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Key Priorities and University Roles to Address Coastal Resilience in Virginia: Findings from the Rotating Resilience Roundtables Workshop Fall 2018

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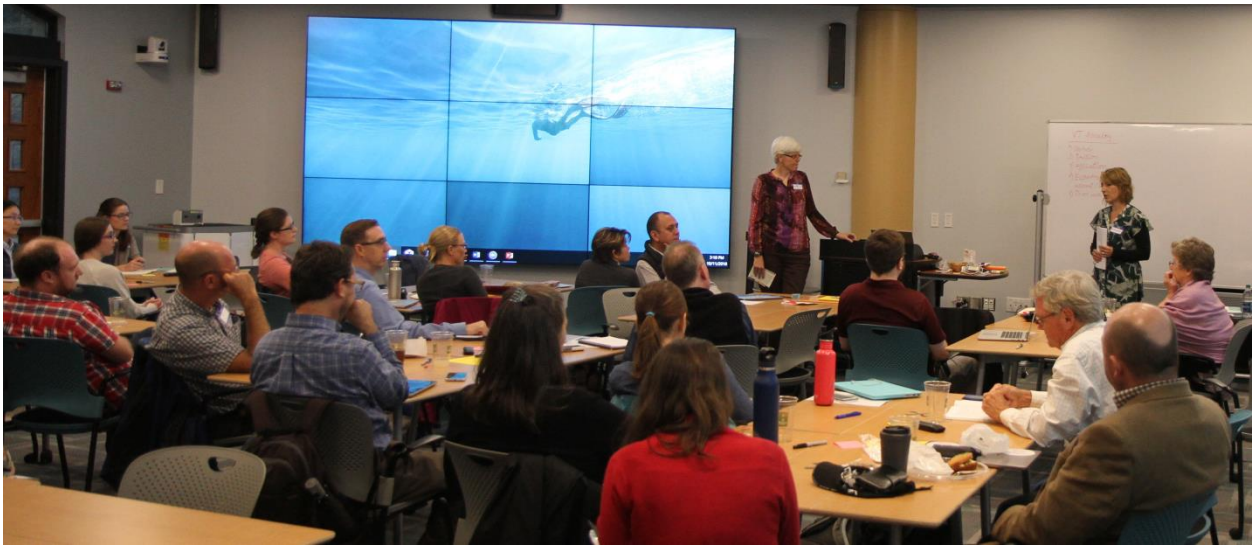

KEY PRIORITIES AND UNIVERSITY ROLES TO ADDRESS COASTAL RESILIENCE IN VIRGINIA

Findings from the Rotating Resilience Roundtables Workshop Fall 2018

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1. Purpose and significance

Coastal Virginia cities and counties are increasingly experiencing accelerated flooding and associated physical and social impacts due to the fastest rate of relative sea level rise on the U.S. east coast (Adapt Virginia 2019; Atkinson et al. 2013). Interactions between ocean currents, global sea level rise, high-water tables and ground subsidence can make even relatively small storms have disproportionate impacts on communities (Ezer 2018). The storm events are also becoming more extreme (Smirnov 2017), often overwhelming stormwater infrastructure and resulting in frequent flooding in many coastal locations. The recurrent inundation due high tides and meteorological events is becoming more common and extensive in low-lying areas, putting both built environment and transportation systems at risk (Mitchell et al. 2013). Sea level rise in Virginia, projected to be over seven feet by the end of this century, is expected to have significant impacts on the Tidewater/Hampton Roads region, namely on coastal communities, tourism assets, fisheries, military facilities and readiness, and insurance premiums (McGarry et al. 2014).

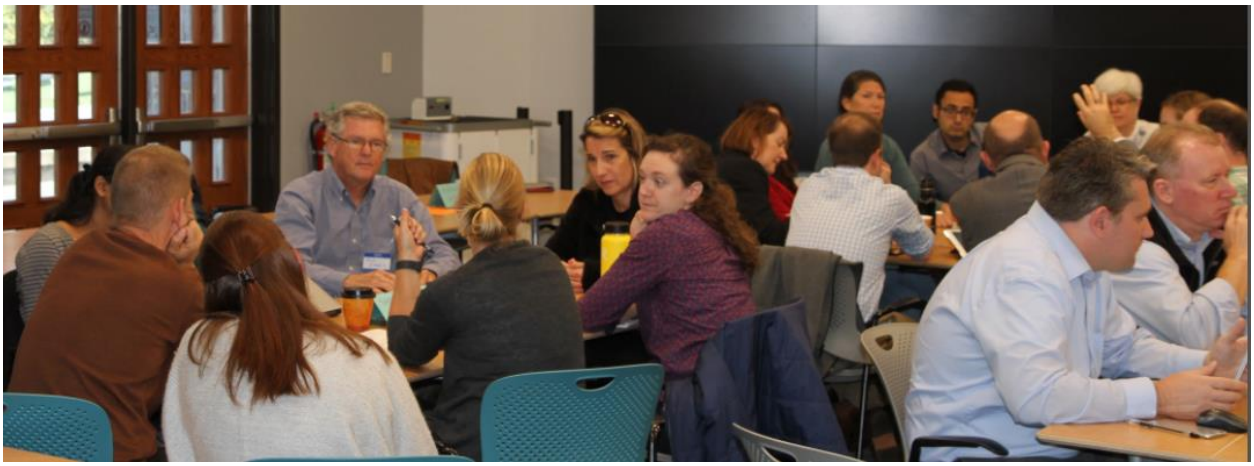
Building resilience to coastal hazards has become an important priority for many local governments, particularly in the urban area of Hampton Roads, made up of 17 municipalities and 1.7 million residents. The Commonwealth has also recognized the importance of resilience to coastal hazards in 2014 by appointing a Chief Resilience Officer to coordinate the state's activities and serve as a liaison between local and federal government initiatives. While scientists and environmental groups have recognized the risk of sea level rise and called for action for decades, efforts to advance resilience in Virginia have become urgent only in recent years due to more invasive flooding and its visible impacts on the coastal municipalities. The Secretary of Public Safety and Homeland Security, the Honorable Brian J. Moran, affirmed the need for integration of intellectual capacities and knowledge to address coastal resilience in the Commonwealth during his visit to the Virginia Tech campus in April 2018 as a part of the Coastal@VT speaker series. He further highlighted the importance of working together across all institutions of higher education and with other public and private partners to generate cohesive and policy-relevant science that will inform highly needed resilience planning in the Commonwealth. Inspired by the Secretary's remarks and overall more supportive climate for the anticipatory resilience planning, the idea of Rotating Resilience Roundtables was conceived as a semi-annual event that builds on this momentum and facilitates the networking and knowledge integration among researchers and other stakeholders.

The first Rotating Resilience Roundtables event took place on October 11 and 12, 2018 on the Virginia Tech campus in Blacksburg and was co-organized between the Coastal@VT initiative at Virginia Tech and Old Dominion University/Virginia Sea Grant Climate Adaptation and Resilience Program. It was designed to respond to the need for a cohesive and policy-relevant science that will align and coordinate efforts between researchers and other stakeholders to benefit the Commonwealth's resilience planning for changing conditions in coastal zone. The Rotating Roundtables' concept was selected to facilitate active engagement of audiences with different coastal themes, as well as to stimulate problem identification, critical thinking, and alignment between the real-time issues and research questions. Further, the event was envisioned as a "rotating" occurrence hosted in sequence by different Virginia universities and endorsing different structures and thematic focus to meet the following objectives:

1. Facilitate interactions between academic and non-academic stakeholders to improve the alignment of science and the existing circumstances in Virginia's coastal zone
2. Identify pressing issues and knowledge gaps vital for future resilience research and programs
3. Build effective networks between science-policy, science-industry, and science-NGO partners

4. Foster collaboration around coastal issues between diverse groups of stakeholders to identify mutually-acceptable resilience strategies and opportunities for shared benefits in the coastal zone
5. Identify opportunities for resilience improvements in coastal-inland interface spaces

This first event in a planned series of roundtables was structured to allow for active interactions and knowledge exchange among participants via traditional presentations, networking, and small roundtable discussions. The roundtable discussions are reflected in this position paper, addressing the key priorities and science gaps in different thematic areas related to coastal resilience, and providing recommendations for the role of universities in research, education, and outreach that would inform the resilience planning for Virginia's coastal zone.

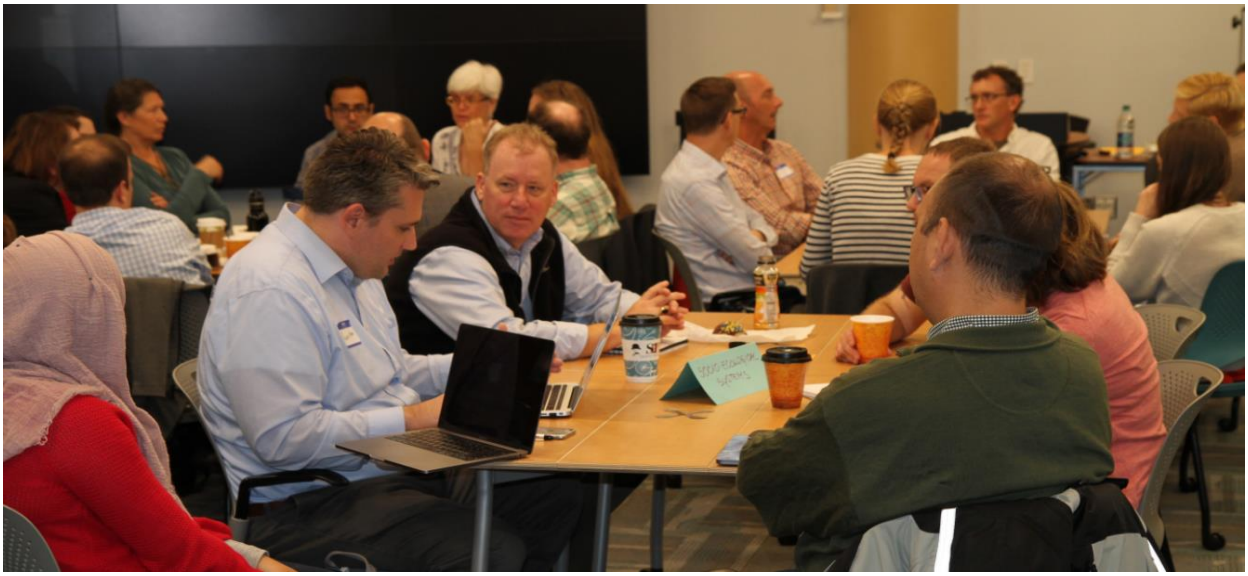


2. RESILIENCE ROUNDTABLES: STRUCTURE AND THEMATIC AREAS

The Rotating Resilience Roundtables gathered over 30 experts and stakeholders from the institutions of higher education, local governments, and non-profit organization with diverse disciplinary backgrounds. On day one, the participants took part in an activity designed to identify which expertise and stakeholder groups were represented in the audience. Next, the guest participants presented their research and projects to Coastal@VT faculty to facilitate knowledge exchange and networking. On the next day, the audience was organized in roundtable discussion clusters addressing the following six themes relevant to coastal resilience in Virginia:

1. Engineering the future with more water
2. Technology as a part of solution
3. Socio-ecological systems
4. Community resilience
5. Should we stay or should we go?

Each thematic roundtable had three rotations of participants bringing different expertise and disciplinary perspectives on individual topics, as well as note-takers and the lead authors who guided the synthesis of roundtable discussions. Each roundtable discussion group was asked to discuss three Coastal Zone Dimensions - Social, Environmental and Economic - and identify the key issues, resource needs, and research questions that are the most pressing.



2.1. Engineering the future with more water

Lead authors: Madeline Flint & Megan Rippy (Virginia Tech)

The panel identified a variety of challenges pertaining to engineering with more water that fall into three broad categories:

1) Water resource (quantity, quality, distribution infrastructure, and fit-for-purpose water);
2) Design (transitioning to high impact design, smart communities, green design); and
3) Long-term prediction (how do policy or design choices affect the region in 100 years?).

The panel also felt it is important to consider the dual challenges of engineering the future with more and less water, as many communities in Virginia have to deal synchronously with both. For example, most of eastern Virginia is dependent on the slow-recharging coastal plain aquifer system, such that communities can be water stressed even in periods of high rainfall. Groundwater withdrawal for water supply in this region can lead to land subsidence, exacerbating the effects of sea level rise (*more water*) while making the aquifer vulnerable to salinization (*less water*). Recognizing and identifying such interdependencies between more and less water is important for both future risk assessment and evaluation of proposed engineering solutions, and represents a key recommendation of the panel.

Water Resource Challenges: The future performance of urban infrastructure cannot be extricated from the risks of sea level rise and precipitation. Rainfall during the extreme storms can overwhelm storm drainage systems already filled with coastal waters and exacerbate flooding, while cracks/breaks in the aging sanitary sewer infrastructure can lead to sanitary sewer overflows, particularly during storms. Because climate change is projected to cause inundation and flooding in areas that were supposed to be safe from flooding (i.e., were not designed with flooding in mind) leaching of contaminants into groundwater (e.g., from flooded waste disposal areas) and contamination of existing aquifers by heavy metals and other chemicals is a real concern. Corrosion of already aging infrastructure by salinized groundwater (either from rainwater containing deicing salts or seawater intrusion) also represents an emerging challenge. Virginia is already listed by the USGS as having high prevalence of potentially

corrosive groundwater. Salinization would increase the galvanic corrosion potential of that water, placing the drinking water supply of ~1.6 million people who rely on groundwater wells at increased risk. Addressing the water resource challenges related to circumstances with more or less water will require a combination of mitigative and adaptive approaches. Adoption of fit-for-purpose water, whereby water is treated to the appropriate level for a given end use, reducing the overall energy required to supply that water, is an example of both. In this approach, cities would be reconfigured with non-potable and potable water delivery pipelines, so that non-potable water could be used in place of potable water where possible, reducing the stress on the potable supply. Encouraging potable substitution, wastewater recycling, and water conservation should be (and in many cases is) part of future water management strategies in Virginia. Indeed, the Code of Virginia, section 32.1-248.2, specifically promotes "reuse of rainwater or grey water as a means to reduce fresh water consumption, ease demands on public treatment works and water supply systems, and promote conservation". Similarly, the Department of Environmental Quality has established guidelines for fit-for-purpose use of recycled water meeting level 1 or 2 standards in Virginia.

Design Challenges: Coastal infrastructure in Virginia tends to be designed for low impact hazards while it needs to be able to withstand the storms with high surge and extensive flooding. Construction standards that reflect future flood risk projections (including non-stationarity of design storms) are highly needed. Adaptable projects are also desirable to reflect the uncertainty in future risk. There is also a need for smart systems in coastal communities that improve our capacity to respond to more or less water in real time (for instance networks of flood warning sensors and smart sensors for urban drainage that increase storage capacity in advance of storms, reducing the risk of flooding).

Adaptation strategies to manage runoff, cope with sea level rise, create migration corridors for wildlife to escape the flooded coastal areas, or sequester carbon, often require large expanses of open space and can conflict with strategies for mitigating carbon emissions, which involve transitioning towards high density attached housing that uses less energy to heat and cool and is co-located with services to reduce travel distances. Reconciling these approaches in coastal community design is a challenge, but may be possible through integration of ribbons of greenspace into cities, design of greenspaces with multiple functions (e.g., park, floodplain protection, and urban agriculture), and reduction of urban sprawl, leaving large blocks of peripheral open space to sequester carbon and buffer storm surge.

Prediction and Decision Management Challenges: Long-term prediction is a grand challenge in the engineering of water systems. Most computational tools are geared towards the short-term prediction and are not well suited for evaluating the effects of policy or engineering design solutions on a region in 100 or more years. Climate change further complicates the situation as information previously used to make decisions about water resources (for instance building dams or reservoirs) may be unreliable under different climate futures and less useful for the long-term prediction. Determining an appropriate protection designs for the storm surge (or other type of extreme loading) is also complicated by climate change, as climate data on rare, short-duration events (e.g., a 100-year or 500-year flood) is less reliable than predictions of long-duration means. Future decision management tools need to be more integrated than they presently are to allow for identification and evaluation of important feedback loops. For example, we need to integrate current and future transportation patterns with urban drainage, building, and greenspace plans to co-evaluate the effects of adaptation or mitigation strategies proposed in one sector across all other sectors. This likely requires a system of systems approach.

2.2. Technology as a part of the solution

Lead author: Tom Allen (ODU)

A technology-focused roundtable discussion evoked a wide range of topics spanning measurement, observations, and methodological advances that are enabling new insights in dynamic coastal changes and/or improving the prediction, and decision-science or policy-making information for coastal communities. This summary briefly captures the leading ideas and major themes in this broad discussion while also retaining differentiation between technological advances versus scientific insight, decision-making, and applications. The highlighted categories of potential technological solutions are:
1) Observation and measurement for coastal systems and change;
2) Modeling and prediction; and
3) Enabling actionable information and dissemination.

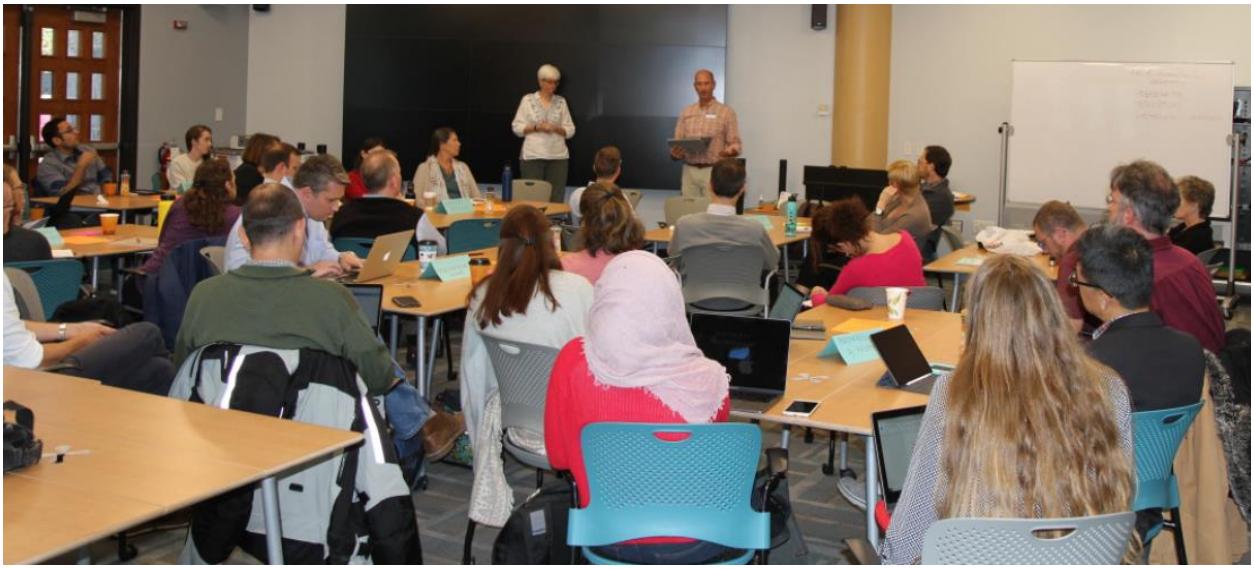
Observation and Measurement: The roundtable discussion focused a lot on technologies that can improve the measurement and detection of changes in coastal environments. These include the recent rapid advances in Unmanned Systems (aerial, autonomous, aquatic or otherwise "drones"), new NASA and other earth observation satellites, recent testing and development of in situ sensors for flood, and water level and road conditions (water on roads, traffic conditions, congestion). **Crowdsourcing** has emerged as one example that has dramatically illustrated public data collection and could be much more widely developed. **Satellite and airborne remote sensing** provide much higher spatial and temporal resolution than in the past, which could improve measurements of sea level rise and storm processes, wetland changes, and urban and environmental processes.

Observations and measurement can also support newer technology for design, such as smart buildings, sensors within built environments, smart cities, and efficient green energy alternatives (wind, solar, tidal, or geothermal.) Nonetheless, some environmental conditions or parameters are still difficult to measure and call for a focused research, such as sea surface salinity and water quality remote sensing, shallow water bathymetry, ground water, and soil moisture. Technological advances for sensors of these phenomena could improve the health risk assessments, potential failure of septic system, algal blooms, flooding, and agricultural impacts of extreme events.

Modeling and Prediction: Advances in **machine learning** and predictive analytics are rapidly finding new applications (weather forecasts, land cover and land use mapping, for instance.) Nonetheless, there is a pattern where these technologies are still only applied to individual problems, where validation is lacking, or where usability is not fully conceptualized or applied. Modeling flood hydrodynamics has advanced to a great degree, yet there remains no high-resolution operational model in coastal Virginia, and modeling of impacts lacks comparable resolution of built environment data (e.g., building first floor elevations, mapping culverts and ditches) to allow robust impact assessment.

Another systemic limitation was identified in the need for technology for **data standardization** and interoperability to promote situational awareness in disasters or allow big picture synthesis for long-range planning. It remains a challenge to collect disparate data from municipalities (e.g., GIS, tax parcels), yet the artificial intelligence could be used to train or cross-walk databases. Technology management and professional practice may "leap frog" into a new, interoperable framework with leadership from the state or collaborative research projects. Archival database examples show some success at allowing data mining (e.g., thesis and dissertation databases) and, eventually, become widely adopted and de facto standard.

Enabling Action: This roundtable discussion focused on several evolving technologies to enable decision-making at multiple time and spatial scales and ranging from individuals to communities. **Access to technology** is itself a concern as evidenced by variable access to cellular data, Wi-Fi, and mobile computing platforms. **Warnings** (e.g., for flooding) can be easily delivered through software, yet the transmission and reception of messaging is variable. Existing mechanisms seem not to be working. Some examples are too new to be clearly evaluated (e.g., "*Know Your Zone*" hurricane evacuation zones.) In addition, there are numerous equity issues in information access that call for social science and risk communication knowledge to improve the messaging strategies. Technology for **web and mobile application development** has also rapidly matured, allowing two-way flow, crowd-sourcing, and educational value. We can show people where flooding is and will occur. However, some major needs remain for **integration** (e.g., Virginia continues to have an antiquated IFLOWS platform of stream sensors that are not connected to hydrologic models, not linked to weather forecasts, and lack a modern web platform and communication framework.) A pilot project that could link IFLOWS to forecasting and warning systems may be a first step, including assessment of communications and accessibility (possibly modeled after the NC Flood Information Management Network and Flood Risk Information System).



Our roundtable also identified several strong research opportunities for development and application of technology to support implementation of coastal planning and sustaining necessary archival and longitudinal data for research and adaptive planning and management. Some of these advances could be transferable outside the coastal zone. Societal problem-solving technologies require integration across academia, public, and private sectors, as well as citizens and non-governmental organizations. On the one hand, entrepreneurial efforts such as "Solve-A-Thons" targeting businesses are developing such technologies, yet they tend to be restricted or biased to only market-based solutions. To improve their impactfulness and relevance, these technologies may be complemented by research that enables stakeholders' engagement and collective action (e.g., participatory GIS.) Some examples of hybrid technology applications still under development include *WAZE* for traffic routing and flood avoidance, and the *Sea Level Rise App* by Wetlands Watch. These individual decision support systems could be further integrated and enhanced, or replicated for other climate-sensitive hazards or planning information. Other processes that may be achievable with new technology include gamifying the

Chesapeake Bay and coastal zone for problem-solving or creating decision support tools that are iterative or enmeshed in public governance processes (e.g., local planning.)

The research needs or near-term projects for actionable science that may be improved by technology include:
1) Assessment of accessibility and communication quality of disseminated information and messages;
2) Inventory of research projects that are generating data and information in the coastal zone; and
3) Promoting the design phase and user-considerations in new technology platforms and systems (e.g., risk communication, user experience, and social and cultural dimensions; sunsetting project technology; archival data; and generally, stronger data management plans.)

2.3. Socio-ecological systems

Lead authors: Tom Crawford (VT) and Molly Mitchell (VIMS)

Key issues identified in socio-ecological systems fell into two broad categories. First, there is a need to embrace the idea that humans and ecological systems are part of a single ecosystem and that there is continuous feedback between social and ecological systems on many scales. This issue is complicated by the fact that both parts of the ecosystem trend in non-linear ways; altering the feedback processes over time. Second, communication between scientists and decision-makers about these feedbacks are hampered by a lack of trust and general knowledge of the issues.

In both our educational systems and our job sector structure, we tend to silo nature, urbanization and engineering, suggesting they are discrete and not overlapping interests. Even when using nature-based features for coastal resilience (such as coastal marsh creation or urban rain gardens), there is a tendency to approach these as engineered features that mimic a function of their natural counterparts (e.g., wave reduction). This is in contrast to restoration science which approaches marsh creation with the goal of recreating the entire ecological system. There is a need to bring these two practices together to achieve truly sustainable and ecologically connected systems. This will require attitude and behavioral changes on many institutional and societal levels.

A key barrier to communication is the widespread belief that processes and feedbacks within the ecological systems are typically static. However, these processes are naturally dynamic, altering when thresholds are crossed. Therefore, it is critical that the natural dynamics and the human-related changes are both communicated to decision-makers on all levels. Without a clear communication of those trajectories, it is difficult for decision-makers to accurately assess the risk levels and their risk perceptions may be highly individual, reflecting their personal beliefs and background knowledge. Successful communication is also hampered by a lack of trust in the communicators or the originators of the message. Trust issues include the idea that someone is trying to control the conversation for political gain (e.g., not being transparent about the scale of impact) or lack of understanding regarding how the research process works (e.g., believing that the science is inconclusive or preliminary). Trust issues can be exacerbated when data are limited, available mostly in technical or scientific jargon, and/or difficult for the public/decision-makers to examine on their own.

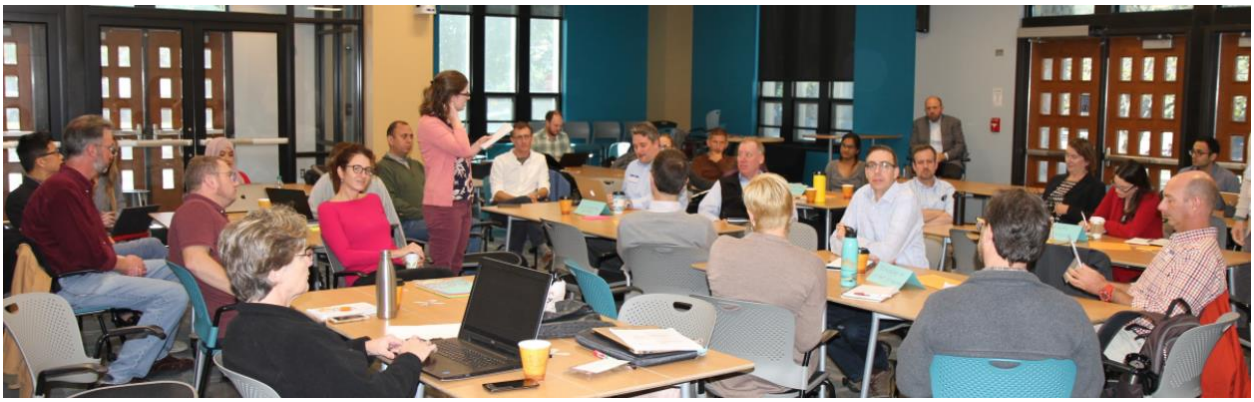
Other issues the roundtable discussion identified are related to the functioning of the socio-ecological interactions. These include poor water quality (due to human land use practices), fish stock depletion (due to human fishing pressures), loss of marshes (due to human desire to protect property) and non-

point pollution (due to numerous human activities). These anthropogenically-driven trends interact with climate-driven ecological trends (e.g., marsh drowning under the sea level rise), putting additional pressures on both the natural systems, by changing their composition, and on the human system, by diminishing ecosystem services that humans rely on. The search for solutions to these issues can lead to its own problems. The community rating system (CRS) is a program that incentivizes certain shoreline management actions expected to reduce flood impacts. Its emphasis on natural landscapes can benefit the ecological condition and connectivity of a coastal area. However, there are many beneficial actions that do not qualify for CRS credit and may be overlooked as solutions if they have less direct economic benefits. Aquaculture is seen as having both economic and ecological benefits, and therefore is considered a viable solution to both the loss of the waterfront economy culture and declining water quality. However, there are use conflicts between the aquaculture and other fisheries, shallow water recreation, and property owner aesthetics.

In some cases, additional research is needed to address these issues, such as case studies on risk perception and how communication, education or outreach can improve individual risk perception; how socio-economic systems are shifting on a variety of scales, from cities to regions; and what are the critical social issues and how are they distributed across the landscape. Barriers to answering these questions are a lack of funding for the research and a lack of political will to prioritize these issues. As a first step to address these research gaps, a workshop to assess the current state of the science could be convened. This workshop should be multidisciplinary and focus on the integration of social and ecological perspectives in responding to these issues.

Specific research questions that should be addressed are:

- How are natural processes that affect marshes changing and what are the impacts of that change on both the resource and the ecosystem services it provides to shoreline communities?
- How are traditional fishing communities changing and what are the social and economic shifts resulting from that change?
- Can we use resource/conservation trading to reduce the economic burden of these activities while still reaping the ecological benefits of the action? If yes, what is the reasonable scale across which these trades can be made?
- Which aspects of climate-change driven changes to ecological systems can we model and reasonably project into the future?



2.4. Community resilience

Lead authors: Chris Neale, Jenny Roe (UVA) & Todd Schenk (VT)

Resilience efforts have traditionally focused on the *preparedness* and *mitigation of apparent vulnerability* to adverse events, whether man-made or natural disasters. The emphasis has been on maintaining *equilibrium* through events like flooding, bouncing back rather than bouncing beyond. This roundtable discussion afforded an opportunity to explore stakeholder perspectives on what constitutes *community resilience* within the context of coastal flooding in Virginia, and how such a concept can be usefully operationalized and measured to support these communities in working towards resilient futures.

Understanding community resilience in the context. First, the panel discussed the meaning of community resilience and what is an appropriate scale to study it in any given coastal community. Some of the key questions that emerged include: What constitutes 'the community' (e.g., different socioeconomic groups)? Is there (extreme) variance between neighborhoods and differential capacities to be resilient? Are there any environmental and health equity issues? Are some community members at greater risk of flooding due to their age, gender, ethnicity or home status? Is the residential makeup of each neighborhood in dynamic flux or stable? The socioeconomic factors influence the level of resilience within a community and how it endures, adapts, and bounces back from extreme events related to sea level rise. They may also shape the appropriateness of resilience (i.e., 'bouncing back') as a goal, rather than working towards a fundamentally different future.

Discussion on rural versus urban contexts at the roundtable suggested that rural areas may be more resilient since they are inhabited by populations that are typically more independent and self-sufficient than those in urban environments; however, more research is required to confirm this argument. A related question is: What is the relationship between individual versus collective control and efficacy in building resilience? While rural areas may generally contain more self-sufficient populations, it is not clear under what circumstances co-dependency with communities can be a strength or a weakness. Yet another important consideration is the sense of interdependency and responsibility communities feel towards each other. In a time of crisis, do communities feel motivated to help each other? In a 'flee' scenario, urban communities may migrate to rural areas, in turn changing the social dynamics of the receiving rural communities.

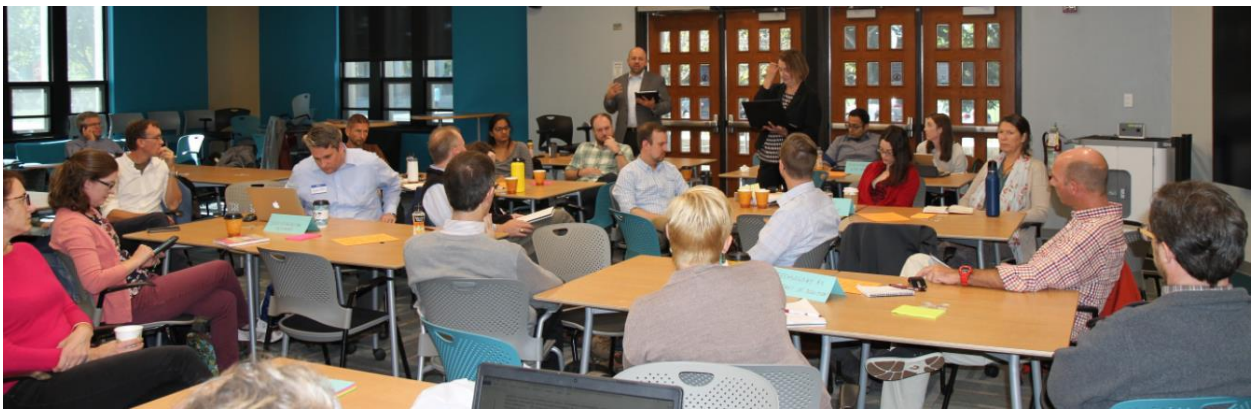
Community engagement: A second critical component to fostering sustained resilience is engaging community members in deliberations. Community engagement is shaped by real and perceived agency at the structural level (e.g., governance and government bodies), the collective level (e.g., voice in the community, shared assets), the individual level (e.g., household decision making, self-assets), and the interplay across those three levels. Given the sometimes-contentious proposals made to advance resilience, significant uncertainties involved, and fact that proposals will often generate winners and losers, engaging communities is integral. Best practices in collaborative governance can be employed to facilitate genuine engagement that helps communities to arrive at effective and broadly supported resilience strategies. For example, 'joint fact-finding' methodologies can be helpful when communities are grappling with contested scientific and technical information.

Lack of stability in political leadership often results in short-term governance strategies designed to generate immediate success and short-term benefits. Nurturing strong community leaders with longer term visions and strategic thinking might help ameliorate this dynamic. Stakeholders also identified a

need for more effective messaging and communication of the risks associated with sea level rise, and strategies for mitigating. A key question is how researchers and/or policy-makers can best engage with communities to inform them of the objective risks to their health, property and well-being? How can these messages better resonate as issues in communities' own 'back yards'? Are particular communities more amenable to certain types of messaging? Are there communities who are happy to 'do nothing', and if so, what are the reasons for taking this position?

Operationalizing community resilience: The third factor to consider is *how* to operationalize and measure community resilience. What level of resilience and interconnection is needed within a given community in order to optimally cope and adapt to sea level rise related issues? Researchers might consider the information and communication infrastructure (both social and technological) that underpins this. It does appear that there may need to be clarity between 'resilience' and mere 'sustainability' and understanding what the differences mean to communities.

Finally, there is interest in understanding if the inclusion of smart designed structures, engineered to reduce the impacts of sea level rise can increase community resilience. Coastal infrastructure has traditionally been 'grey'/built (e.g. bulkheads); how might more innovative green hybrid structures (e.g. living shorelines) support physical (functional) resilience alongside offering recreational opportunities and help create community resilience and health and wellbeing (e.g. the sense of place attachment/identity, community belonging and cohesion that arise from interactions in parks/open spaces).



2.5. Should we stay or should we go?

Lead authors: Anamaria Bukvic (VT) & Sarah Stafford (W&M)

Protection, accommodation, and retreat have been recognized as a key adaptation option for coastal communities with retreat being increasingly proposed as viable strategy for some high-risk hotspots along the U.S. East Coast. The roundtable discussion on retreat recognized that different communities and residents will respond differently to the possibility of relocation due to accelerated coastal hazards such as sea level rise, erosion, repetitive storm surge flooding, and environmental degradation. Residents in some locations will likely have stronger attachments to the place, particularly if their families have been there for generations or their livelihood depends on the coastal ecosystem. Additional considerations that may serve as indirect drivers of gradual and spontaneous retreat are increases in insurance rates, shifts in community character, and broader social changes (i.e., younger

generations having different housing and employment preferences). Discussion participants also noted the lack of knowledge about the factors that may prompt people to consider relocation. There is a need for rigorous cost-benefit analyses on both the household and municipal level to understand when it will become too expensive for people to continue living in high-risk coastal areas given the costs of maintaining infrastructure and services for them. Roundtable discussion stressed the importance of understanding the willingness of people to invest in flood prevention and protective upgrades versus relocating, either from primary data (e.g., surveys and interviews) or secondary information like building permits and real-estate transactions.

Recent voluntary buyout and relocation/resettlement projects (e.g., villages in Alaska and Louisiana and neighborhoods in New Jersey and New York) have set the foundation for the future relocation programs and highlighted some of its disadvantages such as: disproportionate impacts on low income communities; formation of empty spaces throughout the community after random buyout of individual properties; increased cost of service provision for the remaining parcels for municipality; lower income and property taxes; and increased maintenance and security costs for land converted to publicly ownership. Participants also discussed the relocation process itself and the equity of existing policies and programs, especially for vulnerable populations such as minority, low-income, ethnic, older, rural, and other subpopulations that may need different approaches and incentives. They also noted it would be important to identify potential partners in this process who would ensure that relocation unfolds equitably with minimal social costs (e.g., non-governmental organizations and private sector). Some innovation for relocation may be possible via new partnerships between industry and public sector, such as smart urban designs, Transfer of Development Rights (TDR) and other economic incentives that would facilitate gradual transition further inland or toward the higher ground. For example, elevation-based zoning is already included in the City of Norfolk's new zoning ordinance as a part of innovative flood-control provisions such as freeboard, coastal and upland resilience overlays, and resilience quotient system. There is also an opportunity for advanced urban planning - how to repurpose the relinquished land into spaces that can still bring some economic or social benefits for the municipality while facilitating higher densities in safer locations. Among other potential mechanisms to support relocation, roundtable participants proposed voluntary legal agreements similar to conservation easements where developers may acquire properties in low-lying areas for conservation while gaining tax benefits to build on the higher ground.

Roundtable participants also emphasized that relocation is not only about resources and property values, but also about people and communities, social capital and social cohesion, culture, history, and values. There are still many research gaps related to the following questions of social costs and mutual benefits of relocation such as: How do social aspects relate to economic opportunities, workforce profile, security, and environmental services? How do other socioeconomic and demographic changes in communities and neighborhoods affect the risk and willingness of residents to consider relocation (e.g., local employment opportunities, incentives like access to public transportation and community services, and willingness of others in community to cope with flooding before they start considering retreat)?

Although much scholarship on retreat has been added to the literature following recent major disasters like Katrina and Sandy, discussants recognized that decision-makers need more empirical evidence and data about the effectiveness of relocation efforts and its long-term outcomes before considering this strategy for Virginia localities. In particular, we need more information on disaster displacement and reason why some displaced individuals return and rebuild while others relocate permanently. The roundtable participants also recognized that international case studies related to managed and planned relocation can provide the insights about tested best practices for relocation and identify which

approaches may be applied in Virginia given our legal and policy context. The relocation knowledge base would also benefit from more refined methodologies that provide timely and accurate ways of tracking people and the outcomes as they relocate in response to recurrent flooding, major disaster events, and coastal policy changes.

Roundtable participants also identified the lack of disclosure agreements during the real-estate transactions and inadequate transparency related to past flood damages and claims as one of the main obstacles to informed relocation decision-making. Even though it is federally mandated for the new homeowners to learn that their property is in the floodplain and enroll in flood insurance, real-estate agents and sellers are not obligated to disclose the instances of previous flooding that may indicate the actual risk. The panel noted that we need policy change that will prevent the vicious circle in which property owners who found out about flood claims resell their property again without the disclosure to the next buyer. This also opens the market for real-estate speculators and leaves housing market prone to manipulation without consideration for the prospective buyers who may end up carrying both financial and psychological cost of homeownership in a flood-prone area.

3. ROLE OF UNIVERSITIES IN VIRGINIA'S RESILIENCE

In the final workshop activity, participants were asked to think about the role of universities in improving resilience research, education, and outreach and provide the key actionable items that were displayed on the whiteboard. Each participant was then given five votes to prioritize the action or actions they felt were the most important for the universities to pursue. Similar items were combined into a single action and votes were applicable across all categories of research, education, and outreach.

3.1. Research

Lead authors: Brian Badgley, Luke Juran (Virginia Tech) & Ben McFarlane (HRPDC)

Participants unanimously agreed that significant information barriers to coastal resiliency are present. These include a need for increased collection and sharing of information, and improved ability to understand primary processes that are driving changes in coastal environments and to predict outcomes of management options. A variety of research needs were generated during the brainstorming session, and participants identified needs that were of highest priority from their own disciplinary and professional perspective. Research areas that were most highly ranked are summarized below.

Collaborating to Understand Complex Systems
The two research needs designated as highest priority were related to the fact that coastal regions, and the challenges they face, are complex in nature with a variety of interacting ecological and human components. Although the trend towards interdisciplinary research is common across science, the need is particularly great when addressing challenges related to coastal resiliency and global change. In addition to multiple disciplines within the natural sciences, future research must better integrate understandings of human dimensions by fostering collaboration with social science disciplines such as economics, sociology, geography, communication, and political science. Additionally, expertise in research at multiple scales - including temporal, spatial, and system complexity - are required to identify factors that have the greatest impacts on resilience and thus are most beneficial to manage.

Flood Protection
Protection from floods was also identified as a critical research area. The physical flood risk represents

one of the most immediate and pressing challenges in coastal areas. A variety of opportunities exist to develop improved resilience strategies to mitigate coastal flooding that require additional research to implement effectively. These include improved materials for flood proofing of structures, improved tracking of relocation trends, updated policies on retrofitting and rebuilding, and economic drivers of structural adaptation.

Managing Ecological Impacts

In addition to flood protection, coastal regions are confronting a variety of water quality and ecosystem health impacts that have potential to affect public health, fisheries, recreation, property values and ecosystem services broadly. In addition to global change factors, increasing urbanization and aging urban infrastructure are exacerbating these challenges. Given the wide variety of these threats, and the rate of change, it is not currently clear which ecological shifts are still reversible, or at least manageable, and which will require adaptation. Application of a system-level perspective (described above) should strive to identify management interventions that have the most benefit for coastal resilience. Additionally, many best management practices (BMPs) targeting water quality and ecosystem health have only been evaluated at the plot scale. Now that BMPs are being widely implemented, objective research and meta-analyses to determine their actual outcomes at larger scales and over longer time frames are required to guide future investments.

Applied, Actionable Science that Engages Citizens

Multiple participants identified the need for future research to result in direct, actionable outcomes that are relevant to community needs. While basic research is critical, the time constraints placed on coastal regions require that knowledge is translated into policy and management as quickly as possible. Related to this aspect, research should move out of the "ivory tower" and be co-designed from the ground-up by engaging with citizens and policy makers, rather than only conducting outreach after the fact. This approach also requires new methods to communicate complex information to non-scientific and non-technical audiences.

3.2. Education

Lead authors: Christopher Zobel (VT) and Michelle Covi (ODU)

Train the next generation to work in interdisciplinary space

The item that emerged as the most important activity in the education category was training the next generation to work across or with other disciplines, namely by taking comprehensive interdisciplinary coursework. This implies that degrees should actively integrate different disciplines and their perspectives throughout the educational experience. Both faculty and students should be trained to operate in interdisciplinary spaces. For faculty, this could be achieved via targeted cluster hires to focus on training in this space. Students can be encouraged to enroll in broad-based interdisciplinary majors. It would be also important to find best practices and well-tested approaches for keeping the depth of student education while also expanding the breadth. Participants also suggested students should participate in interdisciplinary projects as a problem-based learning pedagogy that introduces new skills and methods across a broad array of disciplines.

Educational engagement with communities

The activity that was identified as a second most important by participants was the development of "Collaboratories" to support engagement of faculty and students in community-based projects beyond the static case study approach. For example, collaborative interdisciplinary design projects would have

different disciplines establishing a common language and collaborating more actively with practitioners on community-based problems outside of the classroom. Thus, in addition to learning to work in an interdisciplinary academic space, students would also gain substantive experience in bridging the gap between academia and practice.

Science communication
The importance of understanding science and science communication as an educational skill was also emphasized by this group. Participants thought that every student should learn science communication and how to use and interpret data through statistics and other analytical methods. They also suggested that students should be trained in the science-policy interface as effective translators of science for policy-making.

New tools for teaching
Participants suggested a several ways to improve education by applying new teaching tools and methods beyond those mentioned above. They recommended active learning, virtual reality and modern technology as potentially effective educational tools. Student workshops on resilience, boot camps, and certificates to support professional development in the resilience sector were suggested as venues that might allow interdisciplinary, community-engaged education. 4VA grants and other collaborations across Virginia universities are programs that were also noted as valuable to this effort.

3.3. Outreach

Lead authors: Michelle Covi (ODU) & Ashley Gordon (HRPDC)

Engage and empower stakeholders
The items that received the most votes from participants were related to the recommendation that universities engage stakeholders at all stages of research projects. With the explicit goal to inform public decision-making, researchers should actively seek out underrepresented communities when proposing new research and delivering findings. University outreach should empower stakeholders and encourage stakeholder participation through research, products, and activities that apply knowledge and funding to help people.

Advocate for science-based policy
Universities have traditionally conducted outreach activities through educational programming and community engagement. Participants believed that universities should go beyond informing and instead advocate for integrating recent research into policy making. A similar suggestion grouped with this idea was that universities could develop a “road show” targeted at elected government officials as a mechanism to advocate for science-based policies. To facilitate the usefulness of research, results should be accessible to decision-makers through tailored products that are widely disseminated. Research findings should be delivered directly to the end-users through accessible formats such as presentations, summary documents, fact sheets, etc.

Outreach to underrepresented communities
Working with underrepresented communities and addressing issues related to environmental justice were also highly valued by the participants. The participants felt that research and/or education work with communities with fewer resources should be incentivized through grants or special programs.

K-12 programs

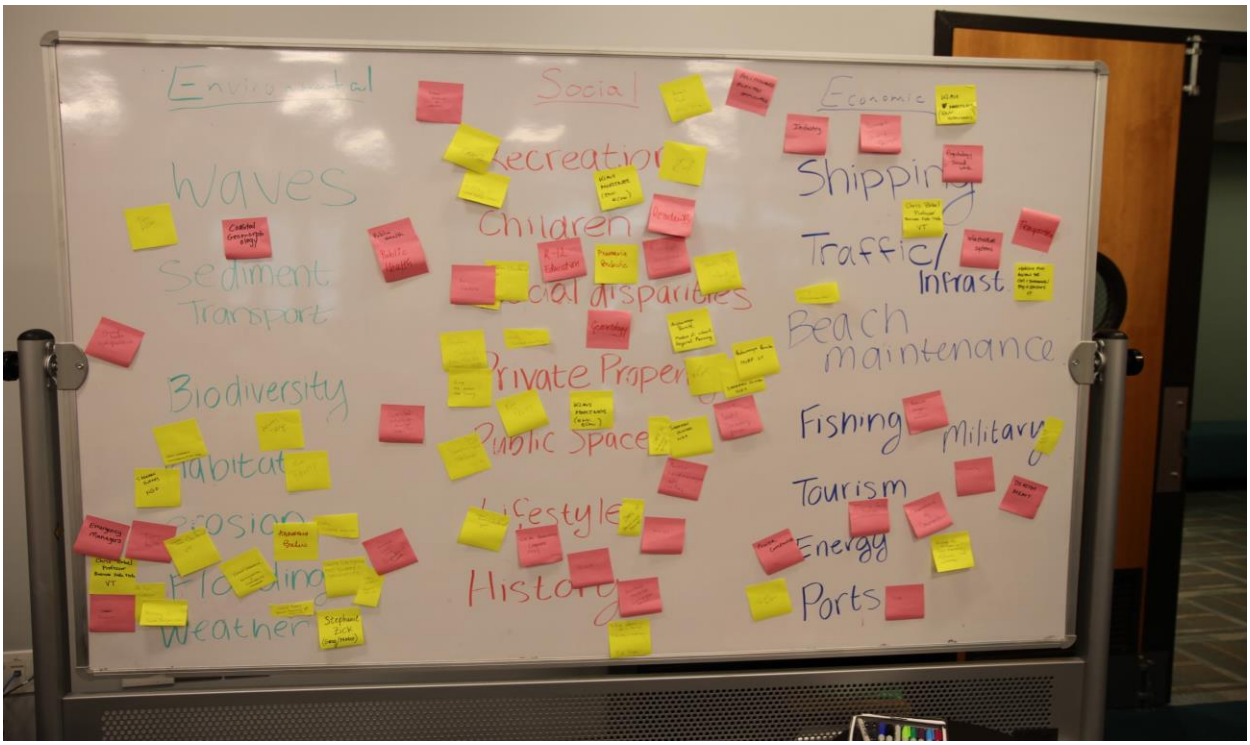
Resilience education should begin at a very early age (K-12 programs). To accomplish this, we need to train future teachers and also train undergraduate and graduate students to go into K-12 schools to educate youth. We need to add resilience ideas into K-12 programs.

Citizen science

Citizen scientists need to be valued and included in research beyond their role in collecting data. Citizen Science programs, apps, and activities that engage communities should be used to inform individuals of project results and outcomes

4. CONCLUSIONS

Even though the 2019 Rotating Resilience Roundtable event was designed to gather a smaller targeted audience to allow for small-group in-depth discussions, the first activity (see photo below) highlighted the lack of representation in some disciplines and stakeholder groups that may have a meaningful role in the Virginia's resilience. Namely, roundtables participants suggested that the following groups are important actors in this dialogue and should be included in resilience planning: utility companies; public land managers; community groups; historians, archeologists, maritime experts; tourism sector; chambers of commerce; military; emergency/disaster management; businesses and private sector/industry; elected officials and politicians; psychologists, social workers; experts from infrastructure/transportation sector; gerontology; residents; marginalized/underrepresented populations; K-12 education; artists; civil engineering/hydrological modelers; local community leaders; religions leaders; coastal environmental and public health researchers and practitioners; state agency leaders; geomorphologists; and groundwater hydrologists.



This exercise emphasized the important role of a diverse range of stakeholders in Virginia's resilience who can contribute to resilience efforts by providing traditional knowledge, professional expertise, as well as a different perspective on the pressing issues of coastal flooding in the State. It is important to establish active communication between different stakeholder groups to better understand the potential for cascading events across different private and public sectors and for community thresholds that could undermine the resilience efforts. Moreover, to build resilient coastal communities, it is important to leverage the existing local capacities and strengthen them by supporting the opportunities for self-organization, creativity and innovation, and new partnerships. This bottom-up approach may remove some of the redundancies and conflicting procedures in the community while building on existing strengths in alignment with community values and norms. Holistic stakeholder representation in resilience deliberations, consistent with the whole-of-community approach to building resilience, will ensure that all parties engage in transformative learning and converge on solutions that will be mutually acceptable and beneficial for all Hampton Roads populations.

As for the science, there already exist well-defined models, hazards exposure, and risk information, and more granular and sophisticated impact projections are emerging by the day. What is needed at this point are ways to translate this science into cost-effective and sustainable resilience strategies that will be compatible with the local context of diverse Hampton Roads communities. Building trust among all stakeholders vested in the state's coastal issues will allow for better data sharing and improved access to targeted populations which can be achieved by engaging local partners in all stages of the research process. In addition to co-production of knowledge, it is equally important to learn from different professional perspectives about what may or may not work in Virginia's coastal zone considering local context.

Another item that emerged as important is inclusion of uncertainty in dialogue on resilience, supported by everyday examples on how individuals, households, and localities deal with uncertainty on a daily basis, to remove the stigma associated with it and to shift focus on the importance of adaptive governance and flexible institutional decision-making. Further, more clarity is needed on who may be responsible and accountable to allow people to live in certain areas. Preemptive discussion with public and private entities on how circumstances are changing in coastal environments may help deal with people's confidence and expectations of the status quo and facilitate their collective engagement with resilience planning. Acknowledging changes in flood patterns and impacts can result in bottom-up innovation and prompt communities to think outside the box to find resilience strategies that will fit their resource availability, development goals, and cultural and historic norms. And lastly, coastal flooding is not an isolated problem that will affect only certain places but will more likely have far reaching impacts on Virginia's economy, society, and demographic profile. Therefore, cooperation among localities who are facing the same problem of accelerating coastal hazards and are at the forefront of adaptation and those who will be indirectly affected by changes in coastal zone will be vital to achieve a resilient Virginia. The 2019 Rotating Roundtable Resilience event represents a first effort to build the intellectual capacity to better understand the issues and resources our state has at institutions of higher education and other organizations to work together in cooperation and synergy to generate the state of the art science that will inform the state resilience planning.

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