme of "Sea-level Rise Science and Planning Needs," the workshops were held May 22 in Nags Head, North Carolina, June 20 in Melbourne, Florida, and June 27 in Woods Hole, Massachusetts. The attendees were invited by e-mail based on prior professional association with sea-level adaptation, coastal research activities in the region, and coastal business activities, and represented end-users of sea-level information from five stakeholder groups: federal and state governments, local government (including city, county, and regional governments), academia, business, and nongovernmental organizations (NGOs).

At the workshops, the morning session focused on summarizing current sea-level research via three or four PowerPoint presentations by principal investigators on the NOAA grant and subsequent questions and answers with attendees. Presentation topics on cross-disciplinary research included observational and geological reconstructions of former sea levels (e.g., Kemp et al. 2011; Horton et al. 2013), tropical cyclone climatologies and storm surge modeling (e.g., Mann et al. 2009; Lane et al. 2011), and semi-empirical models of global sea-level rise (e.g., Vermeer and Rahmstorf 2009). The afternoon had two components: (a) two to four presentations by invited local experts on planning issues in their regions (one additional science presentation was made in the afternoon of the North Carolina workshop); and (b) breakout groups that discussed key information needs for sea level and coastal inundation planning.

All workshops had approximately 40 invitees with over 30 attending. In total more than 100 experts attended the workshops and 96 participated in breakout groups. Almost all North Carolina (NC) and Florida (FL) workshop attendees were from those individual states. The Massachusetts workshop also included attendees from Rhode Island, Connecticut, and New York. There were six breakout groups in North Carolina and five each in Florida and Massachusetts, with four to six members present in almost all groups. Before the meeting, each workgroup was assigned members with confirmed attendance, each from one of the five stakeholder groups listed above. Most breakout groups had all or all but one stakeholder group represented (due in part to late cancellations). Breakout groups were asked to develop answers to the questions: (a) what spatial and temporal scientific information do you need to advance inundation planning in your position? (b) how do you prefer this information to be provided (e.g., format and medium)? (c) how can the science be scaled-up to have a larger impact across multiple disciplines or regions? Responses and discussion were summarized in notes from each group by a rapporteur and chairperson. The two note-takers per group were asked to record and summarize discussion components and told that bulleted summary points were fine. Personal information was not gathered in note taking and processing. The authors' decision to use text analysis to analyze the responses and build a manuscript occurred *a posteriori,* several weeks after the final workshop in de-briefings among project investigators.

Text Analysis

The final notes from the breakout groups from the three regions were processed using mixed methods text analysis (Glaser and Strauss 1967; Bryman 2012). Each of the three workshop locations had five or six separate discussion groups and we received a total of sixteen sets of notes. We typed the handwritten notes to create the text. Units of analysis consisted of 1–2 sentences or bulleted phrases from the notes. Coding was done in stages described below using constant comparison and grounded theory methods based on text analysis (e.g., Glaser and Strauss 1967; Miles and Huberman 1994; Ryan and Bernard 2003). To increase the reliability of the coding procedure, three coders coordinated the process of identifying the most frequent words and phrases in the text using iterative comparisons to scaffold the hierarchies of words and phrases, and increase coder agreement within and among the text structure (Carey and Gelaude 2008).

The initial step in the coding procedure was the identification of reoccurring words and phrases; initial coding was applied to identify commonly occurring key words/phrases (kwps) per unit of analysis. Kwps usually consisted of less than four words (range of one to seven). After iterative examination of the initial coding results, selective coding (focused coding in Charmaz 2006), was used to identify the most frequently occurring and high content kwps. At the finest scale, the coders identified a total of 122 kwps. To develop a hierarchically logical framework of larger scale patterns (Stoll-Kleeman, O'Riordan, and Jaeger 2001), the kwps were then organized by similarity into 23 priority topics and sorted into higher order themes using best available subject area knowledge and iterative reviews (Ryan and Bernard 2003; Jacobs and Bujis 2011). The framework contained five themes at the highest scale: Analytic Tools, Communication, Land Use, Ecosystem Management, and Economics. Three nested scales emerged from the text analyses: (1) kwps, (2) priority topics, and (3) themes, at lower through higher scales (Table 1, definitions of components at all scales are in Supplementary Materials Table 1). These three scales correspond to properties, concepts, and categories in Bryman (2012).

An example of the hierarchy can be seen in Table 1: the analytic tools theme, one of five themes in the table, contains five priority topics within and those five priority topics have a range of 4 to 14 kwps present within. We computed the frequencies of kwps, priority topics, and themes according to the three geographic regions. Several kwps, such as "temporal scale" and "spatial scale," occurred in more than one priority topic, or as priority topics within several different themes, an outcome seen in text analysis procedures illustrating the cross-thematic importance and complexity of some words within specific context areas (Bradley, Curry, and Devers 2007; Yeh and Iman 2007).

Table 1

Themes, priority topics, and key words/phrases identified by text analysis of workshop breakout groups' notes. Numbers reflect the frequency of occurrence of that theme, nested priority topic, or key word/phrase by region

Analytic Tools (FL: 83, NC: 85, NE: 126)

- i. Medium/format (FL: 18, NC: 16, NE: 36)
  - a. GIS (FL: 6, NC:1, NE: 4)
  - b. provide data to NOAA (FL: 1, NC: 1, NE: 2)
  - c. Google: Google Earth, Google maps (FL: 1, NE: 2)
  - d. LIDAR (FL: 1, NC: 2, NE: 2)
  - e. bathtub models (NC: 1)
  - f. SLOSH (FL: 2, NC: 1, NE: 4)
  - g. case studies (FL: 1, NC: 1, NE: 4)
  - h. tool output (NE: 5)
  - i. prioritize tool output to adopters (FL: 1, NE: 1)
  - j. web-based (FL: 1, NC: 5, NE: 5)
  - k. contour map (FL: 1, NC: 2)
  - l. visuals (NC: 2, NE: 1)
  - m. evacuation models (FL: 3)
  - n. probability models (NE: 6)
- ii. Temporal scale (FL: 11, NC: 27, NE: 30)
  - a. historical (FL: 2)
  - b. 0–5 years in future (FL: 1, NC: 5, NE: 3)
  - c. 6–10 years in the future (NC: 2, NE: 1)
  - d. 11–20 years in the future (FL: 2, NC: 2)
  - e. 21–30 years in the future (FL: 1, NC: 5, NE: 5)
  - f. 31–50 years in the future (FL: 2, NC: 3, NE: 5)
  - g. 51–75 years in the future (NC: 2, NE: 1)
  - h. 75–100 years in the future (NC: 2, NE: 1)
  - i. user-dependent (FL: 1, NC:1, NE: 7)
  - j. fine resolution (FL: 1, NC: 2, NE: 3)
  - k. development dependent (NC: 1)
  - l. time series (NC: 2, NE: 4)
  - m. how changes occur (FL: 1)
- iii. Spatial scale (FL: 16, NC: 13, NE: 32)
  - a. individual lot/property (FL: 1, NC: 1, NE: 4)
  - b. local/county (FL: 2, NC: 3, NE: 6)
  - c. city/town (NE: 2)
  - d. coastal system (NC: 1, NE: 1)
  - e. regional (FL: 3, NC: 1, NE: 7)
  - f. global (NC: 1, NE: 1)
  - g. user-dependent (NC: 1, NE: 4)
  - h. fine resolution (FL: 6, NC: 4, NE: 5)
  - i. hotspots identified (NC: 1, NE: 1)
  - j. tipping points (FL: 2)
  - k. less upscaling (FL: 2, NE: 1)

(*Continued on next page*)

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iv. Models/data desired (FL: 30, NC: 22, NE: 16)
- a. storm surge (FL: 7, NE: 3)
- b. storm events (FL: 2, NC: 4, NE: 1)
- c. nor'easters (NE: 2)
- d. land movement, GIA (FL: 1, NC: 1)
- e. post disaster redevelopment planning (FL: 2, NC: 2, NE: 1)
- f. hydrological information (FL: 2)
- g. precipitation (FL: 2, NE: 2)
- h. saltwater intrusion (FL: 1)
- i. SLR & SLR components (FL: 4, NC: 13, NE: 2)
- j. observations (FL: 1, NC: 2)
- k. wind patterns (FL: 2)
- l. guidance (FL: 1, NE: 5)
- m. accretion and subsidence (FL: 5)

v. Messaging (FL: 8, NC: 7, NE: 12)
- a. translate science for public understanding (FL: 2, NC: 5, NE: 2)
- b. explain sources of variation (FL: 3, NC: 1, NE: 9)
- c. English units (FL: 2)
- d. consistent information (FL: 1, NC: 1, NE: 1)

<u>Communication</u> (FL: 70, NC: 59, NE: 38)

i. Messaging content (FL: 24, NC: 23, NE: 20)
- a. dynamic places/ change (FL: 1, NC: 2)
- b. simple messaging (FL: 4, NC: 6, NE: 4)
- c. public understanding (FL: 2, NC: 6)
- d. public disbelief (FL: 2, NC: 2, NE: 1)
- e. positive messaging (NC: 4, NE: 3)
- f. spatial scale (FL: 2, NC: 1, NE: 4)
- g. reliable/consistent (FL: 1, NC: 1, NE: 3)
- h. connecting people to science (FL: 10, NE: 3)
- i. counter disinformation (FL: 2, NC: 1)
- j. consensus science (NE: 2)

ii. Medium/format (FL: 11, NC: 17, NE: 6)
- a. case studies (FL: 3, NE: 3)
- b. Digital/internet (FL: 1, NC: 5, NE: 1)
- c. mobile app (NC: 2)
- d. visuals (FL: 6, NC: 5, NE: 2)
- e. town hall (NC: 2)
- f. social media (FL: 1, NC: 1)
- g. what not to do (NC: 2)

iii. Cross-disciplinary actions/outreach (FL: 20, NC: 8, NE: 7)
- a. education (FL: 1, NC: 3)

(*Continued on next page*)

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- b. partnerships (FL: 3, NC: 5, NE: 4)
- c. policy/advocacy (FL: 4)
- d. citizen science (FL: 1)
- e. marketing (FL: 1, NE: 2)
- f. workshops/conferences (FL: 4)
- g. social science (FL: 6, NE: 1)

iv. Know your audience (FL:13, NC: 6, NE: 4)
- a. public (FL: 11, NC: 4, NE: 3)
- b. local government (FL: 1, NC: 1, NE: 1)
- c. messenger (FL: 1, NC: 1)

v. Messengers (FL: 2, NC: 5, NE: 1)
- a. journalists (FL: 1, NC: 1)
- b. scientists (NC: 2)
- c. city governments (NC: 2)
- d. science translators (FL: 1, NE: 1)

<u>Land Use</u> (FL: 37, NC: 68, NE: 44)

i. Spatial scale (FL: 12, NC: 20, NE: 18)
- a. private property (FL: 1, NC: 4, NE: 1)
- b. public infrastructure (NC: 2, NE: 2*)*
- c. sewer (NC: 3, NE: 2)
- d. water (FL: 5, NC: 1, NE: 4)
- e. user-dependent (FL: 1, NC: 1, NE: 4)
- f. transportation (NC: 6)
- g. fine resolution (FL: 5, NC: 3, NE: 5)

ii. Temporal scale (FL: 5, NC: 11, NE: 12)
- a. near-term (FL: 2, NC: 3, NE: 4)
- b. development/user dependent (FL: 3, NC: 5, NE: 4)
- c. long-term planning (NC: 3, NE: 4)

iii. Adaptation strategies (FL: 9, NC: 15, NE: 4)
- a. case studies/science to inform (FL: 6, NC: 5, NE: 3)
- b. options, alternatives (FL: 3, NC: 10, NE: 1)

iv. Planning needs (FL: 9, NC: 13, NE: 6)
- a. vulnerability assessments (FL: 2, NC: 3)
- b. post disaster redevelopment planning (FL: 2, NC: 2, NE: 1)
- c. defined areas between private and public land (FL: 1, NC: 3, NE: 2)
- d. better tools/information (FL: 3, NC: 1, NE: 2)
- e. policy needs (FL: 1, NC: 4, NE: 1)

v. Property/insurance (FL: 2, NC: 9, NE: 4)
- a. property rights (FL: 1, NC: 5)
- b. planning & property (NC: 3)

(*Continued on next page*)

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c. insurance & SLR (FL: 1, NC: 1, NE: 4)

Ecosystem Management (FL: 13, NC: 18, NE: 10)

i. Natural system concerns (FL: 7, NC: 5, NE: 3)
   a. ecosystem services (FL: 6, NC: 3)
   b. habitat/ecosystem conservation (FL: 1, NC: 2, NE: 3)

ii. Geo-spatial tools (FL: 5, NC: 8, NE: 4)
   a. modeling of landscape change (FL: 2, NC: 2, NE: 2)
   b. vulnerability assessment (FL: 2, NC: 3, NE: 1)
   c. map of ecosystem services & responses (FL: 1, NC: 3, NE: 1)

iii. Spatial scale (NC: 3, NE: 1)
   a. watershed (NC: 2)
   b. political and city boundaries (NC: 1, NE: 1)

iv. Adaptation (FL: 1, NC: 2, NE: 2)
   a. renourishment (NC: 1)
   b. engineering solution (NC: 1)
   c. restoration strategies (FL: 1, NE: 2)

Economics (FL: 9, NC: 9, NE: 5)

i. Insurance (FL: 3, NC: 2)
   a. rates (NC: 1)
   b. subsidizing coastal properties (FL: 1)
   c. temporal scale & spatial scale (NC: 1)
   d. audience (FL: 2)

ii. Storms (FL: 1, NC: 3, NE: 1)
   a. financial aspects (FL: 1, NC: 2, NE: 1)
   b. coast & non-coast (NC: 1)

iii. Policy (FL: 3, NC: 3, NE: 4)
   a. time scale (NC: 1)
   b. driver of decisions (FL: 1, NC: 1, NE: 1)
   c. cost/benefit analysis (FL: 2, NC: 1, NE: 3)

iv. Ecosystem services (FL: 2, NC: 1)
   a. tourism (FL: 1)
   b. dollar value (FL: 1, NC: 1)

FL: Florida; NC: North Carolina, NE: New England.

Comparison of frequencies is an established method in grounded theory analysis to compare patterns among reoccurring content in text (Bryman 2012). When expected frequencies were ≥5, chi-square tests compared observed and expected frequencies of categorical information for themes, priority topics, and kwps to evaluate potential differences among geographic regions. The interpretation of this text analysis must use care given breakout groups were not fully standardized. Group notes were taken by different individuals in different workshop locations and the depth and foci of the bullet points and notes varied among groups. Several text submissions from note takers were more comprehensive than others or focused on issues that may reflect individual participant or facilitator perspectives. We assumed common understanding among group members of most terms based on professional experience, the shared experience before the breakout groups of watching the same presentations on sea-level science and adaptation, information given to the chairs/rapporteurs and breakout group members, and feedback during the meetings.

Results

Stakeholder Composition

The highest percentages of professional stakeholder group representatives were from academia and federal/state agencies (33% and 26%, Figure 1d). NGO, local agency, and business stakeholders were represented at 19%, 14%, and 8%, respectively. In total, 40% of the attendees were from government agencies working on adaptation planning. Many participants were program leaders at their agencies or institutions with decades of coastal science and planning experience.

Needs for Adaptation Planning: Themes and Priority Topics

Table 1 shows total and nested frequencies of kwps for all themes and priority topics. A total of 23 priority topics were identified, five each within the themes analytic tools, communications, and land use, and four each for ecosystem management and economics. Highest total frequencies of specific kwps occurrences were found in the analytic tools, communications, and land use themes with 294, 167, and 149 kwps. The ecosystem management and economics themes had 41 and 23 kwps.

Analytic Tools

The analytic tools theme registered the highest frequency scores for kwps with a total count of 294. Common kwps associated with the analytic tools theme included geo-physical modeling tools such as geographic information systems (GIS), high-resolution radar mapping tools (LIDAR), models for predicting sea, lake, and overland surges from hurricanes (SLOSH) and associated items (see Table 1). Breakout groups of experts from New England (Figure 2) used kwps associated with analytic tools significantly more frequently than Florida or North Carolina breakout groups (χ^2 *p*-value of $<.01$) (Table 1).

The priority topics with the most frequent mentions in the analytics theme were: medium or format of the analytic product, temporal scale, spatial scale, and models/data (all these kwps had >50 mentions total, Table 1). New England attendees most frequently mentioned delivery medium or format of adaptation products (36 mentions in comparison to 18 and 16 for Florida and North Carolina, respectively, χ^2 *p*-value of .005). Florida had fewer mentions of temporal scales (11) in contrast to New England and North Carolina attendees (30 and 27, respectively), χ^2 *p*-value of .01 (Table 1).

The most common kwps regarding temporal scales of analytic products focused on predictions of less than 50 years into the future, particularly, 0–5, 21–30, and 31–50 years into the future (Figure 3). By region, the most frequently occurring kwps for temporal scales of analytic products (years into the future of the forecast)

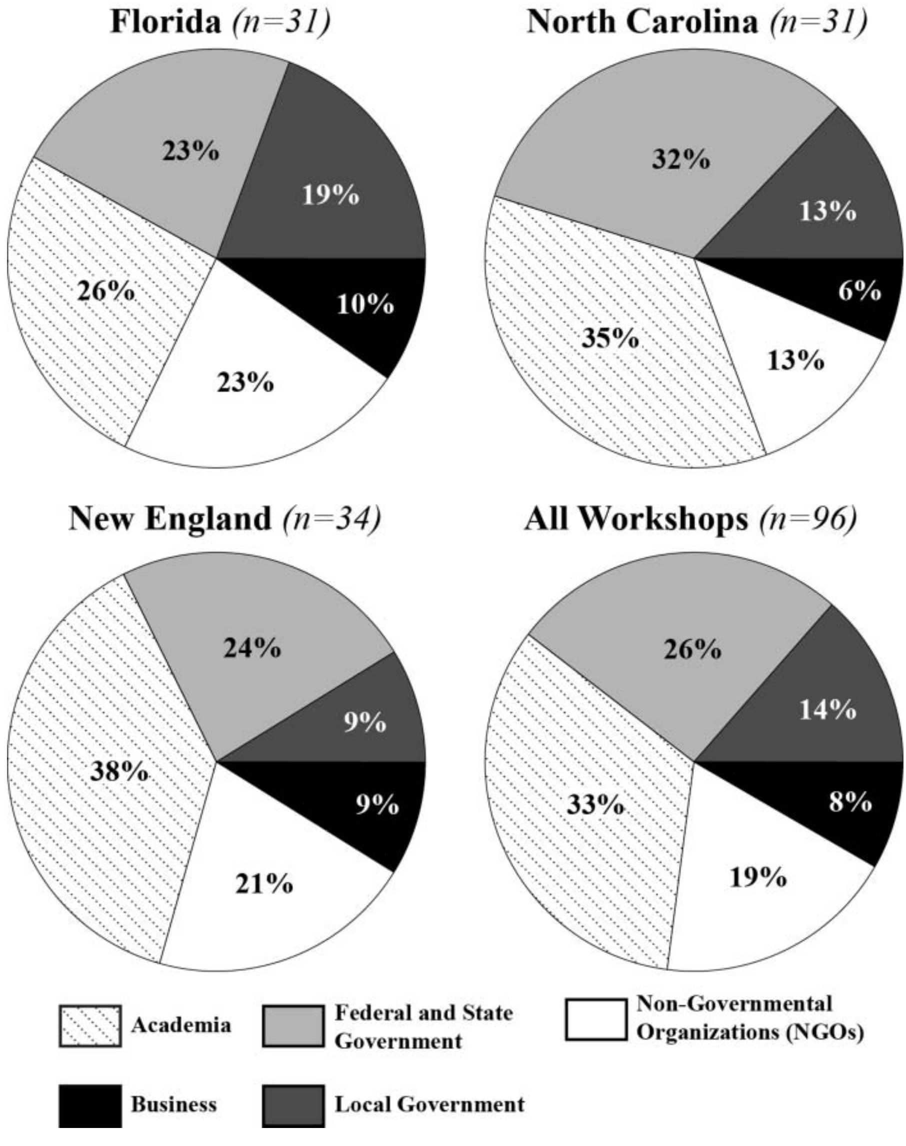

Figure 1. Stakeholder compositions at: (a) North Carolina workshop, (b) Florida workshop, (c) New England workshop, and (d) total of all workshops.

were: 0–5 and 21–30 years in North Carolina; 21–30 and 31–50 years in New England: and 11–20 and 31–50 years in Florida. When these data were pooled for less than and greater than 50-year intervals (i.e., analytic tool products with pre-2060 AD to post-2060 AD timelines) frequencies of occurrence were 37 to 6, respectively (Figure 3). A comment stated, "New York looks at time horizons for different things they are building. A motor to control a flood pump lasts 50 years, the life of a mortgage is 30 years."

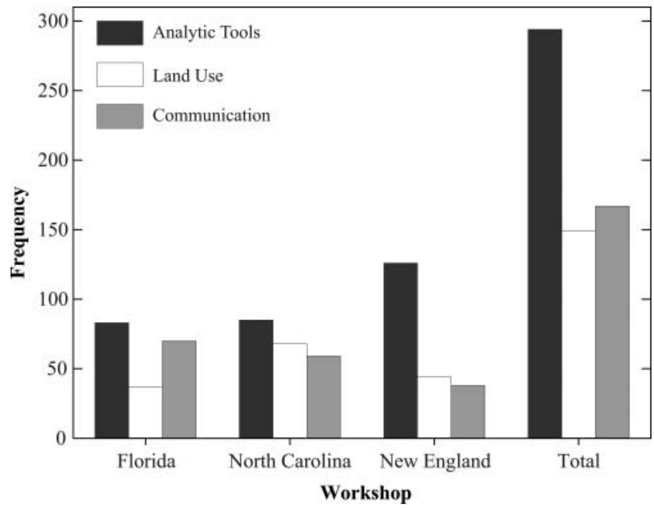

Figure 2. Frequency of key word/phrase occurrence within the most commonly occurring themes by workshop region.

Communications

The communications theme reflected stakeholder needs to improve message delivery on science-based adaptation planning, in terms of both content and medium. With 70 occurrences, Florida attendees had the highest total frequency of kwps in the communications

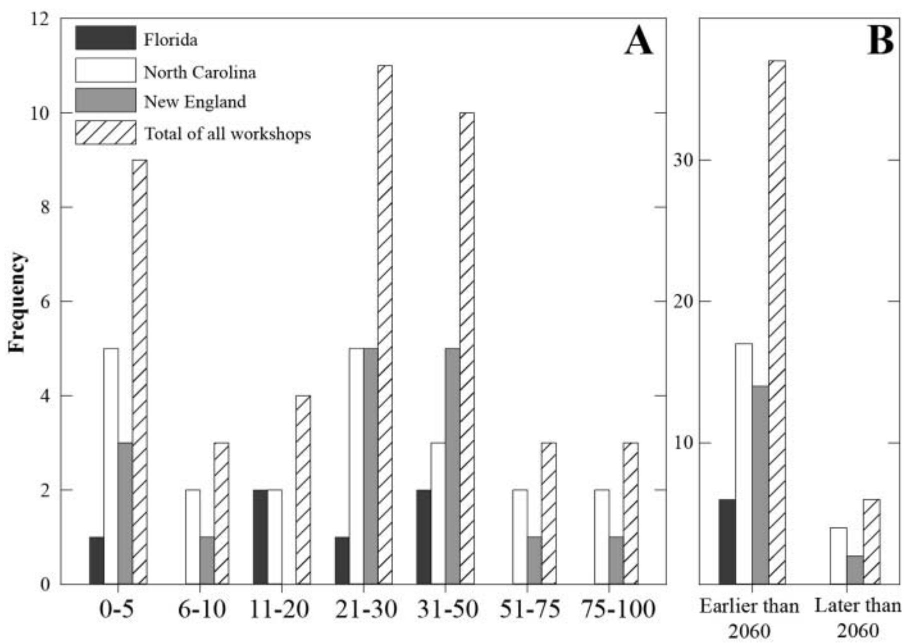

Figure 3. Preferred temporal scales of analytic tools and their products by workshop region. (A) Most common temporal key words/phrases within the temporal scale priority topic in the analytic tools theme, by region. (B) Pooled frequencies for pre-2060 (<50 yrs) and post-2060 (>50 yrs) key word/phrase occurrences.

theme; the New England attendees had the lowest with 38 (Table 1). Breakout groups in Florida and North Carolina mentioned key words/phrases in the communications theme significantly more frequently than New England attendees (χ^2 *p*-value of <.01) (Figure 2, Table 1). For all workshops pooled, the most frequently occurring kwps in the communication theme were in three priority topics: messaging content, format/medium, and cross-disciplinary actions/outreach (>30 occurrences each; Table 1).

Of the five priority topics in the communications theme, messaging had almost twice the kwp frequency as other topics. The most frequent overall kwps were for simple messaging and connecting people to science with 14 and 13 occurrences (Figure 4). Many breakout groups suggested positive messages that better connect people to science. A North Carolina participant stated "When it suits you, you believe in science (e.g., doctor visits and technology) but not with climate change." Some emphasized the need for citizen leaders (champions) to connect climate science issues to local audiences.

Stakeholders spoke of continuing communication challenges in all regions and wanted to deliver science and adaptation messages to their audiences (e.g., elected officials, agency heads) that were understandable and positive (Figure 4). The need for balancing these challenges is acute since most elected officials and property owners have limited experience with coastal geophysics. Various stakeholders recommended against worst case scenarios when discussing storm events or other impact scenarios. For example, "SLOSH model runs should present Category 1–2 storm impact results, not only on worst case Category 4 or 5 storms." Such responses were most prominent at the North Carolina workshop located in the Outer Banks, a region with recent storm damage from Hurricane Irene in 2011.

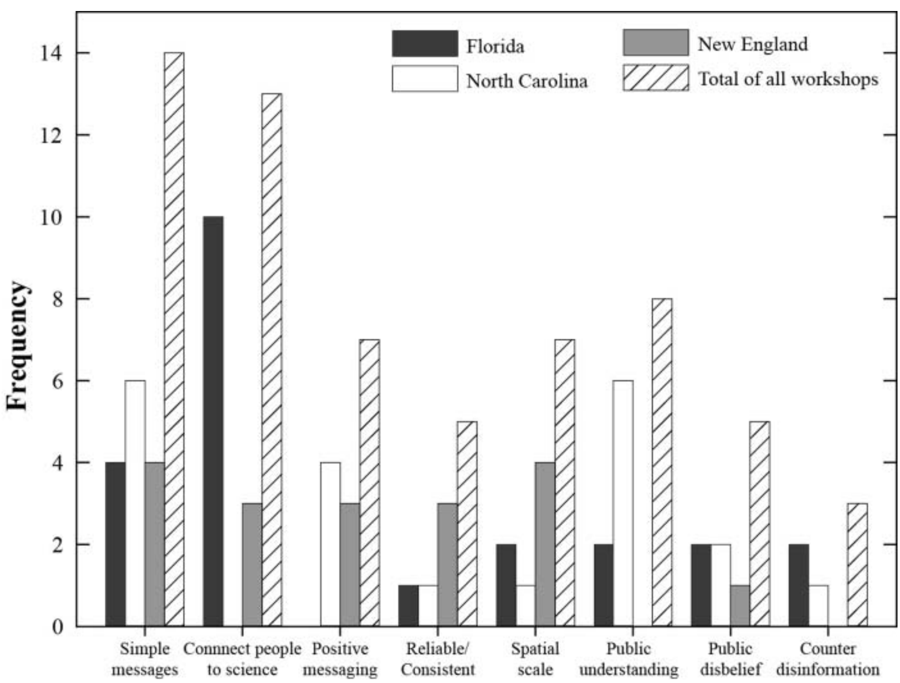

Figure 4. Frequency of occurrence of preferred key words/phrases representing preferred messaging content among the workshop regions.

Many suggested that the science be presented ("translated") into laymen terms. Some words and phrases that scientists and planners routinely use are red flags to non-scientists (e.g., uncertainty = we don't have a clue; synthetic = fake). We identified common word/phrase misinterpretations in coastal adaptation and alternatives using the workshop notes, our own adaptation experiences, and work by Somerville and Rassol (2011) and Houck (2001) (Supplementary Materials Table 2). Over 25 terms can be interpreted differently by those unfamiliar with terminology that scientists and policy professionals take for granted.

Stakeholders sought improved formatting and delivery media for messages. Advanced inundation mapping tools, Web-available digital elevation model products, and supporting databases including GIS layers and shape files were desired. Not surprisingly, almost every possible delivery medium was mentioned including the Web, social media, and smartphone apps. Many agencies and NGOs are responding to such requests by producing varied tools including sea-level visualizations across several digital delivery streams (e.g., NOAA Coastal Services Center, Climate Central's Surging Seas).

Land Use

A broad range of land use and governance issues were identified including private property, public infrastructure, and zoning, often with reference to spatial and temporal scaling. Many aspects of local, on-the-ground adaptation were considered in all workshops, including building codes, transportation, municipal services, comprehensive land use, and post-disaster planning. The priority topic spatial scale had the highest total (50 occurrences). The kwps temporal scale, adaptation strategies, and planning needs each had 28 occurrences (Table 1).

The focus on spatial scales to aid planning occurred in other themes besides land use. For example, in the analytic tools theme, the priority topic on spatial scale contained 61 kwps, many of relevance to land use and planning.

In terms of regional patterns, North Carolina breakout groups had a higher frequency of kwps associated with the land use theme (χ^2 p-value of .005) (Figure 2, Table 1). Regional occurrence of kwps in the spatial scale priority topic is seen in Table 1. The North Carolina workshop had the highest frequencies of occurrence of the kwps private property and transportation, including the comment that "transportation will make us or break us." New England and Florida, respectively, mentioned the kwps user-dependent and water most often compared to other regions (Supplementary Materials Table 1).

Ecosystem Management and Economics

Ecosystem management and economics are clearly essential themes in sea-level planning. However, the total frequency of kwps for these themes was lower than observed for the prior three themes: 41 and 23 key word/phrase occurrences for ecosystem management and economics respectively (Table 1). There was interest in tools that could "convey the costs of 100 year events becoming 10 year events."

There was industry interest in sciences involving sea-level rise with the comment that "we in insurance don't have sea-level reconstructions on the 30-50 yr time scale, we could really use sea-level reconstructions on that time scale." The phrase "ecosystem services" was mentioned 12 times in relation to these two themes, reflecting an inter-disciplinary seam that includes natural and economic capital. If the breakout group questions and preceding presentations had been more focused on ecosystem management and economics, rather than science- and planning-centric, we would have expected much higher frequencies of kwps for these two themes.

Discussion

Science Needs for Sea-Level Rise Planning

Text analysis that uses qualitative or quantitative methods of pattern recognition can identify informative patterns and aid subsequent interpretation (Tashakkori and Teddlie 2010; Bryman 2012). The workshops we analyzed represent a mid-2012 snapshot of adaptation professional needs for science-based planning in three regions of the U.S. Atlantic coast. Using a mixed methods approach, useful patterns can be reflected in the frequency of occurrence of common words and phrases in nested levels (Ryan and Bernard 2003; Bryman 2012). However, the information collected was not fully standardized and the patterns are imbedded within complex socioeconomic systems.

The workshop attendees most commonly mentioned the following science information needs: analytic and predictive tools, information that is easy to present to decision-makers, and land use planning issues (Table 1). Emphasis within the analytic tools theme included acquisition and use of geophysical modeling tools (e.g., finer resolution storm surge models) and information transfer allowing improved visual representations using GIS and other geospatial tools. Comments emphasized that powerful analytic tools are needed and increasingly available but are not enough by themselves. Professionals have to use simple messaging for complex land use decisions by elected officials and citizen boards, typically non-scientists. The information suggests professional stakeholders among the regions understand the basics of climate change and sea-level rise, but need diverse analytic, communication, and policy tools to help their audiences to effectively plan. Several of these themes have been reflected in other workshops (e.g., Culver et al. 2010; Frazer et al. 2010).

There was a common focus on temporal and spatial scaling of technical products. The primary temporal focus was on fine-scale products. Four-year political scales and 30-year mortgage scales were emphasized (Figure 3). Stakeholders typically saw limited direct application for 100-year time scales with property owners and political decision-makers. The same emphasis on fine resolution occurred for spatial scales. Comments on spatial scales focused prominently on kwps such as fine resolution and local (Supplementary Materials Table 1).

Given broad questions regarding the role of science in applied resource governance (e.g., Ostrom 2009; Melillo, Richmond, and Yohe 2014), approaches to scaling up sea-level science and adaptation planning to have larger impacts across regions or disciplines were addressed in several manners. The high frequency and diversity of kwps and priority topics within the communications theme may be informative for improved governance. The workshop attendees valued messages for decision-makers that are framed in positive manners and are non-technical to achieve political traction (Figure 4). This correlates with internal NGO marketing guidance to avoid climate change messaging that "takes the audience from denial to despair."

In terms of preferred information media and formats, there was interest in Web-available products and smartphone apps. Stakeholders also sought advanced outreach tools in adaptation studies on the Florida west coast (Frazier, Wood, and Yarnal 2010) and the Florida Keys (Mozumder et al. 2011). Even with advanced messaging tools, adaptive planning for changes in sea level is inherently sociopolitical; personal and network scale interactions among stakeholders are a fundamental component over time including property owners and coastal business interests (Lackstrom et al. 2014; Ariza et al. 2014). Since the workshops, webinars on diverse aspects of climate adaptation have become increasingly frequent in the eastern United States and this medium has emerged as a cost-effective information transfer tool. Newly developed Storm Surge Advisories produced by the U.S. National Weather Service before and during large storm landfalls may be an important tool for real-time hazard and scenario planning.

The need for people-centric messages for more effective climate policy is documented by correlation of risk perception and other behaviors with cultural programming (e.g., Maibach, Roser-Renouf, and Leiserowitz 2008; Carlton and Jacobson 2013; Campbell and Kay 2014) and suggested in the complex relationships between science, uncertainty, and governance systems (e.g., Funtowicz and Ravetz 1993). For example, scientific communication often underuses relational framing, building the case with copious data that is difficult for non-technical audiences who also may avoid conclusions that don't fit their cultural frame (Nisbet 2009; Somerville and Hassol 2011). Framed messaging guidelines are appearing in new templates for discussing either generic or event-specific climate issues (e.g., Climate Nexus 2012).

Some attendees suggested that most non-professionals are not yet familiar with adaptation planning terminology. The absence of a common language can feed misunderstandings on complex issues and amplify translation challenges already present between scientists and the wider public. Therefore, it is logical to attempt to build a consensus understanding of such terms early in local deliberative processes among all parties. In August, 2013, Satellite Beach, Florida, became one of the first municipalities in the state to approve new Adaptation Action Area planning language in the coastal element of the city's comprehensive land use plan following Florida Statutes 163.3164 and 163.3177. These efforts required years of public deliberations and votes on complex adaptation-oriented language by the citizen Comprehensive Planning Advisory Board including earlier work by a Sea-level Rise Subcommittee in 2010 using adaptation resource handouts and online library resources with the community and city staff.

The lower number of kwps in the ecosystem management and economics themes (Table 1) was not interpreted as disinterest in economic or ecological issues in adaptation, but a reflection of the workshop focus and presentations emphasizing geophysical sciences and planning. Business interests were the least represented stakeholder group in the present study although representatives from the watersports, insurance, and real estate industries were present. Kwps such as insurance and ecosystem services occurred in various groups and there was interest in these issues at both local and regional scales (Table 1). The complexity of sustaining the concentrated infrastructure of mass coastal tourism in Florida and the Caribbean (Lindeman et al. 2003; Tebaldi, Strauss, and Zervas 2012) will require decision-making that considers 30–50 years as well as short time scales. Governance and business institutions may need to be prepared in advance to modify/replace adaptation strategies over multi-decadal scales.

Geographic Comparisons

Geographic variations in public attitudes toward climate change and adaptation have been increasingly well-documented (e.g., Leiserowitz et al. 2012). The majority of attendees in three regions in the present study sought fine-scale inundation modeling products yet simple communication materials (Table 1). There was also evidence for regional variations among workshops (Figures 2 and 4). In Florida, the need to receive more information on stormwater issues, hurricanes, and basic adaptation planning was common. North Carolina breakout groups had a significantly higher frequency of kwps associated with the land use theme and had the highest frequencies of comments regarding "private property" and "transportation" (Table 1). Several patterns may reflect differences in recent local experiences. The North Carolina workshop was held on the Outer Banks in an area that had major road and property damage from flooding during Hurricane Irene in 2011, unlike other workshop regions.

Attendees at the Massachusetts workshop, from three states in New England and New York, focused on issues including advanced analytic needs, land-use planning, and nor'easters. The workshops occurred before Hurricane Sandy, October 2012. The impacts of Sandy have accelerated adaptation discussions not only in the New England region, but also in south Florida where Sandy-driven wave regimes caused flooding and major road closures in Ft. Lauderdale and Miami. The importance of regional context is shown in the perspectives of adaptation professionals on water management issues across the Intermountain West, the Great Lakes, and the Carolinas (Dilling et al. 2015).

Potential geographic variations in this study could, in part, reflect political patterns in the different regions. In the southern United States, two of the largest and most populous states, North Carolina and Florida, have state legislatures and governor offices that have been reluctant to acknowledge coastal climate change (Bush et al. 2004; Poulter et al. 2008; Lindeman, Gibson, and Yu 2010; Haywood et al. 2014). The Florida Office of the Governor has advanced no formal state climate policy since 2011 (Korten 2015). The majority of coastal municipalities in Florida have not developed or implemented formal sea-level adaptation planning (T. Ruppert and K. Lindeman, unpubl. information). The 2012 North Carolina legislature attempted to restrict future state analysis of climate change to only linear extrapolations of past rates (NC House Bill 819). The bill that passed essentially removed that language and delays state applications of new sea-level rise estimates for several years. Such types of legislation are not evident in state governments of the northeast United States where there are multiple examples of formal, local, and state climate adaptation planning (Rubinoff, Vinhatiero, and Piecuch 2008) although challenges to fundamental planning can arise in this region as well (Douglas et al. 2012; Hamin, Gurran, and Emlinger 2014). Examples of full implementation of adaptation plans remain relatively low nationally (Melillo, Richmond, and Yohe 2012). It would be an error of omission to neglect the role of politics given the land use issues mentioned by adaptation professionals at the workshops (Table 1).

Diverse key words and phrases in the economic and other themes reflected direct or indirect drivers of insurance policies. An emerging trend in coastal adaptation is the convergence of differing political interests (e.g., environmental and conservative economic groups) to form bipartisan state- and national-level coalitions to re-examine taxpayer expenditures that subsidize high risk infrastructure investments in flood zones. For example, in 2013, a coalition including both taxpayer rights and environmental organizations was able to achieve legislation and the governor's signature for the removal of state-backed insurance of new buildings seaward of the Florida coastal construction control line as of July 2015 (SSF 2013). At the federal level, efforts to better align insurance with risk were attempted via the Federal Insurance Reform Act of 2012 (the Biggert-Waters Act). This proved unpopular politically due to insurance rate increases and sections have been functionally modified or repealed with work ongoing.

Uncommon partnerships can help advance new coastal policy approaches by diversifying ideas and building on the strength of bipartisanship. Such new partnerships can begin when actors from typically segregated stakeholder groups initiate dialogue with counterparts from other groups to identify points of agreement and avoid stalemates around points of contention. Similar best practices exist for the spatial planning of marine protected areas among multiple coastal stakeholders (e.g., Olsen and Christie 2000; Lindeman et al. 2000; Storbjörk 2007; Warner and Pomeroy 2012). Opportunities for both planning and implementation require combinations of solid scientific information, translation of the science to nontechnical terms, extended engagement among stakeholders, and one or more political champions (Mumford and Harvey 2014). Many of these attributes were reflected directly or indirectly in the workshops in the present study.

Acknowledgments

We appreciate the efforts of three reviewers. We thank all of the attendees for their time, collective knowledge, and enthusiastic participation. We greatly appreciate the efforts of the following breakout chairs and rapporteurs: W. Gray, K. Tzadik, T. Ruppert, G. Henry, N. Gassman, D. Snyder, P. Davis, T. Miller, B. Boutin, R. Rudolph, D. Carpenter, L. Rimer, S. Rogers, C. McGuire, T. Rogers, S. Madsen, K. Soltis, G. Berman, R. Sullivan, J. Tanski, N. Widulinski, J. Knisel, and E. Bryant, We also thank the following: S. Lucas, B. Beard, H. Yu, C. Giannoulis, E. Ariza, G. Appelson, J. Fergus, A. Welchel, G. Miller, S. Traxler, R. Glazer, K. Bagstad, J. Beever, P. Chan, and J. Pritchard.

Funding

The workshops and analysis were a component of NOAA Climate Program Office Award NA11OAR43101, Advanced Regional & Decadal Predictions of Coastal Inundation for the U.S. Atlantic & Gulf Coasts awarded to BPH. Additional funding was provided by the National Science Foundation award EAR 1402017 and OCE 1458903.

Supplemental Material

Supplemental material is available on the publisher's website for the UCMG journal (www.tandfonline.com/ucmg).

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