Examining Local Policy Responses to Changing Hazards in Coastal North Carolina

by

Keith Bollt, Darren Fogarty, and Suzanne Mullins

Dr. Megan Mullin, Adviser

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I. Executive Summary

This study catalogues and examines localized policy responses to changing hazards in coastal North Carolina. As climate change increasingly threatens the globe, North Carolina—with its lengthy coastlines and delicate barrier islands and estuarine systems—stands to suffer greatly from intensifying sea level rise, storms, and other threats. Recent literature shows that it is key to understand how policymakers are responding to hazards on a community scale. Adaptive actions on a local level are particularly important in the climate discussion, given that the most significant impacts are perceived, experienced, and understood on that smaller, more personal scale. Further, local governments in particular hold the most direct responsibility for implementing adaptive solutions tailored to their communities’ specific needs.

Existing research, however, has failed to systematically and comprehensively describe and track local policy action around climate adaptation. This Master's Project seeks to address this gap in the literature. Our project is informed by our adviser and client—Dr. Megan Mullin, Associate Professor of Environmental Politics at Duke University’s Nicholas School of the Environment. Dr. Mullin is on the steering committee for a larger research project: C-CoAST, a Collaboratory for Coastal Adaptation over Space and Time. C-CoAST examines how natural hazard events and subsequent human recovery efforts alter the risks and resilience of communities and ecosystems; in conjunction, they look to determine what policy levers build such resilience.

Our work informs C-CoAST's future efforts, and focuses on three representative North Carolina counties—Dare, Carteret, and New Hanover. We first performed a comprehensive literature review to gain further insight into the role of local governments when developing adaptation policy; we also endeavored to learn which strategies and management practices are most important and/or commonly used in the United States. We further sought to determine if any similarly rigorous cataloguing efforts exist, and as previously noted, found none. From our research, we ascertained that coastline adaptation methods (i.e. beach nourishment, shoreline hardening, nature-based resilience), land use planning & zoning, and septic system management are key areas of focus in the adaptation policy space.

Based on these findings, we compiled a comprehensive index of coastline adaptation, land use planning & zoning, and septic system management policies in the study area. For each policy category, we developed a set of questions, searched gray literature, and catalogued detailed notes and links to provide answers. We then generated a separate, simplified coding catalogue with condensed responses. The intent of these indices is that they will function as stand-alone and accessible policy catalogues to be used by C-CoAST collaborators, as well as researchers, policy-makers, and stakeholders more broadly.

Our project demonstrates that policy responses vary widely, with some localities doing far more than others to prepare for climate-induced coastal change. Many communities are copying state and federal language directly into their planning, which our research suggests is not enough of a response to meet the magnitude of climate-induced threats. In many cases, towns are taking drastically different actions even when compared to other communities in the same county or region. We aim that our catalogue may better foster understanding and cooperation in these scenarios. Every community in our study stands to benefit from studying and building off of the policy action (or inaction) of their respective neighbors.

In addition to exploring overall variation across the research subjects, we perform a brief case study of a particular town, Nags Head, located in Dare County. Nags Head has popularly been known as an innovator in localized adaptive strategies. Though not perfect in its efforts,
Nags Head does stand out across our policy categories as well-positioned to adapt to coastal shifts. Other towns in the region would do well to emulate many of the strategies deployed by the Nags Head community.

Finally, we speculate on potential explanations for variation in observed policy response, and make recommendations for how communities might use our catalogue to improve their individual response to changing coastal hazards. We discuss how variation between communities may be a result of a combination of political ideology, the influence of individuals, socioeconomic factors, location, geomorphology, and geography.

Before this project, no other research has yielded a comprehensive, large-scale database of coastal policy response to climate change. The catalogue yielded by our research is intended to be a touchstone for local policy-innovation initiatives in our study area and beyond; thus, we prescribe to county/town managers and planners how they might utilize our catalogue to improve their communities’ response to climate change. Local decisionmakers in our study area, as well as other coastal regions, can build from our research to collaboratively learn from each other and thus improve community preparedness for changing coastal hazards.
II. Introduction

With around 322 miles of oceanic shoreline and more than 12,000 miles of estuarine coastline, the state of North Carolina (NC) stands to suffer significantly from the intensifying impacts of climate change (Tracing the Coastline, n.d.). Though coastal areas in NC have long dealt with the affliction of tropical storms, hurricanes, and other weather-related incidents, communities are now confronting intensified situations with increased frequency (Bulla et al., 2017). Occurrences that were once considered 100-, 500-, or 1000-year storm and flood events are now happening almost yearly (Irfan, 2018). Further, studies show that certain parts of the NC coast and Outer Banks are already experiencing sea level rise at a higher rate than the global average (Bulla et al., 2017). Mid-range sea-level projections predict that the next 50 years will bring regular flooding exceeding today’s historic records, and even the lowest-level predictions indicate at least a 50 percent chance of flooding exceeding four feet above the high tide line (Strauss et al., 2014).

Without proper adaptive effort, coastal communities in NC stand to suffer significantly as such projections come to pass. However, there is much discussion on adaptation ability at different scales and debate surrounding where planning efforts should be focused (Janetos, 2020). Relevant literature places significant emphasis on the idea that the most practical implementation of adaptation measures must occur on a local scale, utilizing local solutions to best address localized needs (Nalau et al., 2015). What existing research fails to document, however, is exactly what action is currently occurring at the county or town level. In coastal NC, where communities often exist on tiny barrier islands, walled in on either side by neighboring towns, better documentation and understanding of ongoing adaptation strategies, successes, and failures in the surrounding areas could prove crucial to future resiliency.
This Master’s Project endeavors to compile and examine localized policy responses to changing hazards in coastal NC. The research and documentation processes in this project yield two catalogues of ongoing adaptive planning and management in select counties along the NC coastline. This report further provides insight and discussion of the catalogues’ key findings. In developing these resources, we seek to provide tools that may be utilized by researchers and local decisionmakers to craft stronger, more effective resiliency policies.

III. Background

In 2018, the Intergovernmental Panel on Climate Change (IPCC) released a special report discussing the impacts of 1.5 degrees Celsius warming above pre-industrial levels. The report concluded significant anthropogenic changes in the global climate system have occurred since the period between 1850-1900, changes which have already begun to cause societal shifts and impact human well-being (IPCC, 2018). With intensifying greenhouse gas (GHG) emissions and related global feedbacks, climate models project robust differences in regional climate into the future and potentially disastrous repercussions (IPCC, 2018). Without rapid, sweeping attempts to mitigate temperature rise, climate scientists expect increased frequency and magnitude of extreme weather events, sea level rise, widespread habitat damage, species loss, and severe heatwaves and cold snaps in the coming years (IPCC, 2018).

However, mitigation efforts are difficult. Across the globe, societies face political, economic, and technical difficulties in responding to climate change (Janetos, 2020). The IPCC (2018) notes that globally-stated mitigation targets under the Paris Agreement currently will not limit global warming to 1.5 degrees Celsius, even if attained; decline of CO2 and other GHG emissions must be significant and occur well before 2030—a challenging task for many countries across the world. Regardless of what policies are implemented, it is key to note that
existing emissions of long-lived, anthropogenic GHGs are already driving noticeable climatic changes across every continent and in every ocean (Stocker et al., 2013). The most potent GHGs have long residence times in the atmosphere, meaning that their warming capacity will continue to influence Earth’s temperature for many years into the future (Schwartz, 2018).

Thus, it is essential for society to not only consider how to peak emissions and reduce the rate and duration of warming (IPCC, 2018). We must also evaluate how we currently respond to changing hazards and how we can plan appropriately for resiliency in an uncertain future. Coastal regions are particularly threatened by worsening climate-related hazards; across the globe, coastal zones are more densely populated and have higher population growth rates than inland areas (Neumann et al., 2015). In the United States, 40 percent of the country’s population lives in coastal counties (NOAA, 2018). In conjunction, however, coastlines are exposed to increasing and intensifying risk from sea-level rise, extreme storms, and resulting flooding, erosion, and ecosystem loss (Nicholls et al, 2007). By 2035, it is estimated that over 150 U.S. communities will face persistent flooding at least twice per month; by century's end, close to 500 communities will be chronically inundated (Spanger-Siegfried et al., 2017).

Such projections spell disaster for coastal communities in North Carolina. In the state, more than 2,000 square miles of land fall less than four feet above the high tide line; this area contains around $8.8 billion worth of property, including 61,000 homes, 2,500 miles of road, 15 schools, 108 houses of worship, and 131 EPA-listed hazard sites (Strauss et al., 2014). Strauss et al. (2014) further note how impacted coastal regions face issues of social vulnerability, meaning that certain groups of people and places can experience disproportionately worse climate impacts without differences in actual exposure. Evaluating for socioeconomic characteristics that influence communities’ ability to prepare for, respond to, and recover from hazards, 12,000
highly-vulnerable people will be impacted under the four-foot scenario; highly-vulnerable here
refers to individuals who are already intrinsically disadvantaged in some way (i.e. due to racial
background, economic status, etc.; Strauss et al., 2014). Under a higher-level, eight-foot
scenario, 33,000 highly-vulnerable individuals may experience ramifications from climate
change and resultant sea level rise (Strauss et al., 2014). Without appropriate mitigation,
community planning, and adaptive action, these communities and others can expect hazardous
conditions and endangerment of health and well-being into the future.

At the state level, the NC government has recently begun to make specific moves
dedicated to climate action and resilience. In October of 2018, Governor Roy Cooper signed
Executive Order (EO) 80, titled "North Carolina's Commitment to Address Climate Change and
Transition to a Clean Energy Economy." The EO committed NC to the U.S. Climate Alliance
and cemented its plan to adhere the Paris Agreement goals (Exec. Order No. 80, 2018). Key
goals of the EO are as follows:

a. "Reduce statewide greenhouse gas emissions to 40% below 2005 levels;
b. Increase the number of registered, zero-emission vehicles ('ZEVs'; individually, 'ZEV'
to at least 80,000;
c. Reduce energy consumption per square foot in state-owned buildings by at least 40%

The EO thus established the North Carolina Climate Change Interagency Council, which meets
every few months, is chaired by the NC Department of Environmental Quality (DEQ) secretary,
and contains representatives of every state cabinet agency (Exec. Order No. 80, 2018). Under the
EO, various agencies have developed or are in the process of developing a Clean Energy Plan, a
ZEV Plan, a Comprehensive Program on energy, water, and utility use conservation, and a
Climate Risk Assessment Resiliency Plan (Exec. Order No. 80, 2018). NC's Clean Energy Plan, ZEV Plan, and Comprehensive Program all have collective targets, such as retirement of "dirty" fuel sources and promoting better tracked/reduced energy usage in buildings which seek to mitigate climate change and transition the state to a more sustainable future (NC Department of Environmental Quality [DEQ], 2019; Comprehensive Utility Use Conservation Program, n.d.).

The Climate Risk Assessment and Resiliency Plan is designated under Section 9 of the EO and set for publication in early 2020 (Exec. Order No. 80, 2018). The plan will assess the impacts of climate change on government programs and operations, and seeks to bolster government support for communities and climate-vulnerable sectors of the economy (Climate Risk Assessment & Resiliency Plan, n.d.). To maintain the best possible scientific basis for the plan, DEQ partners with the North Carolina Institute for Climate Studies (NCICS) and the related NCICS Climate Science Advisory Panel—programs implemented through North Carolina State University and other regional academic institutions (Climate Risk Assessment & Resiliency Plan, n.d.). In addition, to garner input from stakeholders, DEQ and other cabinet agencies host regional Resiliency Workshops; these enable participants to remain up-to-date on the latest climate science, offer input for state-level recommendations, share regional challenges, and establish priorities for addressing vulnerabilities (Climate Risk Assessment & Resiliency Plan, n.d.).

Overall, the larger-scale efforts of the NC state government are well-documented. However, as noted earlier, localized action along the coastline has not been tracked or recorded in a manner where local decisionmakers can easily locate information on their peers’ adaptive management policies. In undertaking this Master’s Project, we seek to close that gap and allow better accessibility of such knowledge and record.
IV. Overview of the Client and Case

Our project was informed by our Master's Project adviser and client—Dr. Megan Mullin, Associate Professor of Environmental Politics at Duke University’s Nicholas School of the Environment. Dr. Mullin is on the steering committee for a coastal environmental management research project: C-CoAST, a Collaboratory for Coastal Adaptation over Space and Time. C-CoAST’s area of study encompasses the coastal NC counties of Dare, Carteret, and New Hanover. Their overarching goal is to instill a new collaborative capacity in answering the following research questions: 1) How does the event/recovery-driven coupling between human and natural dynamics cascade over time to alter risks and the resilience of communities, ecosystems, and landscapes?; and 2) What levers--actions of individuals, communities, governments, and other groups--enable mutual resilience of communities, ecosystems, and landscapes?

C-CoAST is comprised of a diverse array of experts that are well-equipped to answer these questions. The team contains academic researchers from Duke University, the University of North Carolina at Chapel Hill, the University of North Carolina at Wilmington, East Carolina University, Oregon State University, and North Carolina State University. It additionally includes local government officials from study communities, partnerships with state-level divisions and offices, and representatives from environmental nonprofit organizations and National Wildlife Refuges. This diverse array of expertise, backgrounds, and perspectives hold significant potential for fostering new relationships and producing resiliency solutions for the study counties, as well as all of coastal NC and other coastal states.

Dare, Carteret, and New Hanover counties are well-suited as study regions because they are already hubs for existing coastal research. They also contain diverse geomorphology, demographics, urbanicity, and economic activity, and are thus good exemplars of the types of
counties located in coastal North Carolina. The counties include a broad array of barrier islands, wetlands, river estuaries, and other geomorphic features commonly found along the North Carolina coast. In terms of their populations, communities in the study area are fairly representative of what is typically found in the region; while there is the more urbanized city of Wilmington in New Hanover County, the study areas also contain small tourist towns such as Nags Head (Dare County) and several sparsely-populated communities of permanent residents. Racially, these communities are more Caucasian than the rest of North Carolina, and the average incomes in the three counties are all around the state median. However, cross-county and intra-county racial and economic variation is high.

Our project serves to provide a foundation for C-CoAST's study. Through our literature review (see Section V), we identified a gap in existing research on coastal policies and resilience. It is difficult to determine the best policy levers regarding human-nature dynamics and resilience, or the changes occurring over time, without a baseline understanding of what communities are currently doing in this space. Thus, our Master's Project examines the three NC counties—Carteret, Dare, and New Hanover—and seeks to code and measure the relevant policy responses being enacted at the county and community levels. Driven by findings from relevant literature, we chose three particular areas of climate adaptation policy: 1) coastline adaptation methods, 2) land use planning & zoning, and 3) septic system management. Within these categories are embedded the broad threats to coastal communities in NC, and thus they can provide useful insight into how these communities are planning for threats relating to anthropogenic climate change. The policy catalogues (see Figures 2, 3, and 4) and the takeaways presented in this report should stand as useful tools to support the collaborative research and stakeholder networking expected from C-CoAST's efforts. It is also our intention
that this project provide communities with insight into how their neighbors are responding to changing hazards, and bolster future partnerships, knowledge exchange, and innovation into the future.

V. Literature Review

We conducted an in-depth literature review to assess whether there exist any other projects of this kind. After initially examining more than 60 peer-review journal articles, we found there to be few studies that systematically describe local policy responses to changing coastal hazards resulting from climate change, and none which describe such responses systematically in North Carolina.¹

Levels of Government Action

The disruption expected to the U.S. from changing coastal hazards is substantial enough to necessitate involvement and response from all levels of government—federal, state, and local. U.S. environmental law has traditionally vested authority and power at the federal and state level. In the 1950s, protection of air and water resources was left at the discretion of states. Then, in the 1960s and 1970s, environmental protection became much more top-down oriented with the passage of federal acts such as the Clean Air Act of 1963 and the Clean Water Act of 1972, as well as the creation of the U.S. EPA. In the 1980s, the Reagan Administration emphasized the “devolution of authority to state and local government” in environmental policy to prioritize “regional cooperation” and “levels of government closer to the people” (Hejny, 2018). Since then, U.S. environmental policy has been an interplay between federal and state power, with states tending to have jurisdiction over environmental protection so long as their levels of

¹ Other related work that we are aware of is Sechley (2016), which focuses only on flood preparedness in coastal NC and McPherson (2009), which discusses the coastal law and policy framework of NC generally.
standards and enforcement meet a minimum federal standard (Howe, 1993). This approach to environmental law and policy is consistent with America’s longstanding governance tradition of balancing state and federal power.2

Although power and responsibility for environmental protection has traditionally fallen under the purview of state governments and the federal government, the adaptation literature has tended to place a “strong emphasis” on the role of local government (Nalau et al., 2015). Despite this, Nalau et al. (2015) point out that “the ability of local actors to advance an adaptation agenda effectively is lacking in many ways.” To be sure, climate change and its attending change in coastal hazards can be properly described as what Sabatier (2007) refers to as “system level,” with local influence being only one “policy subsystem.” This means that any policy predictions or inferences based off local change alone will naturally be limited in their scope and generalizability to other settings (Sabatier, 2007). Sabatier (2007)’s discussion of policy constraints also means it is imperative that local governance and policymaking be situated in the context of how it relates to broader federal and state actions (i.e., how it reinforces or extends beyond them).

It stands to reason that the scope of authority for local governments to adequately prepare for sea level rise, severe storms, and changing coastlines is limited. Local governments are often understaffed, underfunded, and face pressure to favor immediate, tangible concerns over long-term, abstract problems (Liu et al., 2010; Borge and Tovmo, 2009). The literature on coastal management, and on local government in general, is consistent in noting such constraints. Individual local governments often simply do not have the resources nor the influence to engage

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2 On the one hand, Article VI of the U.S. Constitution (The Supremacy Clause) provides that valid expressions of federal law will always be superior to any state law “to the contrary” (1788). Yet, on the other hand, the Tenth Amendment to the U.S. Constitution reserves “powers not delegated to the U.S. by the Constitution . . . are reserved to the States respectively, or to the people” (1791).
in meaningful coastal resilience measures at the scale or time-horizon appropriate for defending against sea level rise, increased storm severity, and coastal erosion. In addition, coastal resilience measures, like flood preparedness and hazard planning protocols, are generally conceptualized (and planned for) on scales that are large enough to make transferability to the local level difficult (Yoo et al., 2011; Lawrence et al., 2013; Urwin and Jordan, 2008, Næss et al., 2005). These “multi-level governance constraints” (i.e., broader government arrangements hindering local actors) have the potential to cast the effectiveness of local adaptation efforts into doubt (Nalau et al., 2015).

Given these substantive limitations, what is the proper role of local government in adapting to changing coastal hazards? We investigate this question by reviewing the literature on local governance, especially in the domain of coastal adaptation. Three takeaways emerge:

1) The local policymaking process is influenced heavily by “consensus and coalition building” as opposed to “shifting public moods and opinion,” which dominates at the federal level. This means that local government choices are less susceptible to changing public attitudes and are based more on relevant, tangible realities (Liu et al., 2010).

2) Local government action on climate change adaptation is important because it is the level of government “closest to where the impacts will be felt” (Pasquini and Shearing, 2014). Individuals tend to perceive climate threats as more severe, and have “greater . . . behavioral intentions to address the problem” when climate impacts are framed locally (Wiest et al., 2015). Furthermore, the local level is where “individual behavior may be directly influenced” and the scale at which “responses to climate change are implemented” (Amundsen et al., 2018).
3) Local governments are “most directly responsible for planning and implementing adaptation strategies suitable for the area in which they are located” (Pasquini and Shearing, 2014; Bulkeley, 2010). In terms of practical implementation, “most adaptation efforts will be undertaken at the local level” (Grasso, 2010; Nalau et al., 2015).

These themes indicate that, relative to federal and state governance, local governance tends toward being more closely aligned with the preferences of its constituency; individuals have a stronger connection to local action and their local government because the lines of communication and accountability are more direct. Local governance is also tailored to the specific locations and needs of citizens, and such needs tend to be more homogeneous (i.e., there is less variation) at the local level (Winer and Martinez-Vazquez, 2014). These intrinsic characteristics of local government enable local communities to implement coastal change adaptation through land use planning, infrastructure development, waste management, and disaster management (Pasquini and Shearing, 2014; Burch, 2010).

Local governments in North Carolina are particularly important to explore when assessing policy responses to changing coastal hazards, given NC’s history of explicit state mandates. In the mid-1990s, the state issued local land use planning mandates under the 1974 Coastal Area Management Act (CAMA), by which all coastal counties abided. Despite being state-mandated, the CAMA program reflected a “collaborative state-local partnership” for management of economic development and environmental protection in coastal regions (Norton, 2005). Burby and May (1997) describe these mandates as “moderately prescriptive” and “moderately persuasive” compared to other states’ coastal management systems, indicating that local NC communities still hold significant development discretion under CAMA.
However, despite CAMA’s attempt to tighten development standards in local communities, there has been “substantial and growing evidence” that NC’s coastal resources, like its habitats, wetlands, estuarine health, and water quality, have “continu[ed] to decline” (Norton, 2005). This could be due to local governments’ budgetary constraints, which Liu et al. (2010) show to be the “most critical factor” in local policy agenda-setting. It could also be the case that interest groups (such as business and commercial groups, which are “often dominant in setting local development plans and policies”) have shifted local planning to prioritize economic growth and development over environmental protection (Liu et al., 2010).

Overall, local governance has an essential role in climate change adaptation efforts as the 'on the ground’ implementor of practical changes. But that role is limited by the scope and severity of climate induced coastal hazards, as well as the institutional challenges inherent in multi-level governance that make setting policy and governing adaptation at the local level difficult and potentially ineffective (Nalau et al., 2015). The de facto assumption that the local level is where all the action ultimately happens on climate adaptation turns out to be too simplistic. Our project’s examination of local policies will account for the constraints on local action that we discovered, and will account for the challenges that localities face in governing their own policy responses to a changing climate.

Adaptation Literature

Where the literature pertained to adaptation writ large, studies and articles largely fell into a few distinct categories: (1) discussing uncertainty and the need to better quantify vulnerability and risks; (2) examining how perceptions influence priorities and action; and (3) management strategies and policy challenges.
1. **Uncertainty & Risk Characterization**

Uncertainty plays an unfortunate role when it comes to policy decision making around coastal adaptation. Questions surrounding political, economic, and social values can work to either constrain or enable adaptation responses (Moser, 2005), and when such human factors are combined with constantly shifting research and data, predicting and adapting to future change proves difficult (Kettle, 2012). In North Carolina, policymakers are confronted with the questions of exactly what level of change should be planned for, and how much resource expenditure is necessary to protect and maintain community health and safety (Nash, 2008). Numerous studies concluded that such concerns can better be addressed with improved risk characterization; tools for doing so include GIS mapping and LIDAR modeling, satellite tracking of sea levels, and improved change monitoring networks (Gesch, 2009; Kettle, 2012).

2. **Influence of Perceptions**

Perceptions are a big topic, running in a similar vein to questions of uncertainty. As previously mentioned, many researchers note that the adaptive capacity of coastal communities is highly limited by how people perceive threats from climate change (Bhattachan et al., 2018). Bhattachan et al. (2019) discuss how taking policy action is difficult given contingency on factors like personal experience, trust in science and government, or individual politics and worldview. In some cases, citizens may be ready to adapt but are limited by slow process and lack of policymaker consensus (Bhattachan et al., 2019). Overall, ideological pressures and ideas hold a strong influence in how communities recognize and respond to coastal hazards, meaning that some adaptive strategies might ignore climate change or sea level rise in name, but nonetheless account for their harms (Nash, 2008).
3. Management Strategies

As noted earlier, community values and governance/management strategies—at local, state, and federal levels—are heavily discussed and contested. Studies such as that by Campbell and Meletis (2011) discuss how competing values in vulnerable communities lead to differing ideas of governance; rural areas in particular struggle in aligning "insider" values, such as long-ingrained planning and land-use traditions, with "outsider" or "other" ideas, such as change based on climate science. Bures and Kanapaux (2011) note a similar conundrum, addressing historical planning and adaptation according to "regimes." In many coastal cities, decisionmakers and developers are unwilling to undergo "regime change;" the environment is viewed from the perspective that it is frozen in time, and communities constantly rebuild in the exact same manner— as though disasters did not happen and will not happen (Bures and Kanapaux, 2011).

Other studies suggest transforming management strategies, accounting for and adapting to changes via public-private partnership projects or cooperation between communities (Gopalakrishnan et al., 2017; Shelton, 2011). A model by Gopalakrishnan et al. (2017) promoted coordinated over decentralized management; the study noted that situations where communities enacted an organized effort (coastal planner chooses intersectional projects for multiple towns) versus pursuing projects on their own (acting alone and taking neighbors' actions as given) tended to yield more stable results.

Adaptation efforts generally in the U.S. have grown beyond simply managing gray infrastructure, and now include flood insurance, building and land use regulations, beach nourishment, and coastal zone planning (Platt, 1994). Coastline adaptation methods generally fall under one of seven different categories: (1) beach nourishment; (2) dune restoration; (3) structure elevation; (4) living shorelines; (5) riprap; (6) seawalls; and (7) wetland restoration (see Figure...
Another option available is “planned retreat,” whereby coastal communities evacuate and relocate people and infrastructure to protected areas “behind natural defenses” to altogether avoid increasingly intense coastal hazards and rising sea levels (Abel et al., 2011). Retreating from the coastline is a long-term solution, while coastal adaptation methods are short-term solutions that seek to temporarily stave off the challenges posed by rising sea levels and worsening storm events.

<table>
<thead>
<tr>
<th>Coastal Adaptation Method</th>
<th>Brief Description</th>
<th>Positive</th>
<th>Tradeoffs</th>
<th>Specific Areas Implemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beach Nourishment</td>
<td>Trucking outside sand to beachfront areas to replace eroded sand or prepare for future erosion</td>
<td>Maintains beach width, Can replace sediment loss, Increase of beach public access</td>
<td>Short-term solution, expensive, can have deleterious impacts of environmental conditions, benefits few landowners at the expense of public</td>
<td>United States, California (especially)</td>
</tr>
<tr>
<td>Dune Restoration</td>
<td>Involves rehabilitating or reconstructing pre-existing sand dunes that have been destroyed either due to natural forces or construction</td>
<td>Environmentally friendly strategy that restores an ecosystem, reestablishes storm surge buffer, rehabilitation relatively inexpensive</td>
<td>May take many years for the natural system (wetlands, vegetation) to reestablish itself after dune restoration, rehabilitation projects vulnerable to “coastal sump”</td>
<td>California</td>
</tr>
<tr>
<td>Structure Elevation</td>
<td>Using shifts, columns, or piles to elevate a structure well above sealevel</td>
<td>Defends against sea rise and floods, useful for structures that cannot be moved in retreat programs, useful for structures in anticipation of a retreat program</td>
<td>Short-term solution, makes buildings compliant and can lower insurance premiums (thereby creating moral hazard), can increase coastal erosion by “impeding longshore drift”</td>
<td>United States</td>
</tr>
<tr>
<td>Living Shorelines</td>
<td>Combining natural elements (plants) with shorelines structures “to stabilize or maintain coastlines, bays, and tributaries”</td>
<td>Unifies biological elements to provide flood protection and reduce wave action, relatively inexpensive, require little maintenance, minimize ecological detriments</td>
<td>Can increase coastal erosion down shore, can impair surfbreaks and threaten beach access for beachgoers, name of coastal adaptation method runs the risk of “greenwashing” environmental impacts</td>
<td>California</td>
</tr>
<tr>
<td>Riprap</td>
<td>Shoreline armor strategy that involves stacking boulders and small rocks to mitigate wave impact and reduce erosion, typically parallel to the shoreline itself</td>
<td>Protects against storm surge and flooding impacts, can allow local governments to stabilize property tax revenue (by ensuring that damage is minimized to certain properties)</td>
<td>Protects a highly localized region, highly costly ($1,000 to $4,000 per foot, 5-12% of the initial cost per foot or yearly maintenance), can cause geophysical and ecological disruption if deployed haphazardly, lead to negative externalities on nearby beachfront</td>
<td>United States, California (especially)</td>
</tr>
<tr>
<td>Seawalls</td>
<td>Shoreline protection structure that protects against “encroaching seas” by absorbing wave impact, reducing erosion, and preventing cliffside erosion</td>
<td>Protect individual properties and communities from coastal flooding and storm surges, can allow local governments to stabilize property tax revenue (by ensuring that damage is minimized to certain properties)</td>
<td>Requires careful planning and engineering (costly), must effectively address “wave overtopping, undermining, outflanking,” and extreme storm and flood events, undermines public beach access</td>
<td>United States, California (especially)</td>
</tr>
<tr>
<td>Wetland Restoration</td>
<td>Reestablishing or rehabilitating an impaired wetland by nurturing wetland habitats and</td>
<td>Can carry environmental co-benefits, buffer coastal communities from flooding risk, and can sequester carbon. Restored wetlands are typically self-sustaining</td>
<td>High initial capital cost, difficult to find space (given that coastal erosion is already putting pressure on available wetland area and will continue to do so)</td>
<td>United States, California (especially)</td>
</tr>
</tbody>
</table>

Figure 1. Coastal Adaptation Methods Overview

In order to understand how NC’s coastal communities are responding to changing coastal hazards, we selected three policy areas of interest that emerged from our review. These policy areas are comprehensive metrics that allow us to assess localities’ responses to coastal hazards. More importantly, these policy areas are well within the purview and control of local governments:

1) **Coastline Adaptation**, included because coastal North Carolina is especially vulnerable to sea level rise, and local adaptation measures are necessary to circumvent worst-case outcomes from coastal hazards (Pendleton et al., 2010; Spanger-Siegfried at al., 2017).

2) **Land Use Planning & Zoning**, included because sound land use planning and zoning policy increases an area’s coastal resilience (Bures and Kanapaux, 2011).

3) **Septic System Management**, because this is an indicator of infrastructure policy that has close links to both environmental health and public health. North Carolina’s septic systems stand out as especially vulnerable given the state’s soil conditions, relatively high water tables, and lax oversight on septic system permitting and construction (Duda and Cromartie, 1982).

These policy areas are best managed at the local level because they are area-specific. While commonalities between localities surely exist—which would justify state-level guidelines or mandates—idiosyncratic modifications in these policy areas at the local level based on location-specific needs must always be a consideration by local planners. To examine the variation in local policy responses to changing coastal hazards, we examine Carteret, Dare, and New Hanover’s activity and performance over these three policy areas.
VI. Methodology

This project utilized the key takeaways from the literature review to inform the primary research product—a thorough catalogue of NC policies in the target coastal counties: Carteret, Dare, and New Hanover. We used literary findings to determine our three policy areas for each county—coastline adaptation, land use management and planning, and septic system management. Then, for each of those policy categories, we subsequently developed specific policy questions we wanted to answer and input them into a spreadsheet. Next, we conducted research to answer these questions. Lastly, we created a simplified code that could be easily used by our audience to develop a comprehensive understanding of the policy landscape in our research area.

Prior to developing our spreadsheet, Dr. Mullin provided our team with a list of 21 specific communities within our study area, as well as the larger three counties themselves, for a total of 24 that she wanted us to examine. The communities on our list are all located at least in part along an oceanfront or estuary, and therefore are going to be directly affected by storm surges, beach erosion, and sea level rise. As we conducted our research, we found that two townships in Carteret County on Dr. Mullin’s original list, Bogue and Peletier, did not have a high number of independent policies and therefore largely deferred to Carteret County. Each of us made different decisions as to whether to eliminate one or both of these communities from our respective policy catalogues.

Once we had selected which communities to code, the next step was to decide what bins of policies we wanted to catalogue. Ideally, for work flow purposes, we wanted to generate three bins, one for each member of our research team. As evidenced in our literature review, local governments are well positioned to take a leading role on certain types of policy, such as protecting coastal property from hazards such as sea level rise, maintaining their own
infrastructure (including septic systems), and making land use planning and zoning decisions. Each bin was then assigned to a member of our team, and each of us became an expert on our respective category.

Our third step was to generate questions for our policy categories. Each of us generated specific questions and input them into a spreadsheet, with a row for each of our counties and respective communities, and a column for each of our policy questions. The fourth step of our process was to conduct research and answer our policy questions for each community. We conducted a thorough search of local government websites, news articles, CAMA land use plans, government ordinances, and other documents to answer our questions. Each county/town would have a listed short answer, notes, and appropriate links/references to pertinent information; where necessary, if information was scarce or not found, we left cells blank or noted the lack of data. We left room to add additional question columns, if our research indicated that a new question was warranted.

Once we had developed our initial comprehensive spreadsheet, our final step was to develop a simplified catalogue so that researchers and policymakers can quickly and succinctly understand the policy landscape in our study area. We first eliminated or pared down some of the categories in our initial spreadsheet if they contained information that we deemed to be redundant or not informative. Then we expanded some of our categories into multiple columns in order to more clearly demonstrate the policy differences and similarities between the government entities in our study. These simplified columns questions were formulated to be answered and comprehended in short form—most were answered briefly, i.e. with a “yes” or “no” response. This simplified sheet provides an accurate and clear picture of the coastal hazard response policy landscape in our study area.
VII. Coastline Adaptation Methods

Introduction

Local officials note that, with such a complex issue as climate change, there is need for multi-level cooperation and guidance from state and national government policies (Nalau et al., 2015). There is a shared responsibility when it comes to meeting community needs regarding a global-scale issue. However, given that coastal regions are highly vulnerable to specific, acute change, significant and localized coastline adaptation is required to circumvent worst-case outcomes (Spanger-Siegfried et al., 2017). Though implementing such measures may be costly, the IPCC notes with high confidence that the costs of coastline adaptation on vulnerable coastlines are far lower than the costs of damages due to inaction (Nicholls et al., 2007).

In North Carolina—even in light of climate science—belief in the impacts of climate change has long been contentious among residents, including state politicians and local officials alike (Bulla et al., 2017). For many years, many people living in coastal counties were not convinced that sea level rise threatened their homes and communities (Bulla et al., 2017). Recent data has shown that perceptions may be beginning to shift. As more coastal-dwellers experience firsthand the loss and damage from hazard events, opinions on climate impacts and necessity for mitigative and adaptive action are changing (Albright and Crow, 2019). Irrespective of beliefs, however, the fact is that NC decisionmakers have been dealing with coastal hazard-derived rebuilding and recovery for many decades. The question now is, are they responding (and how) in terms of adapting their coastlines to increasing threats? As climate impacts intensify, are community members ready to cope with the consequences?

Literature Review

A key component of the literature review—and one which was noted across the majority of reviewed pieces—pertained to discussion and/or review of various coastline adaptation
strategies. These fell largely under four types of solutions: (1) beach/dune nourishment, (2) nature-based resilience measures, (3) gray/hardened infrastructure, and (4) relocation/retreat (McGlashan, 2003). Beach nourishment appeared as a popular strategy across studies, describing a process in which dredged material (i.e. sand) is placed in eroding areas to rebuild protective beaches, dunes, marshes, etc. (Croft et al., 2006). Though commonly used, many studies noted rising costs over time as nourishment becomes more frequent and necessary (Gopalakrishnan et al., 2018). Researchers posed numerous questions regarding the efficiency of the beach nourishment processes, and the idea emerged that—though important—nourishment cannot be a universal adaptation solution (Gopalakrishnan et al., 2017; McNamara et al., 2015). Also prevalent were discussions and debates over whether natural or hardened/gray infrastructure is best, or some hybrid combination of the two. Gray infrastructure has historically been a dominant resilience method in the United States and involves implementation of manmade "built" structures like seawalls (Kochnower et al., 2015; Sutton-Grier et al., 2015). However, public interest has recently moved toward implementing or restoring existing nature-based solutions such as wetlands, oyster reefs, and mangroves (Kochnower et al., 2015). Numerous studies noted that natural strategies may provide more benefits than gray infrastructure, improving erosion and flood mitigation, buffering wave energy, and absorbing water from high tides and storm surges (Kochnower et al., 2015; Sutton-Grier et al., 2015).

Given the brevity and scarcity of mentions of relocation in the literature, it appears that the option to relocate communities or retreat from the shoreline is not a popular one. Jurjonas and Seekamp (2018) deem built-environment engineering and nature-based solutions both as better alternatives than relocation, in the sense that such options address threats while simultaneously enabling a continued sense of community and livelihood. However, others note
that maintaining costs of infrastructure would exacerbate existing social inequalities and would be too costly in the long run as hazard impacts become more severe (Woodruff et al., 2018). Evidence from authors like Woodruff et al. (2018) suggests that relocation and retreat will be the only viable options over the next few decades.

Overall, studies conclude that the "mounting resistance" method is the primary focus in NC. Though specific plans and policies were not noted or tracked in the literature, the reviewed articles present a broad picture that North Carolina communities tend to focus on beach nourishment and hardening methods. Past records show little attempt to increase natural resilience or facilitate transitions away from the coast, though this strategy may soon be changed (Boudreau, 2012).

Methods

Following the high-level methodology described in an earlier section, the catalogue and questions surrounding coastline adaptation were crafted based on the actions and strategies mentioned in the previous literature review. Finding the answer to each question varied depending on the county and town; a preliminary scan involved entering key question terms into an internet search bar for county and town website, and then scouring the resulting webpages and documents for answers. Discovering the answers in the coastline adaptation section was not typically straightforward, but rather involved a deep dive into numerous government documents and further google searching for any evidence of the answers. Information on adaptation was typically not aggregated in any way, but rather had to be derived from a conglomerate of newspaper articles, reports, and plans.

When searching county/town websites, documents, and other articles or notes found via a Google query, the preliminary step was first to find if there was any mention at all of the
question terms. Some questions had an easily identifiable "yes/no" answer; however, a "yes" or "no" when discussing inclusion of adaptation measures did not necessarily indicate that the town or county had a concrete plan, or even that a measure was specifically included in the plan. However, if it was somewhere mentioned that a method was being used, the appropriate response was duly noted. Discrepancies often occurred in answering questions, where perhaps an old plan existed that mentioned a technique or goal, but it was questionable at what level action occurred or whether there was a new plan/practice that carried forward to the present day. In such cases, a "maybe," "typically yes/no," or "sort of" answer was deployed, supplemented with further explanation and abundant notes to elaborate on the response.

Coding

Upon completion of the primary spreadsheet that tracked policy inconsistencies and intricacies, a simplified coding system was developed based on prior questions and important understandings gleaned from the larger catalogue. The counties and towns were once again listed in the first Excel column, with the streamlined labels and questions displayed across the top of each column. The goal of this sheet was to provide quick insight about each county/town, their management methods, and policy status. To enable further ease of understanding and consumption, this spreadsheet deployed conditional formatting to color-code answers:

- "Yes" and "Complete" = green
- "No" = red
- "N/A" or "Unclear" = gray
- "Maybe," "Upcoming," "Ongoing," or multiple-status questions (i.e. varies by project, as necessary, upcoming/ongoing) = yellow
The simplified statements and questions read as follows:

- Oceanfront coastline?
- Inland Coastline? (i.e. soundside, rivers, estuaries, etc.)
- Currently falls under state-level coastal resilience/hazard mitigation/management goals
- Currently falls under regional (multi-county) coastal resilience/hazard mitigation/management plan
- Designated local decisionmaker(s) overseeing "hazard management" or "coastal management" at regional level (advisory committee member, etc.)?
- Currently falls under a county-level coastal resilience/hazard mitigation/management plan
- Designated local decisionmaker(s) overseeing "hazard management" or "coastal management" at county level?
- Currently falls under a town-level coastal resilience/hazard mitigation/management plan
- Designated local decisionmaker(s) overseeing "hazard management" or "coastal management" at town level?
- Utilize beach nourishment?
- Beach nourishment upcoming/ongoing/complete?
- Beach nourishment projects planned to recur?
- Utilize dune restoration?
- Dune restoration upcoming/ongoing/complete?
- Dune nourishment planned to recur?
- State-level rules prohibit gray/hardened infrastructure on NC oceanic coastlines, with certain exceptions. Are there any exceptions here?
• Utilize gray infrastructure on non-oceanic coastlines?
• Gray infrastructure projects upcoming/ongoing/complete?
• Utilize nature-based resiliency measures?
• Nature-based measures implementation upcoming/ongoing/complete?
• Utilize structural relocation?
• Structural relocation upcoming/ongoing/complete?
• Is there *any* discussion regarding managed retreat?
• Any concrete plans for managed retreat?
Results

The following figure demonstrates the final simplified coding spreadsheet and the policy outcome results from each county and town.
Figure 2. Coastline Adaptation Simplified Coding
Discussion

Coastal Resilience and Hazard Mitigation

When examining the results for county-level planning, there are no county-level adaptation or resilience plans. Research demonstrated that the counties each had their own "hazard management plan" at some point, but are now each subject to inclusion under regional plans (which take precedent). Dare County falls under the Outer Banks Hazard Mitigation Plan (OBX Hazard Mitigation Planning Committee [HMPC], 2020), Carteret County under the Pamlico Sound Regional Multi-Use Plan (Pamlico Regional Mitigation Advisory Committee [MAC], 2015), and New Hanover County under the Southeastern NC Regional Hazard Mitigation Plan (Southeastern NC Regional Mitigation Advisory Committee [MAC], 2016).

Each regional plan, though they include a number of counties from the area, addresses planning measures and goals for the target county and each of its individual towns. With the exceptions of Nags Head (Dare County), Kill Devil Hills (Dare County), Morehead City (Carteret County), and Pine Knoll Shores (Carteret County), towns are strictly governed by regional and state-level management planning and do not have plans of their own.

Each of the three plans was jointly developed by members of the participating counties and written in compliance with Federal Emergency Management Agency (FEMA) disaster relief programming; such efforts were to ensure that participating jurisdictions are continued FEMA assistance and funding in the coming years.\(^3\) It is important to note that none of these plans are specifically targeted as climate resilience or adaptation-related, but rather address a number of issues such as hurricanes, flooding, wildfires, tornadoes, erosion, and extreme heat. New Hanover's regional plan mentions the term "climate change" once, noting that long-term erosion

\(^3\) See references to Pamlico, Outer Banks, and Southeastern NC Regional Hazard Mitigation Plans
is subject to climate changes; Carteret's plan does not use the term at all (Pamlico Regional MAC, 2015; Southeastern NC Regional MAC, 2016) The Outer Banks Plan (which includes Dare County) is the newest, and as of March 2020 is still in draft form. This plan explicitly mentions "climate change" almost 50 times, assesses vulnerabilities in terms of a warming world, and discusses how climate shifts may or may not influence the risks posed by the plan's noted hazards (OBX HMPC, 2020).

Beach Nourishment

All counties perform beach nourishment, of which dune nourishment appears to be a part. New Hanover's regional plan does not include beach nourishment as a strategy, but notes that nourishment is dealt with annually (at the county level) and is contingent on funding for the year (Southeastern NC Regional MAC, 2016). The oceanfront towns in New Hanover County (Carolina Beach, Kure Beach, and Wrightsville Beach) are all part of a lengthy contract with the U.S. Army Corps of Engineers (2019); nourishment projects have recently been completed in each and are set to occur every few years (Beach Nourishment, 2015; Richardson, 2019). In Dare County, beach nourishment is acknowledged in the town-level sections of the regional plan, which primarily instructs the county to continue ongoing nourishment efforts (OBX HMPC, 2020). Dare County aids each town in funding nourishment, noting that "beach nourishment is the preferred shoreline management alternative" along their ocean beaches (Management Policy Handout, n.d.). Each town in the county has completed a nourishment project within the past three years (Beach Nourishment Completed Projects, n.d.). Carteret County's regional plan makes no mention of beach nourishment; however, the county itself has a beach commission which is overseeing an ongoing, partially-complete beach restoration project for all oceanfront towns (Beach Preservation Plan, n.d.).
Gray Infrastructure

North Carolina state code prohibits permanent, hardened erosion control structures (i.e. bulkheads, seawalls, jetties) on the oceanfront, citing that such structures "may cause significant adverse impacts on the value and enjoyment of...properties or public access to and use of the ocean beach" (North Carolina Administrative Code [NCAC], Title 15A, 7H .0308(a)). Since the passage of a new law in 2011, however, CAMA since permits select terminal groins (Act of June 17, 2011). It was relatively easy in cataloguing to determine if county/town oceanfront contained an exception to the state level hardening prohibition (three were noted); however, it was difficult to determine if/when/where built infrastructure was used inland. Though some towns (i.e. Nags Head, Wilmington) specifically made mention of structures like bulkheading or riprap, built infrastructure really was not included as a definitive strategy in the regional hazard plans. In the simplified coding, answers to the "gray infrastructure" question almost always were derived from multiple searches for key terms and examples from random sources (news articles, etc.).

Nature-Based Strategies

Nature-based resilience strategies appear to be on the rise but are not well-documented in the study towns. Dare County's regional plan—perhaps given that it is extremely new—encourages use of natural barriers over hard structures for controlling shoreline erosion and protecting built infrastructure (OBX HMPC, 2020). Though noted in the plan, however, specific town-level documentation of projects is minimal. In-depth Google searches for key terms yielded mention of only a few projects here and there, such as a living shoreline along a critical emergency route in Kitty Hawk (North Carolina Coastal Federation, 2019). Nags Head (2017a), in its town-specific "Comprehensive Plan," specifically encourages use of "living shorelines and
For New Hanover County, the Southeastern region plan notes that CAMA requires vegetation in the estuarine areas of Carolina beach; it additionally stated that specific towns should revise zoning to incorporate shoreline vegetation buffers along areas of environmental concern (Southeastern NC Regional MAC, 2016). Despite this recommendation, there was little searchable record of if any projects have been implemented, and it was unclear if any towns in the county have ongoing natural resilience efforts.

**Structural Relocation and Retreat**

Dare County and Carteret County do not have any specific adaptation plans in place for relocating structures; there were occasional indications on county websites that it may occur as necessary, under town, county, and/or state-level permitting. The exception to this is again Nags Head, where structural relocation is specifically included in the long-term shoreline management plan and "considers environmental, legal, financial, physical, and regulatory issues/constraints
that will be needed to address shoreline management" in the coming years (Town of Nags Head, 2017a). The Morehead City Floodplain Management Plan also notes that "moving a building to higher ground is the surest and safest way to protect it from flooding" (Town of Morehead City, 2017). In New Hanover County, property-protective actions are included in the Southeastern Region plan, which are defined as actions which "diminish the risk of structural damage through acquisition of land, relocation of buildings, modifying high-risk structures, and floodproofing high risk structures" (Southeastern NC Regional MAC, 2016). However, no specific measures were noted for any area or town.

Lastly, cataloguing bolstered the literature in that managed retreat was found not to be a true consideration in any counties/towns at this time. Thorough search unearthed a few articles and an out-of-date plan in Dare County which noted vague discussion and researchers recommending future retreat (Coastal Planning & Engineering of North Carolina, Inc., 2014). Carteret County yielded more of the same, although one article describing loose recommendations noted that Carteret state Representative McElraft expressed strong opposition to ever considering retreat (Marchello, 2019). Examination of New Hanover County and towns found no considerations or discussion of retreat at all.

VIII. Land Use Planning & Zoning

Introduction

Land use planning and zoning are an important part of a coastal community’s policy toolbox. This is because communities in low-lying coastal areas need to think about how their current homes, places of work and leisure, and way of life fits into a not-so-distant future where rising seas, more frequent flooding events, and stronger storms are a reality. Carteret, Dare, and New Hanover Counties all had well-established land use plans and regulations and zoning
regulations under state laws such as CAMA, as well as their own local codes unique to several communities within a given county, or to an individual community. Our findings demonstrate that there are a number of policies that most communities have adopted, a number of policies that only a few communities have adopted, and that this yields a large number of communities with middling policy responses as well as a few exceptional townships.

Literature Review

Our analysis of academic literature revealed that sound land use planning and zoning policy increases local resiliency to changing coastal hazards, particularly in susceptible places like coastal North Carolina (Bures and Kanapaux, 2011; Ellis, 2008; Pendleton et al., 2010). Our review of coastal land use and zoning policy response both within and outside of our study informed both the selection of the land use planning and zoning questions in our policy catalogue and our analysis of the adequacy of each community’s response.

Various land use planning and zoning policy responses result in different success rates in mitigating changing coastal hazards. Ellis (2008) looked at managed retreat in the United States and Great Britain and examined the policy differences in these two places. In Britain, managed retreat away from the coastlines is more popular, whereas the U.S. generally focuses on infrastructural solutions to sea level rise (Ellis, 2008). Ellis (2008) notes that North Carolina does not allow home construction on sites likely to be eroded by waves; however, in many places there is a lack of awareness of the threat of sea level rise. In areas such the Chesapeake Bay region, which are experiencing rapid population growth, hardening the coast may be too expensive (Ellis, 2008). Ellis (2008) suggests that planners and architects in similar U.S. locations could take the British approach of managed retreat and plan with the future in mind.
Different land use adaptation policies have different levels of success improving community resiliency and decreasing coastal flood risks, and differing infrastructure approaches are being adopted along various parts of the US Eastern Seaboard. Built infrastructure has typically dominated in land use planning, though increasing evidence shows natural solutions and “hybrid” infrastructure may provide better social/economic benefits and flood protection (Sutton-Grier et al., 2015). In addition to strategically-selected, well-integrated infrastructure, flood mitigation policy is a vital piece of a community’s land use planning and zoning response to changing coastal hazards (Sutton-Grier et al., 2015).

Erlandson (2012) looks at a case study of building relocation—another land use planning strategy—in coastal North Carolina. In 2000, the Cape Hatteras Lighthouse, a historic landmark and a tourist attraction, was moved by the National Park Service about half a mile inland at a cost of $12 million (Erlandson, 2012). Similar situations are occurring throughout the state and world as coastal historical sites are being threatened; this speaks to the reality that the areas we have long developed are becoming less habitable, and emphasizes the importance of sound land use planning and zoning. While it can make sense for cases like the Cape Hatteras Lighthouse, building relocation is a resource intensive policy response, and is not a popular, widely implemented, or realistic large-scale response to sea level rise.

Land use planning and zoning policy selection is very location-specific. For example, when developing infrastructure to protect coastal resilience, it is important to select the correct type of infrastructure for the location and to build it well. A study by Williams (2018) dives into the policy weeds on infrastructure response to land use planning and zoning, evaluating land use planning strategies in coastal Texas. This study specifically looked at the effects of softscaping—such as building foredunes to protect marshes from sedimentation caused by hurricanes—by
comparing the effects of Hurricanes Ike and Rita on a southeast Texas marsh (Williams, 2018). Foredunes do in fact make a significant difference in slowing coastal deterioration and sedimentation, as do simple traditional infrastructural features like development and roads (Williams, 2018). However, while features such as foredunes present a higher barrier for water to pass over, storms are nevertheless effective at eroding them, and thus such structures are in constant need of repairment over time (Williams, 2018). In conclusion, the types of land use planning and zoning decisions occurring along the world’s coastlines have significant implications for long-term resilience in coastal communities.

Different parts of the United States coastline have different levels of susceptibility to sea level rise. Pendleton et al. (2010) identify 22 variables, including tidal pattern, wave pattern, and geomorphology, that affect how susceptible a coastline is to this threat. Their statistical analysis of these variables finds that North Carolina’s physical features give it an above-average level of risk due to sea level rise, as compared to other parts of the United States (Pendleton et al, 2010). Drawing back to our research, this work further demonstrates that proper land use planning and zoning policy holds particular gravity for communities in our study area.

The broad conclusions of Pendleton et al. are further bolstered by Bhattachan et al. (2018), who examine the geophysical and political characteristics of rural coastal North Carolina. Bhattachan et al. demonstrate that remoteness, isolation from central planning agencies, and poverty make many rural coastal regions distinctly vulnerable to sea level rise. These conditions are characteristic of coastal North Carolina. For example, the Albemarle-Pamlico Peninsula, which is just north of Dare County, is both socioeconomically-vulnerable and is comprised largely of wetlands and low-lying farmland and forests; the flat peninsula already experiences inundation during storms and saltwater intrusion, which is only expected to worsen and will
impact plant/animal life and human communities (Bhattachan et al, 2018). Thus, climate change adaptation in our study area is inherently constrained and framed by the geomorphology of the land where these communities exist.

Methods

The findings from the literature review informed the policy categories and questions for the land use planning section of this study’s policy catalogue. Most of the information on land use and zoning came from CAMA management plans and town and county ordinances at municode.com and amlegal.com (American Legal Publishing Corporation). Town ordinances generally included the relevant information in a small handful of sections, generally with similar section headings. Many of the towns used very similar, often identical, language for the policies we examined. Our coding process was iterative; if we found a new policy that we had not been coded in the towns and counties we had already looked at, we returned to recode communities we had already completed. For example, partway into our information gathering, we discovered that some towns had their own floodplain administrator and some towns relied on the county-level floodplain administrator. We then went back and made sure to document in each town in our study, including the towns for which we had already filled in our columns, whether “the floodplain administrator” was referring to either the town floodplain administrator or a county floodplain administrator.

Coding

We expanded our first Land Use Planning & Zoning spreadsheet, which had eight columns each containing a question, into a simplified coding spreadsheet with 21 questions. A total of 19 of the 21 questions were “yes/no” questions, one question asked for a year, and one
question asked how many “yes” responses out of a possible 19 each government entity had earned. The following is a list and brief description of each of the 21 questions that we asked.

1. **What year was the CAMA land use planning document last updated (As of December 2019)?** We looked at CAMA land use plans for each of our government entities to understand the types of land use planning decisions they were making. The age of their plan informs us how much of a priority land use planning and zoning is to each community, as well as how up-to-date their planning information is.

2. **Does the entity have a floodplain development permit?** A large part of our study area relied on a “floodplain development permit” to help their government plan for flooding-related planning and zoning. We wanted to include the permit in our simplified spreadsheet.

3. **Does the entity have its own floodplain development administrator?** The floodplain development permit is generally managed by a “floodplain development administrator.” Some towns manage the permit themselves, while others rely on the county-level floodplain development administrator.

4. **Does the entity have building removal regulations?** In light of the relocation of the Cape Hatteras, North Carolina lighthouse within our study area, we included a question about building removal policy.

5. **Does the entity consider climate change in planning?** We awarded a “yes” to communities if their planning explicitly took into account climate change’s direct effects, even if they did not explicitly use the phrase “climate change” or “global warming” in their planning documents or ordinances. We awarded a “sort of” if, for example, a town
acknowledged climate change or its direct impacts but did not include either in its future planning.

6. Does the entity encourage stormwater BMPs? Stormwater best management practices (BMPs) such as pervious surfaces can help manage flooding regulations. Many towns and counties in our study included language regarding BMPs in their respective ordinances. Towns could earn a “yes” in this category by either recommending or requiring BMPs.

7. Does the entity require a stormwater management plan? While some government entities in our study were thinking about stormwater BMPs more broadly, others explicitly codified a stormwater management plan, either in addition to or instead of general stormwater BMP regulations.

8. Does the entity have a sand moving requirement that is unique from higher government entities? While state and federal environmental laws such as CAMA regulate sand removal, some government entities in our study area codified additional strict sand removal regulations.

9. Does the entity require a land disturbance/site plan? Many government entities in our study required a land disturbance or site plan for new development. These plans considered how a project would affect the land surrounding the development.

10. Does the entity have buffer zone requirements that are unique from higher government bodies? Some parts of our study area had explicit regulations relating to buffer zones around freshwater or saltwater water bodies. Buffer zones are relevant to land use planning and zoning because they preserve water quality, limit where development can occur next to flood-prone areas, and slow erosion.
11. Does the entity have subdivision regulations that are unique from the state of NC?  

Most government entities in our study had the same general subdivision regulations, likely borrowing from a state or federal government regulation. In addition, some communities had additional land use planning regulations for subdivisions, most commonly relating to flooding considerations.

12. Does the entity have Planned Conservation Development Areas? One community in our study area had a Planned Conservation Development Area, which demonstrated a commitment to slowed development affected the land use planning and zoning of that town. We wanted to reflect this unique policy in our coding scheme.

13. Does the entity have development requirements for other buildings (cemeteries, hospitals, etc.)? One community in our study area had explicitly codified additional planning requirements for certain types of development that take up large areas of land. We wanted to reflect this unique policy in our coding scheme.

14. Does the entity have a vegetation removal permit? Vegetation is a useful and commonly used tool in slowing down erosion of coastal land in North Carolina and elsewhere (Berry et al., 2013; Shelton, 2011). For this reason, we asked if communities are adding their own regulations on vegetation removal on top of any regulations that exist in state or federal statute.

15. Does the entity have its own land use administrator? One community in our study area had designated a land use administrator in addition to a floodplain administrator. We wanted to reflect this unique policy in our coding scheme.

16. Does the entity have other water quality regulations? Land use planning and zoning decisions affect the quality of a community’s waterways. While water quality does not
explicitly affect a community’s ability to respond to climate change, noting additional
water quality measures was an important measure to holistically codify land use
planning and zoning.

17. **Does the entity have hardscaping regulations?** Hardscaping is more of an adaptation
technique than a land use policy, and is more thoroughly covered in the Coastline
Adaptation section of our project. Nevertheless, it is a land use planning decision to try
to reinforce land from eroding.

18. **Does the entity have a floodplain district?** In addition to National Flood Insurance
Program flood maps, a few communities in our study area had designated their own
floodplain districts. We wanted to reflect this unique policy in our coding scheme.

19. **Are there zoning restrictions on developing in/near coastal zones that are unique
from higher government bodies and other columns in this chart?** This question is a
catch-all for any other coastal policies that other columns in our simplified spreadsheet
had not codified, but for which we decided to not make an additional column.

20. **Are there zoning restrictions on developing in/near floodplains that are unique from
higher government bodies and other columns in this chart?** This question is a catch-
all for any other flooding-related policies that other columns in our simplified
spreadsheet had not codified, but for which we did not make an additional column.

21. **Total Yes (Out of 19).** Totaling up the number of “yes” answers for each town and
county helps illuminate which communities have more land use planning and zoning
regulations. It is not a perfect metric because some towns go above and beyond what
qualifies as a “yes”, and some questions are more encompassing land use planning and
zoning metrics than others.
Results

The figure below demonstrates the final simplified coding spreadsheet and the policy outcome results from each county and town.

<table>
<thead>
<tr>
<th>Government Entry</th>
<th>What year was the CADA land use planning document last updated (As of December 2019)?</th>
<th>Does the entity have a floodplain development permit?</th>
<th>Does the entity have its own floodplain development administrator?</th>
<th>Does the entity have building removal regulations?</th>
<th>Does the entity consider climate change in planning?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dane County</td>
<td>2009</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Duck</td>
<td>2005</td>
<td>Yes</td>
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Figure 3. Land Use Planning and Zoning Simplified Coding

Discussion

As our results section illustrates, the three counties in our study have a wide variety of land use planning and zoning policies. We observe several commonalities, as well as several interesting patterns developing in the coding scheme of our study area. This section offers a descriptive overview of our results section, while later sections of the paper analyze our findings.

Our findings demonstrate that there are a number of policy commonalities across these communities, as well as a few exceptional townships. Based on its depth and breadth, Wilmington has the most comprehensive land use planning and zoning policy response to changing coastal hazards. Nags Head also demonstrated significant strength in these planning areas. In our first catalogue column, these communities’ CAMA plans are most recently updated between 2005 in 2019. All but three towns have their own floodplain development permit, and all but four towns have their own floodplain administrator. 15 of 24 government entities have
building removal regulations on the books. Only 6 communities earn a “yes” for considering climate change in land use planning and zoning, although an additional 4 communities “sort of” take climate change into consideration. We are particularly concerned that more than half of the communities in our study area do not even correctly and fully identify the problem that justifies their taking action.

Towns do better in terms of flood control policy, but not perfectly. 17 of 24 communities at least encourage stormwater Best Management Practices, and 16 of 24 have stormwater management plans, although there is not complete overlap. Only two communities have their own sand moving regulation. Nine of our 24 communities require either a land disturbance plan or a site plan. Only four communities require buffer zones around waterbodies. Exactly half of the 24 communities have additional land use planning and zoning regulations on subdivisions. Only one community in our study has set up Planned Conservation Development areas.

Only one community in our study, Nags Head, has its own land use planning-related development requirements for entities such as hospitals and cemeteries. Three of 24 communities have a vegetation removal permit, and only one community has a land use administrator. Our chart shows that seven communities have additional water quality regulations. Only two communities have regulations for hardscaping. This does not mean that only two communities have hardscaping, as the Coastline Adaptation section of this paper demonstrates. It simply means that hardscaping is an uncommon mitigation response and that it is not strictly regulated at the community level.

Most of these communities fall somewhat short of what our research indicates is a thorough land use management response to changing coastal hazards. Many of our policy questions only had a handful of communities earning a “yes”, which means a lot of communities
are not doing as much as they can to manage the deterioration of the quantity and quality of developed and developable land. Taking a more optimistic look, this means there is potentially room for communities to learn from each other and bolster their land use planning and zoning responses. Every community in our study area might benefit from looking at our simplified policy code, referencing back to our more elaborate policy spreadsheet, and studying where their respective policy response lacks depth and breadth when compared to the policy response of other communities.

IX. Septic System Management

Introduction

How coastal communities manage household septic tanks and drainfields is a key variable of interest in assessing local policy responses for addressing sea level rise. As sea levels continue to rise due to climate change, the septic systems that support coastal households become increasingly imperiled. And when these systems are compromised (either by inundation or storm damage after tank exposure), the bacteria and viruses from the septic waste can easily contaminate both the local water supply and nearby coastal waters. Previous research has noted that the risk to North Carolina’s household septic tank systems is “particularly acute,” not least because of unsuitable soil conditions, relatively high water tables, and local officials approving these systems notwithstanding such serious constraints (Duda and Cromartie, 1982). Upon surveying Carteret, Dare, and New Hanover counties in North Carolina, we found guidance (i.e., ordinances, regulations, or permitting requirements) for septic tank management at the town-level to only periodically deviate from county-level requirements. These county-level
requirements, in turn, tended to recapitulate NC state requirements—with a few notable exceptions (see Discussion section).  

Literature Review

Septic tank drainfield failure contributes to coastal pollution from septic leakage, which constitutes both an environmental and a public health threat. These effects, in turn, can have negative economic impacts on the commercial fishing industry (in North Carolina, this is especially true of the shellfish industry) and on beach tourism (Duda and Cromartie, 1982; Riggs et al., 2011). Duda and Cromartie (1982) reviewed NC DEQ’s water quality investigation, and established a significant, negative relationship between watershed septic tank density and “acceptable water quality” in New Hanover County. “Common sense” management practices, like preserving “sufficient undeveloped areas in each tidal watershed” and only siting septic tanks in “suitable soils,” would correct existing septic tank problems. These precautions could prevent future water contamination, and could mitigate the negative effect of septic tank failure in the event of severe storms or natural disasters.

There appears to oftentimes be a tension between economic incentives and proper regulation and enforcement of septic tank management. Local officials can be categorized, broadly, into two coalitions: (1) “localist” decision-makers, who tend to write off coastal environmental problems as “not clearly linked to local land use”; and (2) “environmentalist” decision-makers, who tend to see “land use policy decision . . . [as] a primary source of . . . continuing resource decline, particularly with regard to . . . septic problems, and shoreline development” (Norton, 2005). DeMarco (2007) notes that there is a “visible disconnect” between

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4 Septic system state requirements are covered under the Sanitation Rules .1901-.1968 of Title 15A Subchapter 18A of the NC Administrative Code. This is represented as “15A NCAC 18A .19XX” where XX ranges from Rule 01 to 68. For instance, specifications on the local of sanitary sewage systems (including septic tanks) is found at 15A NCAC 18A. 1950.
local attitudes toward preservation/conservation of the environment and “actions encouraging development.” There is much “leeway . . . given” with regards to permit authorizers’ consideration of size and septic limits in favor of economic development (DeMarco, 2007). Local planners oftentimes prioritize economic development over sound, responsible septic system planning and management. And this should come as no surprise, given the myriad of budget constraints and immediate priorities that local officials face as they weigh municipal development over risk-averse environmental protection.

Septic system damage is often a vicious cycle. In the aftermath of severe storms, homes suffering septic system damage are “condemned” until those systems can be “temporarily repaired or reburied in the sand.” However, this temporary repair and reburial only lasts until the next storm, whereupon they are “torn apart again” and “repeatedly expose[d] and [broken]” (Riggs et al., 2011). This suggests that septic system damage has lasting consequences until comprehensive, structural reforms are made to the systems.

The literature offers several suggestions about what constitutes improved septic system placement and design. Riggs et al. (2011) notes that many coastal homes and septic tanks are only in the surf zone, but are also well within the public domain even at low tide due to sea level rise. The overriding implication is that these homes’ septic systems should be relocated to safe areas that are not a high flood risk. Cox et al. (2019) recommend “changing the water infrastructure,” with property owners “invest[ing] in more resilient and efficiency wastewater treatment options.” Other authors conclude that there is a “clear case for improving the design and sizing of individual [septic tank systems] so that when systems fail, the contaminants can be attenuated in the subsurface before entering surface and groundwater” (Geary and Lucas, 2019). A recurrent theme is advice to adopt and maintain “adequate vertical and horizontal buffer
distances from groundwater” and to “[prevent] . . . drainfields from being hydraulically interconnected to freshwater creeks and tidal waters” (Geary and Lucas, 2019; Duda and Cromartie, 1982). In short, septic tank permitting should be a more rigorous process that is informed by science, geography, and foresight into what challenges a future world with climate change will bring.

The aforementioned findings warranted inclusion of septic system management in our research. Not only are coastal septic systems likely to be damaged severely by sea level rise; they are representative examples of mismanaged coastal infrastructure that is unprepared for impending sea level rise. Septic system failure is both an economic disaster (i.e., it negatively impacts property values as well as the commercial fishing industry/tourism) and an environmental/public health crisis due to water contamination.

Methods

We asked seven major “yes/no” questions (discussed in Coding section, below) in the septic system management category. We found information on septic system at the county/town level in government document archives, meeting minutes, memos, planning documents, PowerPoint presentations, county or municipal codes/ordinances, and on webpages themselves. Our final spreadsheet of information for local septic systems excluded two questions which turned out to be irrelevant, namely: (1) the depth of the system, and (2) the maximum age of the system. We also expanded our “lot size requirement” question, which was too broad, to two questions: (1) lot size requirement, and (2) lot size restrictions. This enabled us to gain a better understanding into how local communities think about controlling septic system lot sizes.
Coding

“Yes/no” answers are color coded in a “green/red” binary. Likewise, “N/A” and “unclear” answers warranted a gray color code for the box, and “maybe” warranted a “yellow.” Note that the word “unique” is used here to mean any requirement that is “apart from those that exist at the state/federal level” (bolded in Q1). Our questions are as follows:

1. **Does the town/county make mention of unique specifications (apart from those that exist at the state/federal level)?** Our search for “specifications” is purposely generalized. This allows us to capture any top-level information about what might make our county/town comparatively exceptional in septic system management.

2. **Does the town/county have a unique lot size requirement?** If the county/town has any unique lot size requirements, it may indicate that they have put thought into augmenting state/federal guidance on the suitable lot size for septic tank systems for their area.

3. **Does the county/town have a unique lot restriction?** If the county/town has any unique lot restriction, it may indicate that they either (1) are proactively restricting septic tank system areas to places that are not as vulnerable to sea level rise, or (2) have special circumstances (e.g., soil, geography) that would cause them to need lot restrictions.

4. **Does the county/town have unique maintenance requirements?** Is there mention of any maintenance requirements at all beyond those that exist at the state/federal level?

5. **Does the decision-maker differ from officials at the county health department?** For this question, we’re interested in determining where power resides at the local level on authorizing septic systems. If a town has a locally designated individual, this may mean that it exercises more discretion over its septic system planning.
(6) **Is there a requirement for renovation other than a permit from the county health department?** While permit requirements are routine, is there any further guidance or any steps that need to be followed in order to replace, upgrade, or expand one’s septic tank.

(7) **Does the town/county have any credit offerings to incentivize improvements?** We noticed early on that some places discussed implementing a credit/loan program for maintaining or improving septic tanks. Is this a prevalent practice?
### Results

The figure below demonstrates the final simplified coding spreadsheet and the policy outcome results from each county/town.

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<th>Does the town/county have a unique lot restriction?</th>
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<th>If so, what?</th>
<th>Does the county/town have unique maintenance requirement?</th>
<th>If so, what?</th>
<th>Does the decision maker differ from officials at the county health department?</th>
<th>If so, who?</th>
<th>Is there a requirement for renovation other than a permit from the county health department?</th>
<th>If so, what?</th>
<th>Does the town/county have any credit offerings to incentivize improvements?</th>
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<td>2</td>
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<td>No/R</td>
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<td>No/R</td>
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**Figure 4. Septic System Management Simplified Coding**
Discussion

Overall, coastal communities are underprepared for climate change and sea level rise’s future effects on septic systems. Information/guidance on septic systems in most towns and even at the county level (in the case of New Hanover County) is sparse. It appears most coastal areas are going through the motions or simply “checking the box” when it comes to managing their septic systems. This is supported either by explicit statements (e.g., viewing sea level rise as a threat to the local economy, mentioning that there are no septic system maintenance requirements), or is communicated implicitly by the lack of any meaningful guidance on septic system management.

At most, individual towns have three or four “yes” responses to the seven questions. Five towns have zero “yes” responses to the questions. No towns have unique maintenance requirements (Kill Devil Hills “supports periodic or regular inspections,” but there is no guidance or enforcement; KDH Board of Commissioners, 1999). Only one town offers credit to incentivize improvements (Nags Head through the Septic Health Initiative).

The most important questions of the seven were the first (“Unique specifications?”) and the fifth (“Different Decision-Maker?”). These two questions, at a glance, tell us much about how the county or town is managing their septic systems.

Seven out of the 21 towns in the three counties have unique specifications apart from those that exist at the state/federal level. There is a great amount of heterogeneity in these specifications ranging from compliance or approval requirements of septic sites (e.g., Kill Devil Hills, Kitty Hawk, and Cape Carteret) to soil characteristics requirements (e.g., Beaufort and Emerald Isle). At the county level, Carteret County has specifications on the depth of septic tank drainfields in relation to the water table (“Minimum 12 to 18 inches separation between bottom..."
of trench and groundwater”) that exceed state requirements under Title 15A Subchapter 18A of the NC Administrative Code (Carteret County Health Department, n.d.). This tells us, at a glance, that these towns and counties have augmented guidance that already exists at the state/federal government based on their specific locations and needs. Proactively recognizing, and enforcing, soil suitability requirements can do much to prevent catastrophic damage to septic systems in severe floods or storms (Cox et al., 2019; Geary and Lucas, 2019).

Six out of the 21 towns in the three counties have a decision-maker on septic system siting and approval that differs from an official at the county health department:

1) **Nags Head**: Planning & Development Department

2) **Cape Carteret**: Local permit officer

3) **Morehead City**: Soil scientist or land use administrator

4) **Carolina Beach**: Floodplain Administrator

5) **Kure Beach**: Floodplain Administrator

6) **Wrightsville Beach**: Floodplain Administrator

A town having its own, local decision-maker apart from officials the county health department signals that it is capable of siting and permitting septic systems entirely at its own discretion (though within reason). While not per se signifying that the town is using this discretion to its advantage by issuing permits responsibly, it is an indicator that the town has the authority to be selective on where it allows septic system to be constructed, and hence where buildings are placed on its coastline.

Of the five towns which were most proactive on septic system management (defined as having three or four “yes” responses to the seven questions), two were in Dare County, two were in Carteret County, and one was in New Hanover County. This is consistent with the fact that
Dare and Carteret County had the most county-level “yes” responses (three and two, respectively, versus one for New Hanover County). This also means that, to the extent that townships also govern under the purview of their county-level requirements, we would expect towns in Dare and Carteret County to be especially proactive relative to New Hanover County.

The most proactive towns were:

- Kill Devil Hills (Dare) – Three yes’s
- Nags Head (Dare) – Three yes’s
- Cape Carteret (Carteret) – Four yes’s
- Emerald Isle (Carteret) – Three yes’s
- Wrightsville Beach (New Hanover) – Three yes’s

All else being equal, these five towns have the most unique guidance and/or regulations for their septic systems. This does not guarantee that these towns are the most proactive on septic system management, but it does indicate that they might be hotspots for policy action on this front.

X. Case Study: Nags Head, NC

Background and Demographics

Nags Head, North Carolina has a national reputation as a leader and an innovator among coastal communities—and especially among those of a similar size—in its policy response to changing coastal hazards (Shaw, 2018). The Nags Head town planner, as well as others, have been recognized by outside groups for their contributions when responding to sea level rise at the local level. In addition, other communities have cited Nags Head as the catalyst for planning and adaptation decisions being made in their communities (Shaw, 2018).
Until our research, however, there have not been any endeavors to thoroughly comb through Nags Head’s planning, policy by policy, to see if the town is truly ahead of the curve on coastal resilience. In compiling our catalogue, analyzing the three study counties and their towns, and reviewing overall takeaways, it became apparent that Nags Head’s strategy does not perfectly conform to what is recommended in coastal adaptation literature. However, the town did stand out as one of the top innovators in the study space. The following section outlines some of their strategies.

Overview

Nags Head is located on Dare County’s Outer Banks, a region of barrier islands located in the northeastern part of the state. Nags Head is a historic town with a long-standing tradition of being a tourist destination. While fewer than 3,000 people live in the town year-round, during the summer months the town’s population increases to nearly 40,000 (Town of Nags Head, 2017). The town is located at the entrance of the Cape Hatteras National Seashore, and has eleven miles of barrier island oceanfront—the most shoreline of any municipality in Dare County (Town of Nags Head, 2017). While these two facts make Nags Head a popular vacation spot, they also make it especially vulnerable to changing coastal hazards such as increasing and intensifying storms, erosion, and sea level rise. For example, Nags Head’s beaches are eroding at an accelerating rate—currently six feet per year (Bennett, 2018).

Nags Head’s demographics reflect both its geography and economy. As of 2017, the town’s permanent population was 2,855, with a median age is 44.3, median household income of $56,875, and median property value of $319,300 (DataUSA, 2017). The town’s permanent residents are 92.1% White/Caucasian, 3.26% Two or More Races, and 1.26% Hispanic or Latino; common occupations are in the “accommodation and food services” and “health care and
social assistance” industries (DataUSA, 2017). Nags Head has a higher number of white people and a higher household income than the state and federal average, and a long right tail when examining the distribution of property values (DataUSA, 2017). Taken together, Nags Head’s demographics support the idea that the town is made up of a largely white, working-class population supporting a middle- and upper-class seasonal tourist population.

Adaptation

In terms of adaptation, the Town of Nags Head is taking a lead on resilient development at the local level. Aside from falling under the Outer Banks regional plan, Nags Head launched its FOCUS Nags Head project in 2015 (FOCUS Nags Head, n.d.). This project is intended to convert the town's land use plan into a “comprehensive plan,” and to revise existing ordinances into a "unified development ordinance" (UDO; FOCUS Nags Head, n.d.). The first phase of the project, the Comprehensive Plan, was adopted in 2017 and seeks to address climate change and sea level rise, the impacts of which "present potentially enormous challenges to municipalities around the world, especially those with a close connection to the ocean like Nags Head" (Town of Nags Head, 2017). The town explicitly recognizes the necessity of preparing for future hazards in the present moment; the plan includes up-to-date climate science and describes an adaptation study in partnership with North Carolina Sea Grant, which subsequently created a Vulnerability Consequences and Adaptation Planning Scenario (VCAPS; Town of Nags Head, 2017a). As part of VCAPs, community members are invited to engage as part of the resiliency process and apply local knowledge to confront adaptation challenges (Town of Nags Head, 2017b). An education initiative will involve outreach to K-12 students and residents/property owners to promote efficacy in mitigating and adapting to coastal hazards (Town of Nags Head, 2017a).
Beach Nourishment

In addition to these initiatives, the town is deploying updated management goals and plans for various resilience issues, including those addressed via the research questions in this study. Beach nourishment and related dune nourishment are noted as primary adaptation options. In 2011, the Town of Nags Head executed the largest locally-funded beach nourishment project in United States history, nourishing around 10 miles of beach with 4.6 million cubic meters of sand (Town of Nags Head, 2017); this was followed most recently by a joint county- and town-funded project completed in 2019 (2019 Beach Nourishment—Complete, n.d.). Beach nourishment maintenance and dune stabilization projects such as sand fencing and vegetation will continue in an ongoing process as part of the Town's 30-year shoreline management plan (Town of Nags Head, 2017a). The management plan is based around past goals to simply replace sand lost to erosion, protect against storms, and maintain an overall aesthetic and "recreational beach width;" however, the Town notes in the FOCUS report that there is now the additional consideration of a design parameter to specifically address sea level rise (Town of Nags Head, 2017a). The FOCUS plan also acknowledges that at some point beach nourishment will no longer be a viable economic option; however, Dare County and the Town of Nags Head collectively have enough financial resources to accomplish nourishment for the foreseeable future (Town of Nags Head, 2017a).

Gray Infrastructure vs. Natural Resilience

Though Nags Head falls under state-level prohibitions on oceanfront hardened infrastructure, the town also explicitly discourages gray infrastructure projects under FOCUS policies and actions. Under their shoreline management section, the town outlines the need to "prevent the use of sandbags, seawalls, bulkheads, and other hard structures as an approach to
erosion protection for private property;" the plan does, however, note that public protection projects such as terminal groins (which may be exceptions to state-level rules) may be considered as integral to community-wide erosion abatement (Town of Nags Head, 2017a). For inland waters and estuarine environments, the plan lists bulkheads and rip-rap as the current primary methods for protection (Town of Nags Head, 2017a). However, the town presents "soft" stabilization measures as potentially being more effective, preserving the function of natural marshes and shorelines while still preventing erosion. The plan explicitly touts the ability of estuarine areas to filter runoff and buffer storm impacts, and notes that Nags Head should explore living shorelines in areas where they can be successfully implemented (Town of Nags Head, 2017a).

Structural Relocation and Retreat

Nags Head notes that structural relocation is a part of their long-term shoreline management plan and lists "relocation of buildings," along with modification/floodproofing of high-risk structures, as a resiliency and mitigation strategy (Town of Nags Head, 2017a). The town also uses the jurisdiction of various state and local regulations, as well as legal processes through the court system, to remove the storm damaged structures that are increasingly threatened by erosion (Town of Nags Head, 2017a). Overall town retreat from the coastline does not seem to be a considered option at this time; however, the FOCUS plan notes that earlier land use planning encouraged a policy of retreat, and frequent removal and relocation of structures was considered a smart adaptive action (Town of Nags Head, 2017a). The Town received significant pushback from property owners who were unwilling to remove their structures, despite threats of significant damage and inundation. Given the complications of a retreat strategy, the Town shifted gears in its land use planning in the 1990s and directed more
significant funding and action toward beach nourishment (see prior section; Town of Nags Head, 2017a).

*Land Use Planning & Zoning*

Nags Head has one of the more robust land use planning and zoning policy responses in our study area, in both depth and breadth. It earned 11 out of a possible 19 “yes” answers in the simplified land use planning and zoning policy catalogue (see Figure 3). Furthermore, Nags Head has a sophisticated policy scheme that goes beyond earning a “yes” in many categories, and has several policies that no other community in our study possesses. It is our judgment that Nags Head has the second most comprehensive land use policy scheme in our study area, trailing only Wilmington.

Working from left to right in the simplified policy spreadsheet, Nags Head has many exceptional policies when compared to the rest of our study area (see Figure 3). Like most communities in our study area, Nags Head has a floodplain development permit and a floodplain administrator. The third question, on building removal regulations, is where Nags Head begins to differentiate itself from other communities in our study. While many other communities have a regulation on building removal that is nonspecific to changing coastal hazards, we observed that Nags Head has a codified section on how to relocate, and how to destroy buildings that are being threatened by sea level rise. A CAMA permit, a town building permit that includes general safety precautions about items like electricity, and a list of procedural steps are all required under Section 10-153 and Section 10-212, respectively (Nags Head Unified Development Ordinance, 1990; § 6-97, § 6-98).

Nags Head is a leader in some columns, but is not a leader in all categories. For example, it earns a “sort of” for climate change. The town acknowledges thermal expansion of oceans is
causing sea level rise, but "is conscious that sea level rise is a natural process" (Town of Nags Head, 2010, p. 38). Nags Head is relying on North Carolina to study the effects of global warming on its behalf (Town of Nags Head, 2010). While there is a middling acknowledgement of man-made climate change in their most recently-published land-use plan, Nags Head’s UDO (still in the draft stage at the time of our research) may yield more climate discussion.

Like most of the communities in our study with more robust policy schemes, Nags Head encourages stormwater best management practices and also requires a stormwater management plan. As an example of a stormwater BMP, Nags Head requires that development on filled-in wetlands must be able to support the tidal and flood stresses it is exposed to (Nags Head Unified Development Ordinance, 2019, §10.44.3.1). Like all but one other community, Nags Head does not have a sand removal requirement in addition to the restrictions put in place by state regulation under CAMA (Coastal Area Management Act, 1974). Nags Head does, however, require a land disturbance permit and a site development plan for qualified new development (Nags Head Unified Development Ordinance, 2019). Nags Head is a leader in this area among our study sites. Nags Head does not have buffer zone requirements that are different from higher up government entities; only four communities in our study did so. Nags Head has its own subdivision requirements (Nags Head Unified Development Ordinance, 2019). Like all but one community, Nags Head does not have Planned Conservation Development Areas.

Nags Head generally has very robust development requirements for building in climate-change vulnerable area. For example, Nags Head is the only community in our study that has its own unique development ordinances for entities such as cemeteries and hospitals. The town requires that no cemeteries in are located in FIRM flood hazard areas (Nags Head Unified Development Ordinance, 2019, § 8.5.4.6.1) 9.37.9.4. In addition, it requires that for hospitals,
“the hospital building or any accessory building shall not be located in any special flood hazard areas inundated by the 100-year flood” (Nags Head Unified Development Ordinance, 2019, § 9.37.9.4). Nags Head does not have its own vegetation removal permit or its own land use administrator. It does, however, have some of the more stringent water quality regulations in our study area. Nags Head does not have codified requirements for hardscaping, and it also does not have a floodplain district. Nags Head does, in fact, have additional zoning restrictions on developing near coastal areas and near floodplains. For example, generally speaking, its bureaucratic chain of command has been granted a much higher number of potential vetoes on new development than is afforded most communities we looked at for this project (Nags Head Unified Development Ordinance, 2019).

While not all communities in our study area have the financial and human resources that Nags Head’s tourism revenue and tax base afford, other coastal towns may still benefit from learning what works in Nags Head, and considering similar, feasible solutions for their community. Though far from perfect, in general, Nags Head has a more robust land use planning and zoning policy scheme than most of its neighbors. In the Land Use & Planning Results section, it earned 11 out of a possible 19 “yes” responses in our policy spreadsheet. This number does not capture the depth of some of its “yes’s.” However, this number means that in more than 40% of the policy questions we asked, Nags Head does not meet the policy response of another community in our study area. While it is taking many actions to combat changing coastal hazards, Nags Head still has a lot more it can do to protect its citizens.

Septic System Management

In terms of septic system management, Nags Head’s performance is a mixed bag. For instance, on one hand, Nags Head specifically states that the town does not mandate any specific
requirements to “maintain or repair [septic] systems after they are installed.” On the other hand, Nags Head stands out as the only coastal community of those sampled to sport a rather progressive credit offering program called the Septic Health Initiative (Town of Nags Head, 2019a).

Even though Nags Head does not have specific specifications requirements for system maintenance or renovation, it does have thorough guidance on how residents should care for their systems as they age. The town warns that “[septic] system can naturally fail due to age, overuse through high occupancy, or improper use” and that they must “be maintained in order to function properly and extend the life of the system” (Town of Nags Head, 2019a). The town then provides a detailed five-step walkthrough of how to inspect and pump one’s system. Nags Head offers free septic tank inspections and recommends that residents hire a licensed contractor to pump it if such care is necessary (Town of Nags Head, 2019b).

Nags Head does not stipulate any septic system lot size requirements or restrictions beyond what is provided for in the NC state guidelines under 15A NCAC 18A .1950. It does provide a helpful chart that shows residents how often they should pump their septic system based off the size of the system (in gallons) and the number of people in the residence (Town of Nags Head, 2019b).

Nags Head has offered a voluntary program to property owners since 2000 called the Septic Health Initiative. The initiative offers “free services and financial assistance” for having septic systems “pumped out, repaired, or replaced.” Nags Head offers an incentive of a $30 credit on residents’ water accounts upon pumping their system, and the town “offers low-interest

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5 Even though no other towns/counties have maintenance requirements either, the fact that Nags Head goes out of its way to state that it doesn’t require any maintenance is noteworthy.
loans” for septic system repairs. The program is advertised through an infographic (See Figure 5, below) (Town of Nags Head, 2019a).

![Infographic: Septic Health Initiative](image)

**Figure 5. Towns of Nags Head: Septic Health Initiative (Town of Nags Head, 2019a)**

Nags Head advises its residents that “[it is] cheaper to maintain a system than pay for a new system,” pointing out that replacements generally cost around $300 compared to the thousands of dollars that a full replacement would cost.

Nags Head’s Septic Health Initiative represents a proactive mindset that encourages local community members to be a part of the solution on septic system management. It blends together positive incentives (free inspections, credits, and low-interest loan offerings) and clear information on why preventive care for septic systems is a superior alternative to no action. This encourages residents to take a long-term view of their septic system management.

At the town-level, this program signals Nags Head’s commitment to managing septic systems above and beyond what is mandated at the county and state-level. At a minimum, it indicates that Nags Head has thought proactively about how to manage its gray infrastructure for 20 years, and has decided that the benefits of offering financial incentives to residents for managing their septic systems outweighs the costs of the program. This type of proactive
planning is emblematic of the mindset that coastal counties need in order to adapt to changing coastal hazards.

XI. Discussion

Our project’s goal was to map policy response to sea level rise in Dare, Carteret, and New Hanover counties, ultimately bolstering the C-CoAST project and providing an easily-accessible database for community usage and planning. As we collected data for our client and adviser, we observed patterns in our policy mappings and each developed expertise in our respective policy categories. Though the scope and timescale of this project was not able to accommodate specific research into why communities are necessarily behaving as they are, we dedicate this space to briefly speculate on the varying observed degrees of preparedness. In addition, we make recommendations for how planners, policymakers, researchers and stakeholders can utilize and expand on the work we have performed and apply it to their community and region.

Several towns were standouts across all three categories, while other towns had a robust response in one category but a more lackluster response in other categories; in many other cases, communities largely just deferred to their county’s and state’s statutes. For example, one of the reasons we chose Nags Head as our case study is because it was a strong performer across the board in all three policy of our examined categories. Nags Head is taking action on climate-related coastal adaptation measures, is a leader in land use planning and zoning, and it has a model septic incentive system that communities around the United States might look to emulate. The Nags Head Town Planner is winning awards for her forward thinking (Shaw, 2018). On the other end of the spectrum, towns like Bogue and Peletier do not have any ordinances related to coastal hazards, and are deferring entirely to Carteret County. Likewise, the town of Kitty Hawk
is located a few miles up the coast on the same barrier island as Nags Head, and therefore has similar socioeconomic and geomorphic characteristics and faces many of the same coastal hazards. However, Kitty Hawk’s response to sea level rise, beach erosion, and strong storms is nowhere near as robust as that of Nags Head. As another example, New Hanover County and its municipalities, especially the city of Wilmington, are leaders among communities in our study area on land use planning and zoning, but have unremarkable coastline adaptation techniques and septic management policy.

Why do different communities have different policy responses to changing coastal hazards? Some possible explanations are political ideology, including dominant attitude towards climate change; the influence of individuals; socioeconomic factors; location; and geomorphology and geography. In general, eastern North Carolina is a fairly politically conservative area. Areas like New Hanover County, and especially the city of Wilmington, are closer to a politically neutral environment (Bloch et al., 2016). Likewise, pockets within our study area such as Beaufort, where the Duke, UNC, and NC State Marine Labs are located, also tend to be less conservative. On the whole, however, our study area is made up of conservative, largely white, working class voters (Bloch et al, 2018). Perhaps the dominant political ideology of the communities in our study area is influencing local politicians and government officials to be less forward-thinking when it comes to planning for changing coastal hazards. Likewise, perhaps these officials themselves believe that these hazards are not as severe as the science suggests, or that it is too politically costly to incur economic losses today for benefits in the future.

It is worth asking how much political ideology affects policy response to changing coastal hazards. Less than half of the communities in our study area explicitly mention climate
change in their CAMA planning documents, but is politically-influenced climate change denial or skepticism affecting community policy response? Are communities that do not acknowledge the reality of manmade climate change inherently falling short of a full policy response? Anecdotally, the communities that acknowledge climate change and its manmade cause generally have more robust responses to changing coastal hazards. However, there are a number of excellent policies being implemented in other communities as well. Even if community leaders do not believe that changing coastal hazards are the result of a systematic, global, manmade, climactic change, they still may be observing changes in their own community that prompt policy and management decisions that inherently respond to climate change.

In addition, communities that reside in low-lying coastal areas are likely to have policy responses to flooding, storms and erosion, because these problems would still exist (though to a minor extent). Climate skeptic community managers may therefore still have the tools to respond to climate change (without acknowledging it as such). Furthermore, as state and federal laws, regulations, and monies target counties and towns, these communities will have incentive to combat climate change because it makes sound legal and financial sense. For example, if the U.S. Army Corps of Engineers has been appropriated money to renourish beaches every few years, a community might still be interested in applying for a beach nourishment project even if the area leaders do not attribute erosion to “climate change.” Community leaders that do not believe in manmade climate change may tackle changing coastal hazards less aggressively because local planning and adaptation may not be the strongest policy priority on their agenda. However, it is an oversimplification to say that believing in manmade climate change is a prerequisite to proactively responding to changing coastal hazards.
Moving to another theory for policy differences between communities, the influence of individuals: we observe that Kitty Hawk and Nags Head have several similar socioeconomic and geomorphic characteristics, but have very different policy responses in our research categories. Perhaps the difference is as simple as the existence of a handful of forward-thinking and motivated individuals that happen to work in Nags Head. However, there may be other factors, such as financial capability, also affecting which communities are responding to changing coastal hazards. If researchers are studying certain communities more than others, heavily-researched areas are exposed to the sharing of ideas and the influx of grant monies that can be used to help develop an adaptation response.

In addition to outside financial assistance, the socioeconomic makeup of a community influences its tax base. A strong town or county tax base is typically necessary to support hiring planners for writing and implementing CAMA plans, floodplain administrators, grant writers for applying for state and federal grants, and lawyers for creating/implementing town codes and ordinances. Thus, towns with larger population sizes and robust tourism, such as Nags Head, are better financially-situated to develop and implement climate change adaptation policy (compared to other, less economically-advantaged communities). Furthermore, towns that are attracting the temporary or permanent inhabitation of non-locals are more likely to have a higher education level. This is not to say that people with a higher education know “better” how to respond to changing coastal hazards. However, people who have obtained a higher level of education may be more aware of the threats of climate change, more aware of the levers of civic engagement, and have more time to express their perspectives to decision-makers (i.e. job privilege allowing evening freedom to attend town halls, community meetings, etc.).
Location, geomorphology and geography may also play a factor. For example, Wilmington is the largest community by population in our study area, and as the only true “city” likely also has the highest percentage of impervious surface—at about 28 percent as of 2016 (Still, 2017). Wilmington is also one of the few communities in our study that is not located on the oceanfront, but rather sits on the estuarine Cape Fear River. For all of these reasons, it might make sense that Wilmington and New Hanover County are more worried about flooding and land use planning and zoning than they are about losing beachfront due to coastal erosion. Likewise, perhaps the reason Nags Head has the most robust coastal hazard adaptation response in Dare County is because it has the greatest amount of oceanfront coastline in the county (Town of Nags Head, 2017). If Nags Head was not located along the narrowest stretch of a barrier island, but instead had a different shape and was located at higher elevation, perhaps it would not have felt the need to so aggressively tackle the climate change threats facing coastal North Carolina.

Moving forward, the catalogue produced by this project is meant to set a concrete, baseline understanding of current local policies relating to coastal hazards in NC. As one of the first of its kind, we envision the policy catalogue being utilized by town planners and managers as a tool to evaluate their climate preparedness. For our adviser, Dr. Megan Mullin, and her C-CoAST research team, this project sets the stage for understanding how individuals, communities, local governments, and other groups are/should/can be creating a resilient existence. As that project moves forward and collaborates with local leaders, the towns in Carteret, Dare, and New Hanover Counties will now have an easily-understandable, systematic means of comparing their progress to those in the surrounding area. In the future, the catalogue may also prove useful beyond the scope of the study towns; other coastal regions in NC and
elsewhere may look to it as a foundational display of resilience and/or model their own catalogue and strategies off of our guide.

Using the policy catalogue to gauge development preparedness at a community level or to take note of others' actions may have the effect of allowing towns to emulate one another, enabling strengthened resilience overall. Local coastal planners who oversee adaptation policies can improve their own town’s policies by mimicking what “leader” towns and counties are doing in the policy realm for coastline adaptation, land use, and septic system management. For instance, a town like Manteo, NC, could consider revamping its septic system specifications to require property owners to perform routine maintenance on tanks (they do not currently), or it could consider inaugurating a credit offering program modeled after Nags Head’s Septic Health Initiative. NC coastal counties could also model their land use policies after a relatively exceptional town like Wilmington, NC, by having a designated floodplain district, having more stringent floodplain zoning restrictions (than what the state/county mandates), and having strict storm water management requirements [note: these are merely illustrative examples]. Lastly, on the point of adaptation, “laggard” coastal counties could model their adaptation policies after Nags Head by crafting town-specific plans, relying far less on gray infrastructure in favor of nature-based adaptation measures like living shorelines, or by seriously considering structural relocation altogether.

Finally, communities should not limit their policy innovation to the actions being taken in neighboring communities. To prepare for changing coastal hazards, towns and counties can form partnerships to learn from one another on which solutions work and which do not. Towns that have relatively retrograde policies can discuss the extent to which they could implement forward-looking policies, given their town’s unique circumstances. “Leader” towns and counties
could explain their reasoning behind implementing certain policies and procedures to defend against changing coastal hazards, and “laggard” towns and counties could determine which improvements are feasible in their own areas. Overall, our goal is that local policymakers will be inspired by the strategies of our catalogue and move forward to brainstorm additional policy and management ideas that work toward creating stronger, safer, more resilient coastal communities.
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