Tidal wetland resilience to increased rates of sea level rise in the Chesapeake Bay: Introduction to the Special Feature

Taryn A. Sudol[1], Gregory B. Noe[2], and Denise J. Reed[3]

[1] Chesapeake Bay Sentinel Site Cooperative, Maryland Sea Grant, College Park, MD 20740, USA

[2] Florence Bascom Geoscience Center, U.S. Geological Survey, Reston, VA 20192, USA

[3] Pontchartrain Institute for Environmental Sciences, University of New Orleans, New Orleans LA 70148, USA

Corresponding Author: Taryn A. Sudol, sudol@mdsg.umd.edu**,** phone 301-405-6378

Abstract

The papers in this Special Feature are the result of the first Marsh Resilience Summit in the Chesapeake Bay region, which occurred in February 2019. The Chesapeake Bay region has one of the highest rates of relative sea level rise in the U.S., jeopardizing over 1000 km^2 of tidal wetlands along with other coastal lands. The goal of the Summit and this collection of articles is to analyze tidal wetland response to accelerating sea level rise and the effect their response will have on adaptation planning for surrounding communities. Ten Summit presenters share their research in this Special Feature. In this Introduction, we summarize their findings on evaluating restoration potential at the site-specific level, measuring and projecting marsh migration and erosions rates, describing impacts of wetland migration on a marsh dependent animal, effects on human communities, and finally the roles of property owners and government on future tidal wetland extent. These contributions demonstrate that tidal marsh distribution is dynamic in response to sea level rise, and that social, legal, and policy tools can be used and further developed to enable opportunities for restoring or conserving wetlands when stakeholders are engaged effectively. The papers here and feedback from Summit participants illuminate diverse priorities, research unknowns, and next steps for land use planning toward resilience of the Chesapeake Bay region that also can inform global communities.

Key words: Tidal wetland, sea level rise, Chesapeake Bay, coastal resilience

Background:

The Chesapeake Bay, the nation's largest estuary, experiences one of the highest rates of sea level rise in the U.S. (Boon & Mitchell 2015). Virginia and Maryland's coastal areas (including the Atlantic coast) contain urban centers, ports, military infrastructure, NASA facilities, rural towns, agricultural lands, wildlife refuges, and historical sites, as well as over 1,000 km^2 of tidal wetlands (Chesapeake Bay Program 2010, CCRM 2017), all of which are vulnerable to accelerating rates of relative sea level rise. There is considerable scientific uncertainty of the dynamic nature, complex feedbacks, and prediction of the future status of tidal wetlands in response to relative sea level rise. This generates confusion and provides little guidance for Bay coastal communities that are choosing options for adapting to climate change.

Tidal wetlands' current viability and future adaptability is at the intersection of multiple ecological processes and societal motivations such as how to maintain their elevation against relative sea level rise (Kirwan & Megonigal 2013, Kirwan et al. 2016) or the ability to and associated impacts of gradually shifting landward with the extension of tidal flooding (i.e., "marsh migration") (Feagin et al. 2010). The persistence of tidal wetlands can provide valuable ecosystem services to communities such as erosion mitigation, wildlife habitat and recreation value, nutrient uptake, and improved water quality (Costanza et al. 2008, Barbier et al. 2011, Shepard et al. 2011). Yet wetland survival via upland or upriver migration comes at cost of other land uses such as upland forests, nontidal wetlands, silviculture, agricultural lands, or coastal communities with their own ecosystem services and societal value (Ensign & Noe 2018, Gedan & Fernández‐Pascual 2019, Kirwan & Gedan 2019). Understanding which marshes are more

vulnerable, consequences of wetland loss or migration, and where restoration potential exists in the context of competing land uses requires consideration of an array of issues and engagement from a variety of stakeholders. Scientists, land managers, conservation groups, state regulators, town planners, agriculturalists, foresters, educators, and concerned citizenry all have stakes and insights into the future of tidal wetlands in the Chesapeake Bay region.

The Chesapeake Bay Sentinel Site Cooperative (CBSSC) hosted the inaugural Marsh Resilience Summit in Williamsburg, Virginia, on February 5-6, 2019, to discuss the future of tidal wetlands in the Chesapeake Bay. Over 200 professionals representing 115 different agencies attended, including academics, land managers, regulators, and communication professionals (Maryland Sea Grant 2019). This Special Feature reports on research from some of the presenters and reflects the range of resiliency issues discussed at the Summit. Many of the issues identified and lessons learned from Chesapeake Bay apply to other marshes and coastal communities as well.

Overview of the Special Feature

This Special Feature delves into the multifaceted components of tidal wetland response to increased rates of relative sea level rise in the Chesapeake Bay region (including the Atlantic coast of Maryland and Virginia). Articles in this Special Feature begin with a focus on evaluating marsh resilience to restoration actions (Cornwell et al. 2020, Staver et al. 2020), measuring recent change in marsh migration and erosion (Flester and Blum 2020, Gedan et al. 2020), projecting future marsh migration and loss with future sea level rise (Mitchell et al. 2020), and impacts on a marsh dependent animal (Isdell et al. 2020). It further investigates how these marsh

changes may affect human communities and the role private and public property owners play in tidal wetland management; this includes an evaluation of best management practices to protect shoreline (Stafford and Guthrie 2020), and legal, policy, and social considerations to enable adaptation to sea level rise (Andrews 2020, Spidalieri 2020, Van Dolah et al. 2020).

Evaluating marsh resilience to restoration actions

Two paired articles discuss marsh restoration at the Paul S. Sarbanes Ecosystem Restoration Project at Poplar Island in the Chesapeake Bay. Cornwell et al. (2020) assess the chemistry of fine-grained dredge material used for Poplar marsh restoration where dredged material from the channel is mixed with bay water, then placed and dried before reworking in preparation for planting. They note the importance of the drying process itself to chemical changes in the sediment, and observe high ammonium and iron-associated phosphorus content. The processing of material at Poplar results in soils that are nutrient-rich, have an appropriate pH, and are suitable for planting. Staver et al. (2020) demonstrates that with appropriate design, fine-grained dredged material can be used successfully to create tidal marshes that are resilient to the current rate of sea level rise, and are functionally equivalent to natural marshes in terms of carbon sequestration. Fine-grained, nutrient-rich dredged material has promoted a high, but variable, rate of primary production in created tidal marshes at Poplar Island, with macrophytic vegetation showing low root to shoot ratios in the early years of development. Elevation change, measured using surface elevation tables, combined with a carbon budget developed for one of the created marshes, indicates that the rate of vertical accretion is keeping pace with local sea level rise, and that the marsh is sequestering carbon at a rate equivalent to natural marshes in the Mid-Atlantic region.

Measuring recent change in marsh migration and erosion

While Poplar Island provides an example of restoration potential, the present and future state of naturally occurring tidal wetlands throughout the Chesapeake Bay is a question of competing land uses: what is the effect on existing marsh migration of adjacent agriculture, industry, and community resilience? Gedan et al. (2020) focuses on recent land cover transitions of uplands to wetlands and how land-use type affects the probability of change. They investigated recent coastal land cover changes in a county powerfully affected by sea level rise. Low-lying coastal Somerset County, Maryland, saw 6.1 km^2 of uplands transition to wetlands and open water over the course of only eight years. During this time, the county lost 5.7 km^2 of farmland, or 2 percent of the county's agricultural land. More than half of this land transitioned to marsh. When controlling for elevation, agricultural land was more likely to transition to marsh than forested land.

Flester and Blum (2020) investigate how the rates of inland migration and seaside erosion differ between geomorphic marsh type (i.e., headland, valley, and hammock) in Virginia's coastal lagoon system. Marsh geomorphic type will be an important coastal land management consideration when anticipating changes in extent. During a 15-year period, the spatial extent of valley marshes increased more than headland or hammock marsh types. Flester and Blum then extrapolated the rates of marsh migration and edge erosion across the entire Virginia seaside, suggesting the spatial extent of mainland-adjacent marshes increased during the 15-year study but these increases were insufficient to offset marsh losses measured in the coastal lagoon system (i.e., marsh islands within the lagoons and associated with the lagoon-side of the barrier islands).

Thus, the spatial extent of salt marshes within the Virginia coastal lagoon system has decreased since 2002.

Projecting future marsh migration and loss and impacts

Mitchell et al. (2020) shares projections of the future extent of Virginia's estuarine tidal marshes given rising sea levels and geologic and human barriers that prevent tidal marsh expansion. Their study shows that estuarine tidal marshes in the Virginia portion of the Chesapeake are projected to decline by approximately half over the next century; however, patterns of change depend on surrounding land elevations and development strategies. Tidal freshwater marshes, particularly those in the upper reaches of creeks, are at particularly high risk due to a scarcity of retreat pathways. Under increasing sea levels and flooding, the future of tidal marshes will rely heavily on the policy decisions that shape future development and the balance of human and natural landscapes.

Isdell et al. (2020) predict changes in ecosystem system services and the size and functioning of dependent species populations in association with the projections of tidal marsh area presented by Mitchell et al (2020). Specifically, ribbed mussel abundance in 2050 was predicted to be reduced by more than half its population due to a combination of drowning marshes, coastal squeeze, and a shift from higher to lower quality habitat. Mussel losses were greatest along the mainstem of the Chesapeake Bay, with modest gains in the headwaters. The projected mussel abundance reductions result in a greater than 50 percent reduction in mussel-mediated filtration and nitrogen processing, making it more difficult to improve the water quality of the Chesapeake Bay.

Marsh extent and associated ecosystem services may depend on site-specific best management practices, such as homeowners installing living shorelines, as well as larger scale community and governmental efforts. Stafford and Guthrie (2020) provide a case study in Virginia's Gloucester County that used a survey approach to assess homeowners' decision process towards shoreline modification. Properties that are more valuable, are owned longer, or have primary structures closer to the shoreline are more likely to be modified. An estimated 90 percent of the modified shorelines in Gloucester, Virginia, have some sort of armoring in place. While living shorelines are less common, those most likely to install one are primary residents interested in restoring the shoreline and aesthetics. Although other studies have found that a neighbors' modification choice is one of the best predictors of the type of modification that a property owner installs, owners do not cite this as an important factor in their decisions. This suggests that other factors are driving the statistical correlation between neighboring modifications such as shared information networks which independently lead neighbors to make the same modification choice.

Social, legal, and policy influences on marsh resilience

While rural coastal uplands may be ideally situated for wetland migration corridors, the human dimension is often under-considered in wetland migration planning. Drawing upon three case studies from Maryland's Eastern Shore, Van Dolah et al. (2020) discuss key cultural, economic, and political dimensions of rural wetland-dominated landscapes, and highlight important justice issues that can emerge when these factors are under-examined in wetland migration planning. They offer a socio-ecological systems framework as a starting point for identifying

social and ecological imbalances and misalignments that create or perpetuate injustices. They also recommend future research areas to enable wetland migration planning to better support both social and ecological needs in rural coastal places for more fair and robust coastal resilience strategies.

From a state and local government perspective, Spidalieri (2020) describes several tools available for legal and policy planning to facilitate marsh migration. As climate changes and wetlands migrate further inland, state and local policymakers will increasingly be presented with questions about how to conserve and balance migrating ecosystems with existing land uses on privately owned properties. She emphasizes that state and local policymakers should act soon to avoid land use conflicts and that delaying may eliminate some adaptation options. A comprehensive wetland migration strategy must be proactive and bring together the various disciplines and stakeholders (especially at the community level) affected by these decisions. To tackle these difficult questions, comprehensive wetland migration strategies must, at a minimum, involve/account for the following five components: data, planning, voluntary land acquisitions, legal tools (i.e., coastal management and land use and zoning regulations), and community engagement.

Lastly, Andrews (2020) discusses policy challenges intersecting marsh preservation and community resilience, focusing on sample laws and policies in Virginia. For coastal communities that need to consider strategic relocation, there is an opportunity to convert the abandoned areas to wetlands and marshes, but there must be adequate legal authority and significant public education and input in order for communities to decide to pursue such a course. This requires

extensive investment, yet funding is scarce and public needs such as schools, public safety and transportation compete for limited dollars. Therefore, it is difficult to convince local officials to preserve marshes when the issue is still largely considered a future threat. State and federal dollars are limited as well, but there is hope that the new FEMA funding program, "Building Resilient Infrastructure and Communities" (BRIC), can be used to help fund natural and nature-based features and planning for managed retreat. Ultimately planning efforts should be accompanied with additional legal tools to make plans enforceable. As Andrews notes "we need to plan for the water, before the water takes away our ability to plan."

Marsh Resilience Summit Themes

The Marsh Resilience Summit's presentations, including those described in this Special Feature, and facilitated discussions amongst Summit participants, identified several important themes concerning tidal marsh resilience in the Chesapeake Bay.

1. Integrated, long-term monitoring of marshes is necessary – especially to assess the function of marshes. Summit participants desired more observations to inform land conservation choices and to support predictions of future condition. Participants suggested that funding sources could have more monitoring requirements and that scientists could collaborate to monitor metrics more consistently. Data on restored sites, living shorelines on private property, and migrating marshes are sparse and difficult to obtain, though the included articles by Cornwell, Staver, Stafford and Guthrie, and Gedan et al. begin to address these issues. Research questions are emerging about what migrated marshes will look like and how similar will their ecosystem services or habitat be compared to historic marshes. The answers to these questions can inform land use decisions.

2. Stakeholder collaboration is highly recommended but difficult tradeoffs exist between conflicting priorities. Marsh extent and function have far-reaching impacts among different sectors of the community. Summit participants consistently expressed the value in researchers, local governments, watermen, environmental groups, and community representatives, etc., co-producing projects so that environment and culture are respected. Exploring future land uses in the face of sea level rise will require choices on what to save and what to lose. These choices will most certainly differ among the various stakeholder priorities making inclusive representation all the more important.

3. Underserved communities can be more involved by including them on interdisciplinary teams combined with the use of trusted facilitators. Research and discussion at the Summit suggested how underserved communities feel marginalized even though their hazard mitigation needs and conservation potential may be great. Van Dolah et al.'s research (2020) highlights mechanisms to allow the voices and values of underserved communities to be considered in project development. Different discussion groups repeatedly pointed to the use of trusted facilitators (i.e., extension agents, science translators, community liaisons) to connect science and resilience resources to the communities (and vice versa).

Concluding Thoughts

An environmental treasure, economic engine, and cultural time capsule, the Chesapeake Bay region is many things to many people. A proactive approach amongst scientists and decision-makers helps ensure that the threats of sea level rise are fully recognized and the

response options are carefully evaluated. As articles in this special feature demonstrate, marsh distribution is dynamic in response to sea level rise, allowing for various potential land uses, but inaction and/or neglect of stakeholder costs, benefits, and priorities results in lost opportunities for restoring or conserving tidal wetlands or other coastal land uses. The Marsh Resilience Summit took a significant step to convene a wide-ranging discussion of marsh resilience in the Chesapeake Bay region including research professionals and a variety of stakeholders. By identifying new research, untapped collaboration, and the need for better informed land management and policy, this Special Feature and the Summit have laid a foundation for growing marsh resilience in the Chesapeake Bay. Interest in a second Summit remains high. We believe these messages have relevance for tidal marsh resilience around the world.

Acknowledgements:

One of five cooperatives in the National Oceanic and Atmospheric Administration/National Sea Grant Sentinel Site Program, CBSSC is a regional network of federal, state, and local partners who integrate science findings from local observations to improve planning and management decisions regarding sea level rise and ecological changes (www.chesapebayssc.org). The CBSSC launched the Marsh Resilience Summit with significant support from Maryland Sea Grant as well as other sponsors. The CBSSC would like to thank the Marsh Resilience Summit's steering committee, sponsors, and contributing authors as well as all Summit presenters and attendees for their support. We also would like to thank the journal reviewers and editors.

Declarations

Funding: Maryland Sea Grant, U.S. Geological Survey

Conflicts of interest/Competing interests: None

Ethics approval: Not applicable

Consent to participate: Not applicable

Consent for publication: The authors consent to this manuscript's publication

Availability of data and material: Not applicable

Code availability: Not applicable

Authors' contributions: TAS led the Marsh Resilience Summit and the writing of the manuscript, and GBN and DJR co-edited the Special Feature and contributed to the writing.

References (citations to the 10 papers in the Special Feature to be added when complete):

Andrews, EA (2020) Legal and policy challenges for future marsh preservation in the Chesapeake Bay region.

Cornwell, JC, Owens, MS, Staver, LW, Stevenson, JC (2020) Tidal marsh restoration at Poplar Island I: transformation of estuarine sediments into marsh soils.

Flester, JA, Blum, LK (2020) Rates of mainland marsh migration into uplands and seaward edge erosion are explained by geomorphic type of salt marsh in Virginia coastal lagoons.

Gedan, KB, Epanchin-Niell, R, Qi, M (2020) Rapid land cover change in a submerging coastal county.

Isdell, RE, Bilkovic, DM, Hershner, C (2020) Large projected population loss of a salt marsh bivalve (*Geukensia demissa*) from sea level rise.

Mitchell , M, Herman, J, Hershner, C (2020) Evolution of tidal marsh distribution under accelerating sea level rise.

Spidalieri, K (2020) Where the wetlands are—and where they are going: legal and policy tools for facilitating coastal ecosystem migration in response to sea-level rise.

Stafford, S, Guthrie, G (2020) What drives property owners to modify their shorelines? A case study of Gloucester County, Virginia.

Staver, LW, Stevenson, JC, Cornwell, JC, Nidzieko, N, Staver, KW, Owens, MS, Logan, L, Kim, C, Malkin, S (2020) Tidal marsh restoration at Poplar Island: II. elevation trends, vegetation development, and carbon dynamics.

Van Dolah, ER, Miller Hesed, CD, Paolisso, M. (2020) Marsh migration, climate change, and coastal resilience: human dimensions considerations for a fair path forward.

Barbier, EB, Hacker, SD, Kennedy, C, Koch, EW, Stier, AC, Silliman, BR
(2011) The value of estuarine and coastal ecosystem services. Ecological Monographs 81:169–193

Boon, JD, Mitchell, M (2015) Nonlinear change in sea level observed at North American tide stations. Journal of Coastal Research, 31:1295-1305.

CCRM [Center for Coastal Resources Management] Digital Tidal Marsh Inventory Series (2017) Comprehensive Coastal Inventory Program, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia, 23062

Chesapeake Bay Program (2010) https://www.chesapeakebay.net/state/wetlands Date last accessed October 12, 2020

Costanza, R, Pérez-Maqueo, O, Martinez, ML, Sutton, P, Anderson, SJ, Mulder, K (2008) The value of coastal wetlands for hurricane protection. Ambio: A Journal of the Human Environment 37:241– 248

Ensign, S, Noe, GB (2018) Tidal extension and sea level rise: recommendations for a research agenda. Frontiers in Ecology and the Environment 16:37-43

Feagin, RA, Martinez, ML, Mendoza‐Gonzalez, G, Costanza, R (2010) Salt marsh zonal migration and ecosystem service change in response to global sea level rise: A case study from an urban region, Ecology and Society 15

Gedan, KB, Fernández‐Pascual, E (2019) Salt marsh migration into salinized agricultural fields: a novel assembly of plant communities. Journal of Vegetation Science 30:1007-1016.

Kirwan, ML, Walters, DC, Reay, WG, Carr, JA (2016) Sea level driven marsh expansion in a coupled model of marsh erosion and migration. Geophysical Research Letters 43:4366–4373.

Kirwan, ML, Megonigal, JP (2013) Tidal wetland stability in the face of human impacts and sea‐level rise. Nature 504:53–60

Kirwan, ML, Gedan, KB (2019) Sea-level driven land conversion and the formation of ghost forests. Nature Climate Change 9:450-457

Maryland Sea Grant (MDSG) (2019) Marsh Resilience Summit Proceedings, Williamsburg, Virginia, February 5-6, 2019

Shepard, CC, Crain, CM, Beck, MW (2011) The protective role of coastal marshes: a systematic review and meta-analysis. PLoS One 6:e27374