North Carolina Coastal Area Management Act (CAMA) Goal Analysis: Estuarine Shoreline Stabilization Permitting

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North Carolina's Coastal Area Management Act struggles to meet its legislative mandate of "preserving and managing the natural ecological conditions of the estuarine system" because regulatory hurdles discourage the implementation of natural shoreline stabilization, thereby undermining NC Division of Coastal Management's efforts to meet the first goal of CAMA. Several trends have led away from North Carolina's Coastal Management Act achieving its first goal. First, population along the coast of the United States has increased of the past few decades. Second, due to the population and coastal development increase, erosion has also increased along the estuarine shoreline. Lastly, bulkheads became the popular estuarine shoreline stabilization method against erosion, which only exacerbated the problem. Due to the increase in population along the coast of the United States, the leading industry is now tourism, driving the economy. Additionally, sea level rise accelerates coastal erosion, making it extremely important to the tourism industry along North Carolina's coast. Lastly, the popularity of bulkheads is due the permitting process for estuarine shoreline stabilization in North Carolina.

Under the status quo, North Carolina will become more populated and more developed along the coast. With more people and more development, this spells increased erosion. With the current permitting process for estuarine shoreline stabilization in North Carolina, bulkheads and other hardened structures will remain the popular option, exacerbating the erosion problem throughout the coastline. In order for the North Carolina Division of Coastal Management to uphold CAMA's first goal and encourage natural erosion control, it must reevaluate the permitting process currently in place for estuarine shoreline stabilization. Suggested alternatives are a fast track permit, a general permit, and a joint permit for natural shoreline stabilization methods.

The Flower Garden Banks National Marine Sanctuary and the Red Snapper

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The Flower Garden Banks National Marine Sanctuary is located one hundred miles off the coasts of Texas and Louisiana in the Gulf of Mexico and consists of three separate reefs: East Flower Garden Banks, West Flower Garden Banks, and Stetson Bank. The United States established the Flower Garden Banks National Marine Sanctuary in part to protect the reef habitat utilized by highly sought reef fish like the red snapper. Reef fish are an important part of the Gulf States' economies, making up approximately 18% of their commercial and recreational fishing industries. The red snapper relies on the reef habitat for shelter during the day and forages in the nearby muddy areas between the reefs at night. Over the past several years, scientists reported a reduction in reef fish sightings in all three reefs as well as an increase in coral bleaching events. Scientists believe the coral bleaching events are due to unseasonably warm water, pollutants, and even an influx of fresh water from the coast. The National Marine Fisheries Service and the U.S. Coast Guard suspect illegal fishing is the cause of reduced fish sightings, but scientists indicate habitat loss is also a major factor. The National Marine Sanctuaries Act provides Flower Garden Banks protection from commercial fishing and pollution through enforcement by the U.S. Coast Guard and National Oceanic and Atmospheric Administration. However, neither agency has the means to adjust the water's salinity or prevent the water from becoming progressively warmer each summer. One potential solution to help the red snapper adapt to a loss of their natural reef habitat is artificial reefs. Another solution is to include the 15-mile area located between East and West Flower Garden Banks as part of the National Marine Sanctuary. This action would help protect some of the red snapper stock from commercial fishing while they forage at night. The United States created the National Marine Sanctuaries Act to protect marine habitats critical to the survival of marine life, but these areas may require more protection than the government can offer. Scientists and policy makers must address the larger climate issue influencing the condition of the Flower Garden Banks reef system in order to protect the reef, the red snapper, and the Gulf Coast fishing industry. Ultimately, new adaptive measures are necessary to fulfill the original intent of the National Marine Sanctuaries Act.

Managing American Oystercatcher (*Haematopus palliates*) Population Growth by Targeting Breeding Season Vital Rates

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In populations of long-lived species, adult survival typically has a relatively high influence on population growth. From a management perspective, however, adult survival can be difficult to increase in some instances, so other component rates must be considered to reverse population declines. In North Carolina, USA, management to conserve the American Oystercatcher (*Haematopus palliatus*) targets component vital rates related to fecundity, specifically nest and chick survival. We assessed the effectiveness of such a management approach in North Carolina by creating a three-stage female-based deterministic matrix model. Isoclines were produced from the matrix model to evaluate minimum nest and chick survival rates necessary to reverse population decline, assuming all other vital rates remained stable at mean values. Assuming accurate vital rates, breeding populations within North Carolina appear to be declining. Combined nest and chick survival would need to increase from 0.14 to ≥ 0.27 to reverse this decline—rates which do seem attainable based on historical estimates. Our results are heavily dependent on assumptions of other vital rates, most notably adult survival, revealing the need for accurate estimates

of all vital rates to inform management actions. Our approach provides valuable insights for evaluating conservation goals for species of concern.

Morphological Modeling of Hatteras Island During Hurricane Isabel

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Coastal areas are being continuously affected by waves, currents, and sometimes extreme events such as storms during which high waves and storm surges cause overwash, flooding and erosion at the beach. One of the most powerful Atlantic Ocean storms was Hurricane Isabel that made landfall on NC Outer Banks on Sep 18, 2003 as category 2 hurricane and resulted in overwash, flooding, breaching, and infrastructure destruction in several spots along NC coast. Understanding beach behavior and coastal morphology evolution during storms improves forecasts and thus it helps emergency managers in taking better precautions during hurricane.

In this project, which is funded by NC Sea Grant, in order to explore storm impacts on coastal morphological changes a stretch of NC Barrier Island located between Avon and Salvo was modeled and the effect of hurricane Isabel on the beach evolution was investigated. For the simulation purpose we used XBeach which is an open-source tool for hydrodynamic and morphology modeling. The initial bathymetry and topography of the model was derived from Pre-storm LiDAR data and the data for wave properties and water level at the boundaries were extracted from coupled circulation-wave model ADCIRC+SWAN simulation. To improve the results, the effect of vegetation and various land covers were taken into account. Model results were compared to Post-storm LiDAR data and the volume of dune erosion and dune crest elevation change was calculated. The model will later be improved by coupling XBeach with the larger-domain model ADCIRC+SWAN which allows for dynamic feedback between the two models. XBeach passes updated bathymetry to ADCIRC+SWAN, which uses them to compute new boundary conditions. This information will be then sent back to XBeach. The model will later be improved by coupling XBeach with the larger-domain model ADCIRC+SWAN which allows for dynamic feedback between the two models. XBeach passes updated bathymetry to ADCIRC+SWAN, which uses them to compute new boundary conditions. This information will be then sent back to XBeach.

Eukaryotic Phytoplankton Community Spatiotemporal Dynamics as Identified Through Gene Expression within a Eutrophied Estuary

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Estuaries are highly dynamic and productive ecosystems, characterized by steep temporal and spatial gradients in physical and chemical properties. Phytoplankton play an important role in estuaries at the base of the food chain, although at times, may also contribute to the deterioration of water quality through forming dense blooms associated with toxin production and/or bottom water hypoxia. Thus a clear understanding of how phytoplankton respond to spatiotemporal environmental dynamics is necessary to ensuring healthy and sustainable ecosystems. Over the span of a year, we investigated the interactions between biotic and abiotic factors along a freshwater-to-marine continuum within the eutrophied Neuse River Estuary, NC. Through transcriptomic sequencing of eukaryotic plankton RNA in combination with other water quality measurements, we show that there are fundamental cellular processes that guide these interactions. In the upper estuary, phytoplankton allocate more transcripts to cellular component synthesis and carbon metabolism whereas in the lower estuary transcripts allocated to nutrient metabolism and transportation were most abundant, consistent with measured gradients in nitrogen availability. Our gene expression analysis also suggests that dominant eukaryotic phytoplankton functional groups are responding to their environment in marginally different ways, which may be in sync with their life-history strategies. We advocate for the use of RNA sequencing techniques within water quality monitoring programs as a way to examine the dynamics of the microbial communities within coastal waters and to provide a means of gathering information to enable better management decisions and practices.

OBX Stakeholder Values and the CZMA: What is 'Wise Use' and How Can We Achieve It?

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Over recent decades, development in the Outer Banks of North Carolina has become economically and socially driven by tourism. This industry is built upon the publics affinity to the region's natural resources, recreational opportunity and esthetic beauty. The research presented here critically examines the concept of 'wise use' of land and water resources as it applies to the U.S. Coastal Zone Area Management Act (CZMA) and North Carolina's Coastal Area Management Act (CAMA). Specifically, I focus on the definition of 'wise use' resource management in tourism-rich coastal communities like the Outer Banks. In this context, 'wise use' is management that achieves long-term balance between stakeholder values, which are inherently competitive because they rely on finite natural resources. Thus, balance between stakeholders is defined by the relative share of access to, participation in, and satisfaction with the political process.

Relevant stakeholders include year-round Outer Banks residents, second home owners, tourists, business owners, and local and state governments. A holistic evaluation of social, environmental and economic trends and conditions led to the conclusion that sustainable balance is not being reached between these stakeholders' values. Furthermore, a trend of decreasing permanent, working class residents in coastal beach towns is apparent. This can undermine the service and amenity-based tourism industry that these regions depend

on for economic growth. Additionally, an increasing trend in the volume of short-term visitors and second homeowners contributes to inconsistent job opportunities and financial instability that may discourage prospective or current year-round residents. Psychological detachment between people and place is also associated with tourism-rich areas and is linked to planning decisions that favor short-term benefit versus long-term sustainability. This mindset, coupled with power imbalances between economic versus environmental and cultural stakeholders, has created a planning structure that is failing to satisfy the 'wise use' of coastal resources mandated by CZMA and CAMA.

Economic growth at the expense of social and environmental well-being will likely increase seasonal employers' difficulty to staff their businesses and reduce the quality of services provided to increasing numbers of tourists, therefore rendering the Outer Banks less desirable to visitors and the coastal tourism market unsustainable. Due to the Outer Banks' capacity to generate enormous revenue through tourism, I argue that it is wisest for all stakeholders to advocate coastal development practices that preserve, protect and enhance the natural resources that substantiate both the tourism industry and environmental well-being, instead of pitting one against the other.

Goal of the Beach Act: Implications for Myrtle Beach, South Carolina

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Myrtle Beach, South Carolina has seen a decline in swimmable coastal recreational waters due to conflicting political values and failure to uphold coastal policies. South Carolina currently ranks as the 3rd worst state in the country for beach water quality. A part of the goal of the Beach Act of 2000 is for public safety in regards to coastal recreational waters. A beach notification system is to be established and maintained by the state if waters are not up to standard. Beach advisories or closures are issued if the bacteria in the water are too high which could cause a beach goer to contact a swimming related illness. Over the last five years bacteria levels have increased at Myrtle Beach's most popular beaches. Several beaches have been under long term swim advisories since 2007. The City of Myrtle Beach and Chamber of Commerce are focusing on businesses related ventures to increase tourism numbers instead of public safety. The City of Myrtle Beach is failing to meet the requirements of the BEACH Act of having safe coastal recreational waters because of a failing notification system and political agendas in Myrtle Beach; thereby undermining the BEACH acts goal to implement beach monitoring and notification systems to uphold public safety.

Quantifying Fecal Contaminants in Stormwater in Coastal North Carolina

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Poor stormwater quality threatens public health and tourism in eastern North Carolina. The Town of Beaufort (NC) is located directly upstream from the Rachel Carson Reserve (RCR), which includes several highly visited recreational areas. Stormwater receiving waters in Beaufort have previously demonstrated elevated levels of fecal contamination as measured by fecal indicator bacteria (FIB). In order to characterize the extent of this contamination, samples were collected during 15 storm events and four dry weather events between August 2016 and April 2017 from, 1) two stormwater conveyance outfalls in Beaufort, 2) downstream in Taylor's Creek, 3) stormwater pipes upstream of the outfalls, and 4) various standing water sites throughout the town. In addition, an unmanned aerial vehicle (UAV) equipped with a thermal camera was used during dry weather sampling events to visualize the fate of stormwater discharge. FIB concentrations were found to increase using EPA-approved enumeration methods in receiving waters following storm events, with total coliforms reaching 1.1×10^5 MPN / 100mL, *E. coli* reaching 8.6×10^3 MPN / 100mL, and *Enterococcus spp.* reaching 5.3×10^3 MPN / 100mL. In an effort to identify the source of this contamination, multiple human fecal-associated *Bacteroides spp.* (HF183, BacHum, and Fecal *Bacteroides*) molecular assays, as well as gull-associated fecal *Bacteroides* marker and human-associated viral pathogens were employed. Additionally, publicly available meteorological data was combined with the molecular quantification data to identify patterns in contamination and to create a conceptual framework of the potential sources. This tool will be used in an ongoing collaboration with the Town of Beaufort to systematically address sources and reservoirs of fecal contamination to preserve water quality in the RCR.

Examining Fine-Scale Movement of Estuarine Southern Flounder (*Paralichthys lethostigma*) Using a Combination of Active and Passive Acoustic Techniques

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Identifying areas of essential fish habitat is necessary for implementing novel spatial approaches to fisheries management, but can be difficult to achieve for mobile species in cryptic environments. Many estuarine fish species also often exhibit complex life cycles that result in dynamic patterns of habitat use, requiring a multi-scale approach to reveal them. This study applied a combination of three distinct telemetry approaches to examine patterns of habitat use by southern flounder (*Paralichthys lethostigma*) at multiple spatial and temporal scales within a coastal river ecosystem. Two-hundred and ninety-one southern flounder were surgically implanted with VEMCO model V9 acoustic transmitters and released into the estuary during four consecutive summers (2012-2015). Following pre-defined transects, active acoustic tracking was completed at 23 stations positioned roughly 500 m apart within a large tributary (Northeast Creek) of the New River in order to quantify activity space and creek residence time at time scales of weeks to months. Focal follows were completed for a subset of tagged flounder (n = 7) using active tracking (fish position

estimated every 10 min) for periods from 36-48 hours in order to determine daily activity space and identify diel or tidally-driven patterns in movement. Lastly, an array of 38 VEMCO model VR2 acoustic receivers were anchored throughout the estuary to continuously monitor flounder movement and the timing of emigration behaviors at a broad spatial scale. The results of focal follows revealed flounder to demonstrate small daily activity spaces (0.0016-0.007km2 95% minimum convex polygons and 0.0015-0.003km2 95% kernel density estimates). There were no detectable diel patterns in either activity space or rate of movement. Weekly transects indicated an expanded activity space, relative to daily movement patterns, for the entire summer nursery period (0.25 - 0.41 km2). Most of the study fish used shallow habitats in close proximity to the shoreline which were associated with dense and diverse prey fish aggregations. Estuarine emigration occurred along two main pathways and mainly (> 80% of migration) during a 3-4 week period in mid fall (~ Oct 15 – Nov 15), with only moderate variation in timing among years. Migration behavior was linked to body size and multiple environmental features associated with cold front passage, and once initiated, resulted in estuarine departure within approximately ten days.

Rural Coastal Community Resilience: Developing and Testing a Framework for Evaluating Climate Change Vulnerabilities in Eastern North Carolina

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Sea level rise threatens coastal regions globally. Rural coastal communities however, have unique vulnerabilities to the associated flooding and saltwater intrusion impacts compared to coastal urban areas that have growing populations, increasing property values, stronger industries, and extensive infrastructure. In contrast, the Albemarle Pamlico Peninsula, a rural coastal region in eastern North Carolina, has a local economy that is dependent on traditional livelihoods like farming, logging, commercial fishing, and eco-tourism businesses. These industries have started to realize decline as rural flight, rising startup costs, agriculture abandonment, salinization of soils, and increased environmental change make it more difficult to maintain a rural way of life. Further, compared to the nearby Outer Banks that have a strong tourism industry and high property values, the region has unique planning challenges created by a smaller tax base to finance planning and mitigation strategies. To address these vulnerabilities, this research engaged stakeholders with semi-structured interviews, focus groups, and a residential survey to better understand local perceptions of vulnerabilities and needs for building adaptive capacity. This outreach and a review of resilience research developed the Rural Coastal Community Resilience (RCCR) framework. The RCCR framework balances community resilience and vulnerability to coastal hazards and climate change with five pairs of opposing indicators that address local livelihoods, economic prosperity, sustainable development, community cohesion, and both governmental rigidities and community agency for implementing adaptation strategies. Results support the conceptualization of the RCCR framework, and highlight the APP communities' strong attachment to the rural way of life, concern about an aging population, and perception that residents have always been adapting to coastal hazards but that hazard-planning workshops are needed for enhancing the system's resilience. Furthermore, our study highlights the utility of the RCCR framework in engaging citizens and community leaders to begin necessary conversations for building community climate readiness.

A Natural and Human Systems Coupled Agent-Based Model to Evaluate Housing Dynamics of Coastal Communities Facing Storms and Sea Level Rise

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An agent-based model (ABM) is developed to explore the effects of storms and sea level rise (SLR) on soft-engineered coastal protection projects and households' housing decisions at the coastal town of Nags Head in North Carolina, USA. The ABM links the behavior of individual households and coastal managers with morphological coastal change caused by long-term erosion, SLR, and storms. Storm impacts are estimated by combining the process-based model XBeach (Roelvink, 2009) results with the ABM framework. The integrated ABM framework is applied to simulate housing dynamics under forcing from storms and SLR over a time frame of 50 years. A timeline with storm events is created from historical data and the intensity of the storm in the midpoint of the timeline was varied to investigate the effect of storm intensity on the community. Results suggest that increased storm intensity hinders development and in some cases can cause community occupation growth to stagnate or decline. The results also indicate a feedback loop between the natural processes, management decisions, and household decisions. After a severe storm, structures are damaged, expenses are increased, and community occupation declines. A diminished community cannot invest in protection measures and in turn becomes more vulnerable to future storms. A tipping point may occur, where the community stagnates with respect to its household occupation. Additionally the influence of varying SLR rates on community housing dynamics is explored by forcing the model with different SLR scenarios. Simulations show a decline in community attractiveness with increasing SLR rates. This trend is attributed to (1) absence of expenses incurred in other scenarios to mitigate recession caused by sea level rise and (2) lower flooding risk.

Hypoxia and Algal Bloom Modeling for the Neuse River Estuary

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Severe bottom dissolved oxygen (DO) depletion (hypoxia) and elevated chlorophyll levels are common problems in the upper and middle parts of Neuse River Estuary (NRE), North Carolina. Frequent algal blooms diminish the aesthetic and recreational

value of coastal waters, may produce toxins, and exacerbate hypoxia, leading to fish kills and reduced biodiversity. In this study, I develop a water quality model for the NRE in order to provide fisheries and watershed managers with timely forecasts of how the system will respond to changing meteorology and nutrient loading scenarios. In developing the model, the NRE is coarsely segmented longitudinally and vertically. Segments are treated as well-mixed reactors, on which flow, nutrient, and DO balances are performed. The resulting series of differential equations are solved using numerical methods. Parameter estimation will be conducted using Bayesian inference. In this poster, I present a preliminary model formulation assuming bottom-layer DO is consumed by organic matter decomposition in the sediments and water column, and it is reaerated from the upper layer via exchange across the pycnocline. Reaeration is parameterized as a function of the Richardson number, which is estimated from linear models with river discharge, air temperature, and wind velocity as predictors. Historical water quality, streamflow and climate data for NRE is compiled as model input. Biweekly observed DO concentrations are used for model calibration and validation.

American Aquaculture: Pitfalls, Values, and Alternatives

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The National Aquaculture Act passed both the house and the senate in 1980. Surrounding this time in history, conservation policy efforts made great strides with the passing of the Marine Mammal Protection Act of 1972, Endangered Species Act of 1973, the creation of the National Ocean and Atmospheric Administration, and more. In addition to conservation legislation, the political arena during this time was centered on issues of foreign trade relations. In 1973-1974 and 1979-1980, the U.S. experienced oil crises which sent gas prices skyrocketing and the American economy into a recession. These historic events shaped the purpose of the National Aquaculture Act which states:

"Congress declares that aquaculture has the potential for reducing the United States trade deficit in fisheries products, for augmenting existing commercial and recreational fisheries and for producing other renewable resources, thereby assisting the United States in meeting its future food needs and contributing to the solution of world resource problems. It is, therefore, in the national interest, and it is the national policy, to encourage the development of aquaculture in the United States" (Pub. L. 96–362, § 2, Cornell University Law School).

For the purpose of this research, the primary goals pulled from the legislation was "reducing the United States trade deficit in fisheries products" and "encourage the development of aquaculture." Goal metrics were assigned to assess whether the National Aquaculture Act is accomplishing what it had intended. Such metrics include the seafood trade deficit and production of fishery products. Since 1989, the trade deficit has steadily increased, failing to align with the identified goals of the act. The trend for fishery product production varies over time, but a steady decline was observed since 2004, also failing to accomplish intended goals. Some conditioning factors for these trends include increased consumption of fishery products, decreased number of fish farms and acreage, the presence of regulatory hurdles, and opposition from various stakeholders. It is projected that if these conditions remain, the trade deficit will continue to grow as production of fishery products declines. Every conditioning factor can be traced back to a set of core values that influence the conflicting and oftentimes deterring regulatory processes and legislation that inhibit aquaculture. Some alternatives were identified as a means to mitigate the various core values surrounding aquaculture regulation including land-based and offshore operations. A policy analysis was conducted for each alternative and a recommendation was made.

Intergenerational Transfer: Are Children the Key to Building a Climate Resilient North Carolina Coast?

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The need for a climate literate citizenry is growing along with the challenges posed by climate change. Although experts agree that increasing climate literacy (CL) is critical to effective climate adaptation, accomplishing this has become progressively difficult, as adults typically base climate change perceptions on ideology rather than scientific facts. Promisingly, research suggests adolescents are better at parsing climate science fact from political context than adults. As actions taken by voters and decision makers today will have direct impacts on the coastal communities of tomorrow, an approach that addresses climate literacy levels among both current and future generations is needed.

We are exploring how education focused on children can be leveraged to build climate literacy among both students and their parents. The theoretical framework of intergenerational transfer (IGT) posits that interactions between members of two separate generations can result in the bidirectional transfer of knowledge, attitudes, and behaviors. Conventionally, IGT is conceptualized with parents transferring learning to their children, but research suggests the opposite direction is possible. For instance, marketing research has long shown that campaigns directed at children can have an impact on parent purchasing behaviors and choices around products from toys to breakfast cereals. Similarly, children's programming around animal conservation, recycling, and water quality have been linked to parent knowledge and behavior outcomes. However, the potential for climate change learning to "trickle up" from students to parents has never been empirically tested.

Our research is addressing this need through an experimental evaluation of how climate change education impacts both students and parents in coastal North Carolina. We have recruited 7 treatment and 8 control teachers, associated with 475 and 493 students, respectively. We trained treatment

teachers in a climate change curriculum specifically designed to maximize IGT, including a field-based service-learning project to encourage intergenerational discussion. Preliminary data analysis of our pre-test data from 180 coastal families suggests family discussions on climate change, parent climate-friendly behaviors, and student climate risk all predict student climate-friendly behaviors ($p < .01$, $R2 = 0.283$). These results highlight a relationship between parent and child climate change views, supporting the potential for climate change education to transfer from students to parents, which we will experimentally evaluate when post-test results are available in May 2017. Future coastal planning decisions will require a climate-literate citizenry, and IGT may help accomplish this goal.

Are All Rivers Created Equal? Determining How Food Web Dynamics Affect Fish Nursery Habitat

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Estuarine fish nursery areas are managed based on habitat types. The structure and quality of the planktonic food web may be key to the survival and recruitment of fish. We investigated how differences in lower trophic level food web affected river herring strategic habitat area in Chowan River, and Tar/Pamlico River, N.C. Our objective was to determine how seston and zooplankton fatty acid composition, and zooplankton species composition, would affect larval fish fatty acid composition. The presence of particular fatty acids is linked to larval fish survival. We found differences in the seston and zooplankton fatty acid composition over space and time in Chowan River and three of its tributaries, in the Tar/Pamlico River and three tributaries. Seston fatty acid concentration in Chowan River had more green algae and terrestrially derived material compared to other locations, and only one group had a detectable amount of the essential omega-3 fatty acid docohexanenoic acid (DHA, 22:6n-3) (Figure 2a). The Tar/Pamlico River had more variability in the seston fatty composition and had more omega-3 fatty acids present (α-linolenic acid (ALA) 18:3n-3, stearidonic acid (SDA) 18:4n-3, and eicosapentaenoic acid (EPA) 20:5n-3). The zooplankton for both mesh sizes had similar groupings for Pungo River and Blounts Bay. Each location was characterized by a high percent of omega-3 fatty acids (DHA, 22:6n-3 and EPA, 20:5n-3). There was some grouping by location across the two mesh sizes. Overall, the zooplankton from the 200 µm mesh from primarily freshwater locations were characterized by higher percentages of the omega-3 fatty acid EPA (20:5n-3) and this is likely related to the high abundances of cladocerans in these locations. The zooplankton species composition changed from copepod and cladoceran community to cladoceran community in the tributaries, with higher percentage of copepods in the main stem of Chowan River. The mesozooplankton were higher in EPA and DHA in the main stem, and tributaries had higher levels of EPA and ALA. Differences seen in the seston and zooplankton fatty acid composition can change the growth and fatty acid percent composition of larval river herring.

Were the Post-Sandy Staten Island Buyouts Successful in Reducing National Vulnerability?

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Following Superstorm Sandy, hundreds of homes in Staten Island were acquired by New York State through the New York Rising Buyout and Acquisition Program. An increasingly common post-disaster mitigation approach, buyout and acquisition programs are generally intended to reduce vulnerability to future disasters and move participants out of harm's way. However, to the author's knowledge, there has been no quantitative evaluation of whether or not these programs meet their objectives. Through a change in vulnerability analysis, this study quantifies the success of the Staten Island buyout program in reducing the national vulnerability of people and property to coastal flood hazards. Vulnerability, in this context, is measured in terms of exposure, sensitivity and adaptive capacity. Aggregate vulnerability of buyout communities just prior to Superstorm Sandy is compared with vulnerability following the implementation of the buyouts. By analyzing trends in the relocation of buyout participants and quantifying the aggregate change in vulnerability, policy recommendations have been made to improve the efficacy of federally funded coastal buyout programs. Of the 323 buyout participants studied, nearly 82% relocated within New York State, 75% relocated within Staten Island and 22% relocated within their zip code of origin. Nearly 30% of the buyout participants moved to a property of equal or greater vulnerability than their home in Staten Island. Future coastal buyout programs may benefit from further consideration of the nuances of retreat from densely populated urban areas, appropriate incentives and the importance of both sense of place and social capital.

Affects of Noise Pollution on Marine Mammals

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Marine mammals are currently being negatively impacted by noise pollution that is cause by human activity. Anthropogenic noise pollution is caused by many different marine activities such as explosives, seismic airguns, military sonar, and ship traffic. Noise pollution in the ocean is increasing due to a growth in anthropogenic activities. This poses a serious threat to marine animals. Marine animals rely on acoustics to navigate, hunt, reproduce, and communicate. The public has become more aware of animal welfare issues due to the increase in media coverage. When animals are killed or injured for entertainment or from human activities, there has been a public backlash. The increased of noise caused by human activities has been linked to mass strandings of marine mammals. After a mass stranding off the coast of North Carolina in 2005 after a United States Navy exercise, the U.S. government reported that the strandings had features that were atypical of sonar-related strandings. The increase of oil and gas production and consumption has given rise to more seismic surveys in order to find oil and gas reservoirs. From these three trends, it has become clear that

society values the environment, security, and oil and gas. Alternatives that need to be considered are to have marine sanctuaries for critical habitat areas, invest in newer quieter technologies, to require ramp-ups before surveying an area, and funding research to better understand how to reduce the impact of noise pollution on marine mammals. Better mitigation practices need to be invested in or implemented because marine life is being negatively impacted by noise pollution. It is important to research the best alternative that meets both the needs of society and the needs of marine life.

Oregon Inlet: Can We Solve the Unresolved Morphological Puzzle?

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Oregon Inlet has remained open for over 170 years in an environment that has evolved from an uninhabited barrier island to a touristic destination with over 300,000 visitors during the summer. During the first century after the opening of Oregon Inlet, its dynamics were solely controlled by natural processes that moved sediments into, around, and out of the system. With the population and tourism growth in the Outer Banks since the 60's, the inlet began to be shaped by the demands from fisheries, residents, sailors, and tourists. Examples of these human-induced changes in the system are the Bonner Bridge across the inlet, a terminal groin on its down-drift side, and dredging activities in the navigational channel, which are some of pieces that have been added to the morphodynamic enigma of Oregon Inlet. Today, natural processes and human-induced activities and structures altogether form the puzzle of Oregon Inlet morphodynamics.

To solve such a complex puzzle, I am using a state of the art numerical model that allows simulating hydrodynamics and morphology of the inlet at temporal and spatial scales that have not been studied before. In its current state, the model includes the effects of tides, waves, the Bonner Bridge, and the terminal groin. Quantitative and qualitative validation methods indicate that the model accurately reproduces the hydrodynamics of the system. Recent evaluation of the morphological behavior of the model indicates that it can capture general erosional and depositional trends within the inlet. Future work to study the response of the inlet to natural processes and structures will couple model outputs with multi-temporal geospatial analysis of the main morphological features of the inlet (e.g. northern spit, shoals). This poster will present an overview of the model, its capabilities, and my strategy in the most recent attempt to solve the morphological puzzle of Oregon Inlet. Solving the intrinsic connection between all pieces would lead to the understanding of the behavior of Oregon Inlet, which has become urgent given the economic and environmental interests to achieve sustainable and reliable sand management plans in the region. Solving the morphological puzzle of Oregon Inlet also represents a step forward for future management decisions in ever-evolving environments, where decision-makers must face the challenges of a changing climate, rising sea levels, and growing coastal population.

Invasion of the Body-Snatchers: Salinity Limits the Spread of an Invasive Castrating Parasite in Populations of North Carolina Mud Crabs

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Invasive species are a threat to community stability and the persistence of trophic relationships, especially in estuarine environments in North Carolina that are heavily impacted by human activity. The threat posed by biological invasion is not well characterized in major estuaries like the Pamlico and Neuse Rivers, which merge to form Pamlico Sound: the largest lagoonal estuary in the United States. This is especially true for non-native parasites, organisms which can disrupt trophic networks because of the functional links they form with one or more hosts. We tested the hypothesis that the prevalence of Panopeid mud crabs (primarily the white-fingered mud crab *Rhithropanopeus harrisii*) infected with an invasive castrating parasite (*Loxothylacus panopei*, a rhizocephalan parasitic barnacle) increased with increasing salinity in the Pamlico and Neuse rivers. This is the first study to explicitly test the prevalence of *L. panopei* infection along a salinity gradient. Preliminary data indicate that infection prevalence is greater in moderate to high salinity (> 8-10 ppt) areas, which is consistent with findings from monitoring work done in the Chesapeake Bay. Because mud crabs are an important component of estuarine food webs, heavily infected populations may result in altered predator-prey dynamics.

Effect of Bromide on Formation of Antibacterially Active Products During Chlorination of Water Containing Doxycycline

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Trace levels of antibiotics are present in water impacted by human activity. When this water is disinfected with chlorine, some antibiotics (specifically, doxycycline – a highly used human antibiotic) can react with chlorine and form other antibiotics. Antibacterially active products that may form during water and wastewater treatment could be a currently unknown source of antibiotic resistance as well as a potential source of new useful antibiotics. Presence of bromide can potentially lead to formation of even more potent antibiotics when drinking water is chlorinated. Elevated bromide concentration is often present in drinking water in coastal areas where it is deposited from the seawater aerosols or via diffusion into groundwater from coastal waters. Also, recently there have been reports of elevated bromide concentration in waters impacted by coal burning power plants. Additionally, with North Carolina exploring the possibilities of hydraulic fracturing in the state, the integrity of the confining layer may be disturbed. Therefore, it is important to understand the effects of elevated bromide on water quality beyond the traditional disinfection byproducts.

This research investigated the products that form when water containing the antibiotic doxycycline and bromide are chlorinated. The study evaluated the antibacterial properties of the products that formed and compared them to the products in the absence of bromide. The goal of this work was to determine whether the presence of the bromide ion leads to formation of more potent antibacterial products when chlorine is substituted with bromine in the product structure. Antibacterial assays were used to determine antibacterial properties of the products that formed during chlorine disinfection. Drinking water and wastewater effluent were used to provide a realistic background matrix of a full-scale water or wastewater chlorination, which included any other possible reactions of chlorine, doxycycline or intermediates with background constituents. Samples were drawn from each collected aliquot and analyzed with high performance liquid chromatography coupled with mass spectrometry to identify transformation products. Chlorine and bromine stable isotope ratios were used to identify the halogenated products. The residual concentration of the parent antibiotic doxycycline was compared to the residual antibacterial activity measured by the assays. Addition of bromide to ultrapure water prevented formation of antibacterailly active products. Samples in drinking water matrix at 24 h exposure time (to mimic drinking water storage and distribution) showed potential formation of antibacterially active products.

Naturally Armoring North Carolina's Shores: Techniques and Benefits

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North Carolina has experienced a dramatic loss (85-95% loss) of oyster populations over the past century, prompting massive efforts to restore and sustain this multi-million-dollar fishery. Unfortunately, the limited scientific knowledge about the best conditions for oyster-reef growth has resulted in some ineffective restoration efforts. We developed a model that helps define the areas in North Carolina's estuaries where oyster reefs will thrive, optimizing restoration cost with fishery productivity as well as guiding management practices. Notably, this research identified that reef-scale growth and topography respond to oscillations in water levels that occur over time periods <1 year, indicating these habitats are more responsive than any other coastal ecosystem to changes in sea level. We also examined the coupled geologic evolution of saltmarshes and oyster reefs and determined that armoring marshes with oyster reefs is an effective method of preventing shoreline erosion and loss of carbon-rich sediment that has been naturally occurring over the past century. These results combined with our model of oyster-reef growth will help guide the development and implementation of "living shoreline" projects, the natural alternative to artificially hardened shorelines for protecting coastal property from storms and flooding.

Shellfish in the Human Dimension: An Examination of CAMA Protection of Coastal Resources

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At varying levels of governance, the Clean Water Act, the Coastal Area Management Act, and the Coastal Zone Management Act all cooperate and work together to set standards for, as well as monitor and enforce, water quality parameters for shellfishing waters. When shellfishing waters do not meet federal water quality standards, the area is closed down to harvesting. In conjunction with the cultural and economic impacts that result from the closure of shellfish harvesting areas, closures indicate a broader problem concerning public and coastal health; poor water quality. Heightened fecal coliform levels in shellfish and their habitats pose a risk to public health. As filter feeders, shellfish bioaccumulate pollutants such as fecal coliform, which, if consumed, can cause illness in humans. The functionality of shellfish provides a critical service to the health of coastal communities and coastal ecology. Fecal coliform is most commonly transported into shellfishing waters by stormwater runoff via impervious surfaces. Stormwater runoff occurs after rain events and land disturbing activities such as coastal development, which results in an increased percentage of impervious surfaces. In recent decades, coastal populations and development have increased for much of the North Carolina coast, especially in southeastern North Carolina. The increase in development has lead to an increase in the percentage of impervious surfaces that accommodates runoff. This has made shellfishing waters more vulnerable to higher fecal coliform levels, more harvesting closures and, consequently, poor water quality. Examining southeastern North Carolina as a case study, this analysis explores how current stormwater runoff mitigation methods are not effective enough at protecting coastal resources and ensuring that water quality standards outlined by the aforementioned legislation in shellfishing areas are up to par to prevent closures and ensure coastal health.

Estimating Mortality for Southern Flounder Using a Combined Telemetry and Conventional Tagging Approach

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The southern flounder (*Paralichthys lethostigma*) is a valuable marine resource in North Carolina that is currently designated as overfished with overfishing still occurring. We used a combination of acoustic telemetry and conventional tagging methods at two spatial scales over three years to generate direct estimates of fishing (F) and natural (M) mortality. Southern flounder tagged with acoustic transmitters were released and tracked in a single estuary to provide system-specific estimates of F and M using a multistate capture-recapture model. Conventional tags were deployed throughout the state to provide additional direct information about F on a larger scale and indirect information about M. Over 2300 conventional tags have been deployed statewide since fall 2014 with an overall return rate of ~9% (n = 209). This effort combined high and low reward tags to allow estimation of the reporting rate for low reward tags. Comparing return rates of high and low reward

tags gave a reporting rate of ~50% over the first 3 years of the study. An additional component of the conventional tagging study involved double tagging a subset of fish each year to estimate tag loss. This tag loss estimate will be applied to telemetered southern flounder as both studies utilized the same external tag design.

During 2014-2016, totals of 94, 96 and 81 southern flounder were tagged with acoustic transmitters respectively, and released throughout the New River estuary between May and December. Additional external tags contained contact information and a high monetary reward to meet the assumption of 100% reporting of recaptures. Fish were detected via a passive array of acoustic receivers, with data downloads every ~ 3 months, and manual tracking that occurred bi-weekly or monthly. Harvest removed an average of ~30% of individuals from each annual cohort over 3 years with commercial landings responsible for over 70% of reported fishing mortalities. Fishing removals occurred throughout the estuary and were associated with multiple gears (14 recreational hook and line, 8 recreational gig, 19 commercial gig, and 43 commercial gill net). The fraction of fish emigrating from the system each fall ranged from ~25-30% of the total number of individuals in each annual cohort. Currently 16 individuals from the 2016 cohort are assumed to be still at large in the estuary with 4 confirmed surgery-related mortalities and 6 individuals that have not been detected since tagging. Active and passive tracking is ongoing to determine fates of fish from the 2016 cohort still at large in the estuary.

Modeling Nitrogen Loading Trends in Three North Carolina River Basins

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Excessive nutrient inputs from point and non-point sources can lead to algal growth, hypoxia and fish kills in estuarine waters. Diminished water quality in North Carolina's estuaries prompted the introduction of Total Maximum Daily Load (TMDL) requirements in the 1990s for limiting nitrogen loading into upstream surface waters. Despite such efforts, an increase in nitrogen has been identified in the past couple decades. Possible causes for this trend have been suggested, including urbanization and the loss of forested riparian buffers, animal waste from Confined Animal Feeding Operations (CAFOs) and trends in fertilizer application. An understanding of both the temporal and spatial dynamics of nutrient loading is needed to further assess the efficacy of TMDLs and inform stake-holders as to appropriate management measures.

Developed here is a nutrient-load model for the Neuse, Cape-Fear and Tar-Pamlico river basins in North Carolina. Total Nitrogen (TN) loads from 1994-2012 are estimated at 21 stations across the Neuse, Tar-Pamlico and Cape Fear river basins using the Weighted Regression for Time Discharge and Season method (WRTDS). An Export Coefficient approach is used to estimate TN contributions from land-use types, livestock operations and dischargers. Trends in land-use are assessed using National Land Cover Database satellite imagery, livestock counts are gathered from USDA census data, and discharger data from North Carolina's Department of Environmental Quality. Trend analysis from the data, WRTDS nutrient estimations, and preliminary modeling results will be presented in this poster. Further development of the model will incorporate a Bayesian statistical framework to quantify uncertainty of loading predictions.

An Exotic Species Alters Patterns of Marine Community Development

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Predictions of ecological patterns can be strengthened through replication of foundational studies under different environmental conditions to evaluate the consistency in their underlying processes. In this study, we replicated Sutherland and Karlson's 1977 classic ecology study that tested terrestrial paradigms of community development in a marine fouling community. The abundance patterns of marine fouling species were quantified on sequentially submerged settlement plates to investigate the effects of disturbance date on short- and long-term patterns of community development, and the original study's datasets were re-analyzed for comparison. In both studies, community structure was initially shaped by disturbance date due to monthly and annual variation in larval recruitment; however, the influence of disturbance date diminished over time. Despite these similarities, the underlying drivers of long-term patterns of community development have shifted substantially since the 1970's. During the present study, an exotic tunicate, *Clavelina oblonga*, dominated plates over time and its dominance was associated with significant declines in species diversity. In contrast, the 1970s long-term community was characterized by a heterogeneous mixture of species that varied interannually, yielding increased species diversity over time. Continued observations of our settlement plates indicates that *C. oblonga* remains the dominant species in this community, suggesting that these findings are not the result of a single, novel recruitment event. These results highlight how an exotic species can alter patterns of community development and biodiversity. Moreover, this study demonstrates the need to replicate foundational ecological studies to evaluate community dynamics and underlying processes in light of ongoing environmental change.

Density-Dependent Role of an Invasive Marsh Grass, *Phragmites australis*, on Ecosystem Service Provision

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Invasive species can positively, neutrally, or negatively affect the provision of ecosystem services. The direction and magnitude of this effect can be a function of the invaders' density and the service(s) of interest. We assessed the density-dependent effect of an invasive marsh grass, *Phragmites australis*, on three ecosystem services (plant diversity and community structure,

shoreline stabilization, and carbon storage) in two oligohaline marshes within the North Carolina Coastal Reserve and National Estuarine Research Reserve System (NCNERR), USA. Plant species richness was equivalent among low, medium and high *Phragmites* density plots, and overall plant community composition did not vary significantly by *Phragmites* density. Shoreline change was most negative (landward retreat) where *Phragmites* density was highest (-0.40 ± 0.19 m yr-1 vs. -0.31 ± 0.10 for low density *Phragmites*) in the high energy marsh of Kitty Hawk Woods Reserve and most positive (soundward advance) where *Phragmites* density was highest (0.19 ± 0.05 m yr-1 vs. 0.12 ± 0.07 for low density *Phragmites*) in the lower energy marsh of Currituck Banks Reserve, although there was no significant effect of *Phragmites* density on shoreline change. In Currituck Banks, mean soil carbon content was approximately equivalent in cores extracted from low and high *Phragmites* density plots (23.23 ± 2.0 kg C m-3 vs. 22.81 ± 3.8). In Kitty Hawk Woods, mean soil carbon content was greater in low *Phragmites* density plots (36.63 ± 10.22 kg C m-3) than those with medium (13.99 ± 1.23 kg C m-3) or high density (21.61 ± 4.53 kg C m-3), but differences were not significant. These findings suggest an overall neutral density-dependent effect of *Phragmites* on three ecosystem services within two oligohaline marshes in different environmental settings within a protected reserve system. Moreover, the conceptual framework of this study can broadly inform an ecosystem services-based approach to invasive species management.

Estimating Southern Flounder Population Connectivity Using Otolith Geochemistry

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Otolith geochemical signatures have been effectively used as natural markers to estimate population connectivity in migratory fish. With this approach, we inferred the degree of exchange of southern flounder (*Paralichthys lethostigma*) among broad U.S. South Atlantic regions by predicting the nursery origins of adults captured in North Carolina and South Carolina estuaries. Nursery profiles were established by analyzing stable isotope ratios (δ13C, δ18O) and trace elemental concentrations (Li:Ca, Mg:Ca, Mn:Ca, Co:Ca, Cu:Ca, Zn:Ca, Sr:Ca, Ba:Ca) sampled from the otolith material corresponding to the first year of growth in age-1 southern flounder (2011 year-class; n=199). After optimizing the combination of trace elements, quadratic discriminant analysis (QDA) was able to distinguish state-scale nursery regions (North Carolina, South Carolina, and Florida) with 76% cross-validation accuracy. Adult southern flounder (age-3+; n=47) from the same cohort were subsequently classified to the atlas of nursery signatures obtained from the age-1 fish, sampling otolith material as aforementioned. Of the adults captured in North Carolina and South Carolina, 47% were estimated to have originated from within their respective state waters. The remaining 53% of individuals classified to nursery states outside of their capture location, including several with a high probability (>95%) of originating from Florida. These results suggest the potential for broad-scale movement of post-migration adults along the U.S. South Atlantic coast, which may be important for identifying appropriate spatial scales for management. Ongoing analysis is aimed at defining nursery geochemical signatures with improved accuracy and finer spatial resolution.

New Jersey Public Beach Access

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Within New Jersey's Coastal Management Plan under Enforceable Coastal Policies, there is a legislative mandate of providing for the public "physical and visual access" to the waterfront. New Jersey, and particularly many its coastal communities are dependent on summer tourism related to the beach and surrounding amenities. Public access is crucial to stimulating the economy and keeping the values of various stakeholders satisfied. The Public Trust Doctrine mandates the right to public access, which is a longstanding common law. In some cases, the state falls short of its goal of physical and visual access because some municipalities, private organizations and private property owners attempt to limit access to the general public by means of exclusion. This project explores the goals, trends and conditions associated with visual and physical access and the situations where it is being limited. The project also provides projections and alternatives that may help the State of New Jersey meet its goal. The main reasons why public access is an issue is because there is not a set standard of public access that each municipality must provide, there is struggle for authoritative power in implementing public access plans between the New Jersey Department of Environmental Protection and local communities as well as several value driven differences between the public and private property owners in locations that have attempted to limit access.