

Rising Seas; Falling Funds:

An Analysis of Beach Nourishment Finance in Dare County, NC

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Table of Contents

Title Page	1
Abstract.....	3
Introduction.....	4
Background and Literature Review	6
Coastline Dynamics	6
Impacts of Climate Change.....	8
Adaptive Processes	9
Beach Nourishment.....	10
Federal Funding	12
Local Funding	13
Community Awareness.....	14
Political and Economic Implications of Beach Nourishment	16
Case Study: Dare County.....	21
Methods	22
Newspaper Article Analysis.....	22
Tax Assessor Data Analysis.....	25
Results.....	29
Newspaper Article Analysis.....	29
Tax Assessor Data Analysis.....	35
Discussion.....	41
Newspaper Article Analysis.....	41
Tax Assessor Data Analysis.....	44
Conclusions & Future Research.....	46
Acknowledgements.....	48
Works Cited	49
Appendix.....	58

Abstract

Climate change presents considerable risk for coastal communities in the southeastern United States, driving adaptive processes, like beach nourishment, with multi-million-dollar price tags. The municipalities of Dare County, NC receive no federal subsidies, but have funded nourishment by establishing Municipal Service Districts (MSD) with additional millage rates for properties that benefit most from project implementation. Despite these municipalities' recent success in completing projects, the relative distribution of costs and benefits was subject to great community protest and debate. This project assesses the drivers of news coverage and public concern for Dare County nourishment, and the distribution of owner-occupied properties within the MSDs of Duck, NC. Results suggest that in Dare County, news coverage and public concern increase two years after a coastal flood event occurs. In Duck, analysis of properties suggests that successful MSD construction may hinge on satisfying the interests of the voting contingency, rather than reflecting the project's economic benefit.

Introduction

Since the 1960's the United States has experienced dramatic population growth along its coastlines. Many of these coastal communities have been built on a tourist economy, relying on summer travelers to bring in considerable revenue to local businesses and the local government (Wilson & Fischetti, 2010). These communities are often marked with small resident populations and large volumes of summer visitors, leaving large oceanfront properties empty during the remainder of the year. In some areas, like barrier islands, where population growth and development are restricted by the width of the barrier, the municipal revenue stream is reasonably locked in its current state. Barring a dramatic rise in property assessment values or millage rates, coastal municipalities along barrier islands are subject to flatlined revenue streams.

Unfortunately, these communities are also at considerable risk in the face of climate change. Sea level rise and increased frequency and severity of storms threaten the very properties that drive the local economy. As the climate changes, so will basic sediment transport, causing shoreline instability and erosion (Slott, Murray, Ashton, & Crowley, 2006). Historically, federal support for coastal climate change adaptation, namely beach nourishment, has covered 2/3 of project costs for communities willing to undergo the lengthy application process (Valverde, Trembanis, & Pilkey, 1999). This is beginning to change. As the seas rise, federal funds fall. Federal budget proposals ignore allocating funds for beach nourishment, and communities that have been grandfathered in are reaching the end of their allotted funding (Wagner, 2017).

This forces coastal communities to address their adaptive needs on the local level, with limited revenue streams. Project costs often fall on the order of millions of dollars, and current project lifespans total only five years. This suggests communities that choose to armor their coastlines will be forced to pay more taxes, and pay them more often (Gopalakrishnan, Landry, &

Smith, 2018). The extent to which a community can act collectively and efficiently determines how quickly it can adapt to rising seas and shoreline loss, but history suggests that neither collective action nor efficiency has accompanied municipal beach nourishment projects.

Moving forward, coastal communities along the southeast will be forced to design funding mechanisms that support multimillion dollar infrastructure projects every few years if they hope to secure their tourist economy and most valuable properties. This is met with political pressure to satisfy constituents, keep taxes low, and ensure power in local government is not lost. These political pressures are often at odds with the economic implications of beach nourishment projects: ensuring that the distribution of project costs reasonably reflects the distribution of project benefits. Currently, due largely to federal subsidy, very few communities are faced with these funding design challenges (Valverde et al., 1999).

Dare County, NC, situated along the Outer Banks, is just one example of several municipal governments currently facing the political and economic gridlock. Dare County serves as a blueprint for other coastal communities, as the economy is dependent on wide beaches and summer tourism, but property owners are polarized on how the funds should be raised. Oceanfront property owners see the erosion out the window but are met with debate on how the costs should be distributed. This analysis looks further into the nature of the problem and hopes to provide some insights on what drives public awareness for beach nourishment, and how Dare County is funding these major infrastructure projects.

Background and Literature Review

Coastline Dynamics

Coastlines are constantly subject to change. While rocky coastlines along the western coast of the United States are typically associated with larger waves and more turbulent waters, the specific geomorphology and weather patterns on the east coast present specific concerns. The Southeastern coast is home to various barrier island communities, all separated from the mainland by inlets, bays, tributaries, and varying in length, width, and height above sea level (Dolan & Lins, 2000). Ocean City, Maryland; Kill Devil Hills, NC; and Hilton Head Island, SC are just a few examples of barrier island communities. Despite largely contrasting demographics, all three communities rely on their coastlines as economic drivers, but they remain public finance burdens.

All sandy coastlines are subject to natural ebbs and flows of sediment. With each passing wave, sediment is stirred up through the water column. Some of this sediment is deposited near shore, and some is transported via the undertow throughout the “surf zone,” or area where waves are breaking. This constant flux of sand generally has a net zero effect on erosion, assuming that the water is behaving under normal, non-storm, conditions and no net alongshore transport exists (Dolan & Lins, 2000).

The fine sand grains along the east coast are considerably lighter than rocky coastlines, making sediment transport considerably easier and faster. Depending on the width of the barrier, that is, the distance from the ocean to the bay across the island, complete overwash can occur with even small disturbances (Asbury H. Sallenger, 2000; Dolan, Lins, & Hayden, 1988). As storms transport near-shore sand, this leaves a depression in the coastline, resulting in decreased beach width and a landward moving coastline. In addition, the southeastern coast is subject to a net alongshore transport. This sediment transport is driven from north-to-south due primarily to

northeastern swells. Incoming wave angle and coastline shape drive beach accretion and erosion along sandy coastlines (Barnhardt, W.A. et al., 2009).

The nearshore sediment, specifically along unique coastlines such as North Carolina's cusped coast, is highly vulnerable to this alongshore transport. The amount of alongshore transport is driven by the offshore wave angle and direction, and can greatly alter sandy coastlines. Currently, along the coast of NC, most net alongshore transport occurs from north to south. The balance of asymmetry (or proportion of waves from different angles) and offshore wave angle has created a series of capes along the North Carolina coast that is highly dynamic and subject to shifts throughout time. As climate changes, and subsequently the wave angle and asymmetry change, this could have significant impacts on shoreline shapes (Slott et al., 2006). The smaller the beach width becomes, the greater risk to dunes and oceanfront properties.

In addition to the shoreline loss from alongshore transport, hurricanes, tropical storms, tropical depressions, and nor'easters can also cause significant erosion along sandy coastlines. Large storms typically bring high winds, storm surge, and large waves, all of which increase the rate of sediment transport from near-shore to offshore, often deposited at the end of the surf zone in the form of sandbar ("Beach Erosion - Coastal Change Hazards: Hurricanes and Extreme Storms," n.d.; Dolan et al., 1988). The degree to which sediment is lost depends on a number of factors, most of which relate to the amount of water being forced further up the coastline, and the velocity of that water. Should storm surge be large enough, this can cause overwash of the entire community, as water passes the entire barrier island and is deposited in the bay or tributary behind the barrier (Plant & Stockdon, 2012; Stockdon, Thompson, Plant, & Long, 2014).

Impacts of Climate Change

The storm related erosion risks are intensified by the effects of climate change. As the oceans warm, hurricanes are expected to become stronger and more frequent (Holland, 2012). While data on hurricanes is lacking, due to inability to record non-landfalling storms prior to satellite implementation, the IPCC is very confident that climate change will result in more heavy rain events, and report that stronger tropical cyclones are likely (*Working Group I*, 2013). Although hurricanes and their associated trajectories are challenging to forecast, and these larger storms may never contact land, the risks for coastal communities still rise.

In addition to increased storm risks, warming oceans and melting land ice are expected to raise ocean surface levels. It is reported that within the past century, ocean surface levels have risen approximately 8 inches. This rise is only expected to accelerate in future years, and the distribution of sea level rise risk varies across coastal communities (Ingram, Dow, Carter, & Anderson, 2013). This somewhat small rise in ocean surface levels will result in a natural decline in beach width and increase risk of storm surge. Miami and Charleston, two major ports and urban areas along the southeast, are among many communities that already experience the effects of sea level rise, as high tides and spring tides send water up through sewer systems and past the dunes (Ingram et al., 2013). As land ice continues to melt, sea level will continue to rise, increasing the risk of coastal erosion even in the absence of storms. According to a 2011 report from the Georgetown University Climate Center, with one foot of sea level rise, the state of Virginia will incur damages of up to \$5 Billion (Grannis).

Adaptive Processes

Very little can be done in the short-term to prevent storm erosion. Except for placing sandbags along shores and coastlines to prevent waves from reaching homes, most adaptive processes are long, expensive, and highly technical.

Three general types of adaptive processes are implemented on sandy coastlines; 1. Hard structures, 2. Soft structures, and 3. Retreat (Ferreira, Garcia, Matias, Taborda, & Dias, 2006). Each follows the name. Hard structures are groynes, seawalls, or jetties, and often made of rocks or concrete. Groynes run perpendicular to the coastline, aiming to trap alongshore sediment transport and preventing erosion in a particular spot. While sediment is trapped on one side of the groin thus creating a sandier beach in that area, there is often a sediment gap on the other side, eventually resulting in formation of a “groynefield” down the beach (National Research Council, 2007).

Seawalls run parallel to the coastline and are essentially concrete walls designed to keep water away from structures. Usually constructed in areas with considerable erosion and shrinking coastlines, seawalls are often battered by waves, thus worsening erosion at the site of the seawall and requiring regular repair and maintenance. Jetties also trap sediment, but are often used to prevent sediment transfer from shallowing a boat access point from a bay/inlet to the open ocean (Pilkey, Neal, Cooper, & Kelley, 2011). None of these structures are a long-term solution to sediment transfer, and often looked down upon by environmental groups for changing shoreline dynamics and animal habitats, without providing uniform protection from storms across municipal lines (Gittman et al., 2015).

Soft structures include building/promoting dunes and beach nourishment. The general trend along the southeast is towards soft structure implementation. Still only a “band-aid,” and very costly, beach nourishment is slightly more politically salient and provides reasonably uniform

benefits along the length of the project (Pilkey et al., 2011). Beach nourishment will be explored more thoroughly in the paragraphs to follow, as it is the most common project aimed to protect costly oceanfront properties and, in turn, the tourism economy driving coastal communities (Phillips & Jones, 2006).

Beach Nourishment

Beach nourishment is just one of a few names for the soft-structure process used to stabilize sandy beaches. Also known as “beach *renourishment*” or “beach replenishment,” beach nourishment is just one of a few adaptive processes that provides length to beaches, protects homes and communities, and provides a buffer of sandy support after large storms and overwash causes significant erosion along the coastline (Bird & Lewis, 2015; Pilkey et al., 2011). Nourishment typically involves lengthening the beach by adding sand to the coastline. The origin of this sand can vary, but recent nourishment activities have trended towards extracting sand from nearshore and pumping it to the coastline area. This method helps to ensure sediment grain size matches, and while more expensive than other strategies, typically extends the lifespan of the project (Bird & Lewis, 2015).

The range in project size can vary extensively. Erosion does not occur uniformly across the length of the coast, meaning some areas may suffer more damage than others, despite little spatial variation. Because of high fixed costs, most nourishment activities are still quite large. Often, they are greater than 1,000 cubic yards of added sand volume and cost millions of dollars (Hoagland, Jin, & Kite-Powell, 2012). For these reasons, nourishment is done on a periodic basis, with some understanding that the beach width impacts both potential travelers’ willingness to pay for a beach trip and the property values of oceanfront homes. With this in mind, the period between events should seek to minimize shoreline loss (Gopalakrishnan, Landry, Smith, & Whitehead,

2016). Most nourishment activities project a lifespan of ~5 years, but given uncertainty around storms, the reality can vary greatly. Matching the sediment used for nourishment helps extend the project life, and can be sourced from inlets or offshore, depending on the size of the project. In North Carolina, there is significant pressure on viable sand for projects, as the benefit of nourishment is local, but the sediment source is a common pool resource. As a finite resource, the cost of sand is expected to rise as supply declines (Gopalakrishnan et al., 2018). As coastal areas continue to develop and tourism economies flourish, and without some new technology, nourishment will continue to be the most viable “band-aid” against coastal erosion. The tipping point for sand costs remains somewhat uncertain, but as the cost burdens increase, coastal communities may have to accept narrower beaches or, in extreme cases, even retreat (Gopalakrishnan et al., 2018).

Considerable discourse around nourishment has occurred since federal support and project implementation grew in the 1960s (Valverde et al., 1999). Sandy coastlines are constantly shifting, and development of coastal communities has required efforts to ensure these shifts do not result in property losses. For many coastal areas, tourism is the primary economic driver. For example, towns in Dare County, NC inflate to seven times their normal population during the summer months. Much of the revenue generation hinges on valuable oceanfront properties that are also at greatest risk from coastline change, large storms, and sea level rise. This desire to protect valuable structures incentivizes beach nourishment, which in turn encourages coastal development and endogenously raises the value of homes on nourished beaches. This feedback cycle creates a perpetual benefit to nourishment, so long as funds can be generated and projects subsidized (Gopalakrishnan, Smith, Slott, & Murray, 2011).

Federal Funding

Historically, federal support has been provided to coastal towns for beach nourishment and shoreline stabilization. Three different mechanisms for federal support exist, under three different entities: the National Oceanic and Atmospheric Administration (NOAA), the Federal Emergency Management Agency (FEMA), and the US Army Corps of Engineers (USACE) (National Resources Council, 2001). Operating under separate statutes and authorities, each program provides subsidies to coastal areas. NOAA operates under the Coastal Zone Management Act of 1972, providing support to 94% of US coastal area. NOAA operates alongside FEMA, providing states with information and technical support to mitigate coastal erosion damages (NOAA, 2010).

FEMA subsidizes coastal communities primarily through the National Flood Insurance Program. In the event of large, destructive storms that require emergency aid, FEMA provides financial support for coastal communities. Otherwise, the National Flood Insurance program provides federal insurance to property owners in flood prone areas that may not have access to private insurance. Many private underwriters do not provide coverage in coastal flood zones due to heightened risk. In addition, the National Flood Insurance Program provides support through hazard mitigation, potentially including beach nourishment (National Resources Council, 2001). Nourishment activities provide protection for coastal communities, but there has been little agreement regarding the extent to which FEMA should invest in beach nourishment, as it is only a short-term solution and does not have an even distribution of benefits. For US east coast barrier island nourishment, federal emergency funds only accounted for approximately 6% between 1923-1996 (Valverde et al., 1999).

The USACE has the most direct connection to beach nourishment amongst these three agencies. Operating under the Flood and Coastal Storm Damage Reduction Program, the USACE provides federal support, usually 65% of project costs, for beach nourishment. According to

Valverde et al., approximately 43% of total US east coast barrier island beach nourishment came from Federal Storm and Erosion funds under USACE (1999). Receiving federal aid requires application by the municipality, with assurance that the other 35% of cost can be met through other means, such as local or state funds. Approval can take up to five years, and requires considerable effort by municipalities. If the application is approved, municipalities have federal support for up to fifty years (Hedrick, 2000). Despite a history of providing funds for municipalities throughout the coastal United States, threats of budgetary risks pose an uncertain future for small municipalities with large nourishment needs.

The 2018 budget included no appropriations for beach nourishment, inciting concern across coastal communities (Wagner, 2017). Much of the southeastern coast has relied on federal subsidy to meet the multi-million dollar price tag of nourishment, and budget cuts signal the need for innovation in municipal finance to ensure coastline stabilization (Valverde et al., 1999).

Local Funding

As mentioned, most municipalities are still expected to meet approximately 35% of project costs, if not more (National Resources Council, 2001; Valverde et al., 1999). While the strategies for meeting these costs varies from state-to-state, most coastal areas have established some beach preservation fund that generates revenue through local occupancy taxes. These local occupancy taxes are collected from rental properties, hotels, etc., from travelers staying in the respective area (Griffiths, 2011). Given the somewhat competitive and substitutable nature of Southeastern coasts, there is not considerable variation in local occupancy taxes. In essence, a higher occupancy tax in one town could incentivize travelers to stay in a nearby town with a lower occupancy tax (i.e. lower cost to the consumer) but similar benefits, thus resulting in a greater net benefit. In 2016

within the state of NC, occupancy taxes were capped at 6% (excluding Mecklenburg County), with up to 2% allowed for beach nourishment funding (Magellan Strategy Group, 2017).

The level of government associated with these beach preservation or stabilization funds varies. For example, in South Carolina, the occupancy tax is collected at the state level, and then distributed to the municipalities as needed, with the option for municipalities to collect up to 1% more on a local level (SC Department of Revenue, 2017). Conversely, in Dare County, NC, the occupancy tax is collected on a county level and then distributed (“Occupancy Tax | Dare County, NC,” n.d.). For communities receiving federal subsidy, these beach preservation funds and some allocation from the general fund typically suffice to meet 35% of project costs.

As federal support declines and communities meet the 50-year threshold for projects, new financing mechanisms will have to emerge. Municipalities only have a few options for revenue generation, severely constraining the ability to raise large sums of funds for costly infrastructure projects. In general, these local level governments can raise revenues through: 1. Local occupancy taxes, 2. Property tax millages, and 3. Sales taxes (Griffiths, 2011). Each funding source has some opposition and distribution of winners and losers. The challenge for local leaders lies in meeting these funding needs with limited revenue streams without upsetting a large enough contingency of voters to risk reelection.

Community Awareness

As beach nourishment is funded on a local level, successful financing mechanisms hinge on adequate community buy-in. For many coastal municipalities, specifically those that do not recognize the risks from climate change, beach nourishment is typically financed when inaction otherwise present significant risk to property owners (Bulla, Craig, & Steelman, 2017). While this need for community buy-in complicates the details of the financing mechanisms implemented by

elected officials, it can help ensure that enough voters see eroding beaches and potential property loss as a threat to ensure a referendum is passed.

Gauging public concern for a topic can be challenging. Surveys often result in individuals without an opinion picking a side, when they may not be otherwise engaged, or being subject to opinion variability. This is reflected in a 2015 study by Potoski, Urbastch, and Yu regarding the relationship between temperature variation and climate change opinions and the associated “temperature-induced response bias.” Studies and academic texts suggest that studying media outlets gives a reasonable proxy for public concern, as they typically reflect public opinion. Newspapers, TV, radio are generally for-profit and seeking to reflect topics of interest to the associated populous (Holtz-Bacha & Strömbäck, 2012).

Within coastal communities seeking to pass referendums funding beach nourishment, media analysis can provide an idea of how public concern has risen or fallen over time, and how it correlates with “shocks.” Media studies suggest that the American public is subject to a cyclical process regarding news cycles. Typically, an event occurs, it is picked up by news media, and then quickly subsides after interest wanes or a new topic arises. This emergence of media spikes reflects media in the internet age, and can apply to both news and entertainment outlets (Leskovec, Backstrom, & Kleinberg, 2009). Given nourishment projects are typically sparked by large storm events, media coverage should reflect the same cycle.

A simple google trends search of “interest” in beach nourishment in North Carolina over time suggests a history of peaks and valleys. Interest is defined as a fraction of whatever number of searches are the historical maximum. So, the time associated with the most interest in the search term is given an interest value of 100, and all other values are computed relative to that (“Google Trends,” 2018). Google search interest suggests that since 2004, the earliest date of available data,

overall interest peaked in 2004 and 2005, and has since leveled out (figure 1). Given Hurricane Isabel struck eastern NC in 2003, causing \$347 Million in property damage, this result is unsurprising. This reinforces the literature regarding major shocks and corresponding media coverage.

A 2017 study by Bulla et al. surveyed 283 local officials throughout coastal NC to determine what influences decisions to adapt. The survey attempted to gauge what risks posed the greatest influence on “WTAA” or “Willingness to take adaptive action.” At low levels of risk, there was no significant difference in WTAA based on political ideology, but under moderate to high levels of risk, the WTAA was much higher for all groups, but especially high for moderates. This study seems to reflect how adaptive action is correlated with perceived risk, and in the case of beach nourishment, likely correlated with serious storm erosion (Bulla et al., 2017).

Political and Economic Implications of Beach Nourishment

Consistent with the timeline of federal subsidy in the US, coastal communities that thrive on tourism and undergo nourishment have seen a dramatic shift in the homes on the coast (Bagstad, Stapleton, & D’Agostino, 2007). Smaller, slab built homes are being torn down for 10-bedroom rental properties on stilts, seeking a higher rental price tag and competitive gains in the tourism market. A 2016 analysis conducted by Armstrong et al. suggests that within the state of Florida, homes on nourished beaches are larger and more valuable, suggesting that nourishment may be encouraging development in areas more prone to erosion. The potential for bi-directional causality between nourishment and development in flood zones exists in this analysis. Development in flood zones leads to nourishment, but nourishment also leads to development in flood zones. Rarely are these oceanfront homes occupied by their owners, but rather serve as investment properties. Studies suggest that the value of these investment properties is highly dependent on beach width,

thus motivating protection (Gopalakrishnan et al., 2011; Pompe, 1999). These rental properties, as well as the local small businesses, rely on a constant stream of travelers to ensure the return on investment is secured. In addition to increasing the individual home value and protecting the property, a wide beach keeps coastal communities competitive with their substitutes, thus producing economic benefits throughout the entire area (Shivlani, Letson, & Thesis, 2003).

Most Southeastern coastal communities experience highly variable population densities. During the summer months, the population can multiply several times the census-reported population, requiring local infrastructure to meet peak demand of only around 10 weeks. In Dare County, the population swells from approximately 33,000 to 225,000 during peak season. These 10 weeks represent an approximately 70% of gross receipts for the year in Dare, putting strain on local officials to ensure this short economic window is maximized (Tippett, 2015). Beach nourishment is just one example of infrastructure within coastal communities that presents complications for local officials. The beach width is one of many factors included in the decision-making process by potential summer visitors, and studies have shown a significant feedback loop between nourished beaches and tourism growth (Corral & Schling, 2017; Shivlani et al., 2003). Tourist towns that nourish tend to grow, requiring more nourishment to protect the local economy, which again drives growth.

The rise of nourishment and coastal growth together put local officials at odds. Nourishing beaches is necessary to protect the community's economic value, but it is costly. The decline in federal support means revenue will have to be raised locally, likely to pay off a general obligation bond or revenue bond (Griffiths, 2011). Current nourishment projects have a life-expectancy of five years, meaning elected officials must establish mechanisms for repaying millions in debt on a regular basis, and do so in a way that does not risk their seat in local politics. Local property

owners, albeit a small contingency of total property owners, have the greatest impact on funding mechanisms. These individuals have the voting power and voice necessary to ensure their preferences are met (Hajnal & Trounstone, n.d.).

Within the political sphere, most voices are heard on the ends of the bell curve, because these individuals have the most to gain or lose. Rarely are complaints heard from those that remain roughly the same regardless of political action (Hajnal & Trounstone, n.d.). This finding is mirrored in literature from fisheries management. A 2005 study suggests that attendance at National Marine Fisheries Service meetings regarding quota allotments is not representative of all participants within the fishery. Looking specifically at surf clam and quohog fisheries, statistical analysis suggests that meeting participants are “larger, nearer, and more extreme firms.” In sum, participation in public forum is costly, so firms gaining the greatest economic rent from attendance are most likely to be represented. More capital, closer proximity, and more impassioned views typically characterize participants (Turner & Weninger, 2005).

Beach width is a public good, thus falling victim to the tragedy of the commons. Regarding beach nourishment financing, this typically corresponds to oceanfront property owners, and property owners inland or outside of the nourishment site. Oceanfront property owners seek to maximize the length of their respective beachfront while minimizing the associated costs, while the other side seeks to minimize their costs and “free ride” on some small benefit (Pompe, 1999).

Nourishment activities rarely extend the entire length of a municipality. As mentioned previously, erosion does not occur uniformly, and thus nourishment is typically segmented within communities (Pompe, 1999). The distribution of benefits from beach nourishment is typically highest amongst those homes in the direct area of nourishment, but given that fine sediment diffuses from the project area somewhat uniformly, there can be benefits both updrift and

downdrift from the original project area (National Resources Council, 2006). In short, the project length is not a perfect proxy for distribution of benefits from nourishment. From the perspective of local officials, this complicates the decision-making process.

The demographics of these southeastern coastal communities vary to some extent, but the political affiliations and age are relatively uniform. The average age typically trends towards older populations, and a 2013 NOAA report states that “the growth rate among the age categories differed substantially, demonstrating an aging population on the coast” (National Coastal Population Report). Analysis of recent elections suggests a correlation between older populations and republican voting in presidential elections (Chalabi, 2016). Given the conservative nature regarding taxation often associated with republican candidates, it seems a correlation can be drawn between older populations in coastal areas and resistance to taxation. Given the three funding streams for beach nourishment mentioned previously (local occupancy tax, sales tax, and millage rate increase), only one option satisfies the resistance to taxation of local voters, the local occupancy tax. Despite this political salience, the local occupancy tax makes the given tourism community less competitive in the market, and thus is not the ideal choice for local officials.

Sales taxes distribute cost burdens between both visitors and residents, but arguably have a greater burden on residents over the length of a year and fail to reflect the unequal distribution of benefits from nourishment activities. Conversely, property millage rates can be manipulated on a finer scale, assigning higher costs to those who benefit most from nourishment, and distributing some lower cost to a larger contingency of properties. Presumably, this allows for some equitable distribution of costs relative to the associated benefit (Pompe, 1999).

There is a general understanding that beach nourishment financial burden cannot be uniform throughout a coastal municipality. Hedonic property models have shown that the greatest

increase in value accrues to those properties directly on the oceanfront within the nourishment area (Gopalakrishnan et al., 2011). Although the beach is a public good accessible by residents and visitors alike, the property values of coastal structures is reflective of beach width. With this understanding, constructing financial mechanisms requires the creation of Municipal Service Districts, or MSDs, and respective millage rates (Pompe, 1999). Different proposals for construction of finance districts have been discussed in the literature, but the customary practice in Dare County involves establishing two MSDs, one for oceanfront properties within the project area, and one for the remainder of the community (“Tax Rates | Dare County, NC,” n.d.). The opportunity for variability resides in how the cost-burden is distributed between those MSDs, and is often a function of several key demographics.

Attempts to model how communities will fund their nourishment projects have been made. A recent model by Mullin, Smith, and McNamara (2017) analyzes characteristics of communities including percent owner-occupancy, the number of oceanfront homes relative to all properties within a municipality (“thickness”), and political awareness have been included, and each seem to project impacts on how funding mechanisms will be structured. Each of these characteristics are important independently, but combine to create a unique set of challenges for elected officials. The percent owner-occupancy reflects the proportion of property owners whose preferences are represented in municipal decision-making. Thickness is directly related to how the properties and nourishment benefits are distributed within a community, and political awareness gauges how actively community members will advocate for their preferences in local politics.

Presumably, communities with a higher percent owner-occupancy, specifically off the oceanfront will be more likely to distribute higher costs to oceanfront property owners. Similarly, in “thick” communities, or those with oceanfront homes representing only a small portion of the

total properties, the model predicts a greater distribution of costs to the oceanfront. A greater level of political awareness would imply more challenges in meeting the preferences of the loudest voters, and thus a distribution of costs that better reflects the associated benefits.

Case Study: Dare County

Currently, little data exists on how this model reflects actual outcomes. Few communities along the southeast receive no federal subsidy, although all will soon be trending that direction. Dare County, on the Outer Banks, has both fallen behind and taken the lead regarding public finance for beach nourishment. By missing the deadlines for federal subsidy, Dare is faced with real political and economic challenges in securing major infrastructure projects and one of the first areas to test the outcomes of economic models. Nourishment is not a long-term solution nor is it a favorable solution for many interest groups, but for areas like Dare County with no interest in sacrificing valuable properties to rising oceans and receding coastlines, it is currently the only option.

Dare County is made up of 21 tax districts, but only six incorporated towns: Duck, Kill Devil Hills, Kitty Hawk, Manteo, Nags Head and Southern Shores. The populated portion of the county resides on the Outer Banks, a barrier island chain on the coast of NC. Despite a highly dynamic coastline, prior to 2015, only Kitty Hawk had undergone beach nourishment at any point throughout the town history, but most major municipalities were at risk of property loss if a storm arose. As of 2017, Duck, Kill Devil Hills, Kitty Hawk, and Nags Head have all undergone beach nourishment, and did so without federal subsidy (“Completed Projects | Dare County, NC,” n.d.).

For the purposes of this master’s project, the research will investigate how communities within Dare pay for nourishment, how this reflects the models of Smith et Al. (2009) and Mullin, Smith, and McNamara (2017), and the relationship between public awareness and storm events.

Methods

Conducting this Master's Project required two separate and distinct methodologies. The first methodology involved a news review of articles pertaining to Dare County Beach Nourishment from 1983, the earliest available archive, to present day, in hopes of finding correlations between storm events, as listed on NOAA's storm database, and media attention. This analysis aims to assess if public concern for nourishment is consistent across time, or whether interest peaks post-storm and wanes in fair weather. The second methodology involved data collection and statistical analytics on tax assessment, community thickness, and demographics for Dare County and similar areas along the southeastern US. Community thickness reflects how many rows of housing there are across a barrier island. A thin community might have just a few rows, e.g. a row of oceanfront homes and just several rows behind the oceanfront. This analysis addresses how communities pay for major municipal projects under concerns over voting pressure and equitable distribution of benefits and costs.

Newspaper Article Analysis

While not an initial part of this MP, literature review seemed to suggest that Dare County needed beach nourishment long before they finally passed an ordinance. Given the unique geomorphology of this area, and the strong Republican leaning demographics, passing tax ordinances that meet the financial needs of costly beach nourishment while suiting the equity concerns of homeowners has been an ongoing challenge. The North Carolina State Board of Elections and Ethics Enforcement reports that there are 9,011 registered Republicans, 8,745 registered Democrats, and 11,234 unaffiliated voters within Dare County ("Voter Registration Statistics," n.d.). While the registered republicans and democrats are nearly equal, results from 2012 and 2016 presidential elections suggests that overall, Dare voters lean republican According

to NY Times election results data, in 2012 57.4% of Dare County voters chose Romney, compared to 41.2% for Obama. 2016 fared similarly, with 58.4% of voters selecting Trump versus 36.8% for Clinton (“President - Live Election Results,” 2012; “Presidential Election Results,” 2017). This inspired using Duke University’s Library System to analyze all newspaper articles related to “dare county beach nourishment” since 1983.

The initial search returned over 700 results, some of which were duplicates, but many of which were unique. Most articles came from a local paper out of Virginia, *The Virginian-Pilot*, but others reached a broader audience in the state (*The Charlotte Observer*) and the nation (*Washington Post*, *AP News*). A timeline was created in excel, and articles were assigned to their associated month and year within that timeline. The article title and link were attributed to the month and year of publication within excel. Only articles from the news media were included. Any articles that were produced for governmental purposes were excluded. In addition, all duplicate articles were excluded. If titles were an exact match, even if the publishing newspaper was different, the second, third, etc., article was excluded. In addition, all articles were skimmed to ensure that the text was related to: 1) Dare County and 2) Beach nourishment. The articles included information on public hearings, public opinion, proposed projects, and historical/future needs. If the article met the two requirements mentioned earlier, they were included. This search process included articles that mentioned Dare County in light of federal reductions in spending, or as a case study for similar areas.

A significant drop off in article frequency was noted after 2010. This seemed to contradict the rising debate over financing beach nourishment within Dare County since 2013, so additional inquiry was required. The *Outer Banks Sentinel*, a local weekly paper for the community situated along NC’s northern barrier islands was established in mid-2006, slowly shifting readership from

Norfolk's *Virginian-Pilot* to the local issue. Beginning in early 2008, the Outer Banks Sentinel began publishing pieces on the topic of beach nourishment. Including the Outer Banks Sentinel added another 150 articles to the total count. The final article frequencies were plotted by month and year, and totals by month across the entire timeline (1990-2017) and by year were established.

After all 850 articles were examined and only those related to the topic were added to the timeline, NOAA's storm event database was analyzed. The database provides information on all storm events within the United States and their associated property and crop damages. The search was limited to winter storms, storm surge/tides, coastal flooding, high wind, high waves, hurricanes, tropical storms, and tropical depressions in Dare County, NC from 1996 to current, as that aligns with the earliest recorded data. 57 storms were listed. The dates of these storms were added to the timeline to look for correlations between frequency of storms and articles. Somewhat unsurprisingly, Dare County gets hit by storms almost every year. For this reason, the property damage values and death counts were assigned to each storm to assess how these damages affected beach nourishment media attention. The value of property damage varied widely between storm events, causing a scale issue. To aid in visualization and scale, the log of each annual property damage value for Eastern Dare County was taken and used to assess trends.

Using this information and Excel software, a graph was created that depicts the frequency of articles in line form and $\log(\text{total property damage})$ as bars. To assess if beach nourishment media attention experiences a latency period after damaging storms, the article frequency was also lagged two years, and graphed opposite $\log(\text{total property damage})$ in the same fashion. This information was assessed visually for trends between storm damages and article frequency across newspaper sources. Frequency of articles was plotted across time to look for trends in news

coverage between 1983-2017. In addition, articles were aggregated monthly across the entire dataset to assess monthly trends in news coverage.

The NOAA storm data and article frequency data were then analyzed statistically, using Stata software. Using data from ASBPS's beach nourishment database, the number of nourishment events within Dare County in each year were added to the dataset. Storm events were then classified into two categories, "coastal floods" and "storms," as coastal floods may have an independent influence on beach nourishment media attention than traditional storms, which often have impacts outside of beach loss. Summary statistics and correlations were run between the variables to ensure the dataset is not subject to unnecessary bias. Regressions were run with robust standard errors to assess the effect of the independent variables on article frequency. Finally, a time series analysis was conducted, lagging articles by one, two, and three years. The lagged data was then regressed against other variables in the model, using robust standard errors, to explain the variation in article frequency over time.

Tax Assessor Data Analysis

One important challenge of this topic is that most of the data is not yet aggregated, and reductions in federal spending for beach preservation are not happening uniformly. Dare County is of particular interest, because unlike many areas along the Southeastern coast, it receives no federal support or state support. Despite somewhat similar geomorphology just north of Cape Fear, but south of Cape Hatteras, these areas have attained federal support over time and thus are locked into subsidies for the near term. Similarly, South Carolina largely leans on federal funding for beach nourishment, as well as a state "Beach Preservation Fund" subsidy ("S.C. Renourishment," n.d.; Thurmond & Hembree, 2014). Dare County is much more reliant on municipal forms of funding than these other coastal towns, leaving little wiggle room outside of Local Occupancy

Taxes and Property Tax millage increases to repay the incurred municipal debt (“Frequently Asked Questions | Dare County, NC,” n.d.). Dare County’s current reality is the future for many, if not all, coastal towns in the US. Federal funding is continuing to decline, and states can only subsidize to the extent that these funds cover. Dare County is a case study into the future of Public Finance and Coastal Climate Change Adaptation in the US.

Dare County provides tax assessor data for download through the county website. Each town/incorporated area’s tax assessor data is available separately. This data was downloaded for Duck, NC (21-DUCK), Kill Devil Hills (07-KDH), Nags Head (14-NH), and Kitty Hawk (08-KH). Using Stata, valuable characteristics for this analysis were attained. The number of residential properties, oceanfront properties (both commercial and residential), and the associated home values of each category were calculated and recorded, as they reflect the “thickness” of the community, as well as how the distribution of cost must be spread. T-tests and regressions were run to determine if home values on the oceanfront are significantly different than those in the remainder of the community. Similar statistical tests were run on other variables for exploratory analysis.

Another important component of passing these ordinances for financing large projects is public perception and feasibility of reelection. Unpopular ordinances likely cause incumbents to be replaced. Within the available dataset, the mailing address for both the property and the preferred address of the owner are listed. If the preferred address fell within Dare County, it was considered “local” for the prospect of voting in local elections. While this is likely an overestimate of individuals willing to drive to participate, it provided some understanding of the distribution of homeowners and actual occupants within the selected towns.

In addition to this data, census data was obtained. This data included median home value, average age, median household income, percent of population on SNAP benefits (as a proxy for poverty), total population, percent white, and other various housing characteristics, such as “owner-occupied.” In addition, using data from the American Shore and Beach Preservation Society’s (ASBPS) National Beach Nourishment Database, information on the total volume (in cubic yards) and total cost of the most recent nourishment event was obtained, along with a count of total events throughout history. In addition, town ordinances provided data on the associated millage rate in MSDs and project cost sharing between the town and Dare County. This data was aggregated into a single spreadsheet for statistical analysis.

Further investigation into the data suggested that an analysis of just a few towns may prove insignificant for statistical power. Again using ASBPS’s National Beach Nourishment Database, coastal towns along the Southeast were observed and selected based on meeting a number of criteria:

1. The town must be separated from the inland areas by a bay, inlet, sound, or other large body of water,
2. The town must have undergone nourishment since 2010, to ensure applicability of 2010 census derived data, and
3. The town must exist in its own right. That is, the town must be an independent entity, not a private community or subset of a larger community.

These criteria severely limited the available towns. Of the states investigated (MD, VA, NC, SC, GA, FL), NC and SC provided the most options. Several private communities fit the criteria, but do not have census specific data available and likely do not undergo the same funding issues as municipalities.

For the reasons listed above, only a few towns could be added to the analysis. These include: Ocean City, MD; Atlantic Beach, NC; Bald Head Island, NC; Emerald Isle, NC; Kure Beach, NC; Topsail Beach, NC; Surfside Beach, SC; Edisto Beach, SC; Folly Beach, SC; and Hilton Head Island, SC. No central database exists that lists how beach nourishment is funded, so proposals and budgets from municipal websites were used to aggregate data on: 1) The expense incurred by the municipality, 2) The funding mechanism to cover that expense, and 3) The expense incurred by federal/state government. This data was aggregated for each town and added to central database.

As mentioned previously, Dare County is in a unique position. The county did not sign on for federal nourishment subsidization and thus is without financial support. But, given this subsidization will end in the next couple of decades, Dare is the first real area grappling with municipal funding for these large and highly debated projects. Analysis of funding mechanisms for municipalities within Dare County resulted in significant interest in Duck, NC. MSDs in Duck do not follow the similar pattern of high millage rates for oceanfront properties owners and a smaller increase for the rest of the town. In Duck, only those properties aligned with the project (along the width of the island) fall under additional taxation. For this reason, the properties were investigated further.

Using the tax assessor dataset, “owner occupied” was determined by matching mailing addresses and property addresses within accounts. Binary 0 or 1 values were assigned to properties, signifying failure or success, respectively. Once matches were established, they were listed and added to a separate worksheet. Using MSD maps provided by the Town of Duck, these addresses were plotted. Properties were assigned a value of 1 if they fall within the MSD, 0 if outside. For

accounts within the MSD (1), it was then determined if these properties are on the oceanfront. For accounts outside the MSD (0), their respective direction (N/S) relative to the MSD was recorded.

Insights from Dr. Andrew Keeler of ECU suggested that determining contribution to decision-making is not so binary, as many individuals own properties in one town for rental income and live in a neighboring town. Thus, another analysis of properties within the MSD was conducted to include property owners who live in other municipalities within Dare County, as they can still participate in public forums and participate in the political sphere. Another variable “local” was created. Properties were assigned a value of 1 if the corresponding mailing address was based in any town or census-designated area in Dare County, and a value of 0 if not. Then a similar analysis was conducted, determining the location of these properties relative to the MSD.

Results

Newspaper Article Analysis

Using only Duke University Databases, the initial search rendered 680 results. By skimming each article and creating an aggregated list of titles to eliminate possible double-counting and unrelated pieces, a final tally of 330 articles was recorded. These databases only date back to 1983, thus limiting the scope. The Outer Banks Sentinel was added to this tally, generating 149 additional articles.

Patterns were analyzed both across years and across months by aggregating frequency data. Without the Outer Banks Sentinel data, there was a significant drop off in related articles after 2008 (Figure 2). Given that most of Dare County did not undergo nourishment until 2015-2017, this did not seem to reflect level of concern as projected. Upon addition of Outer Banks Sentinel

articles, the trend seems to reflect expected media response, with a trend towards increased newspaper attention over time (Figure 3).

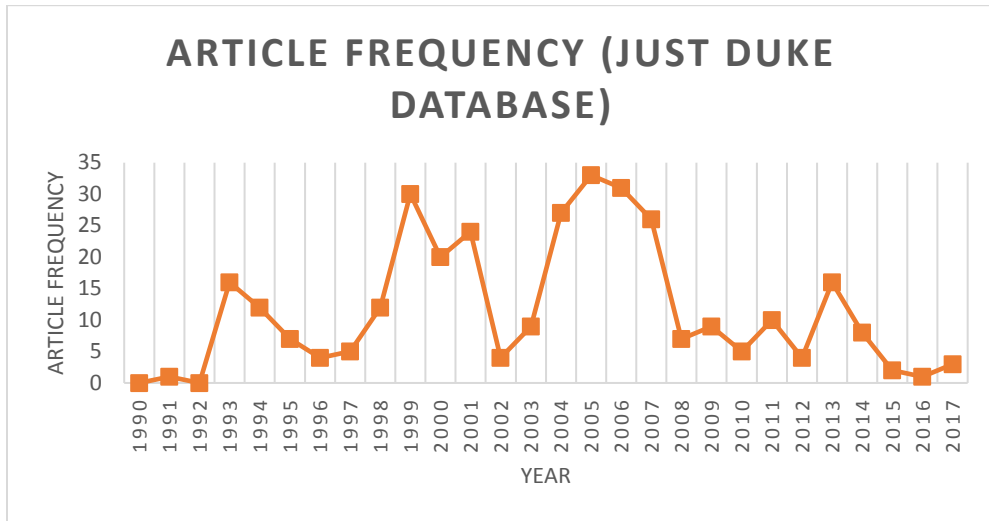


Figure 2: “Beach Nourishment Dare County” Article Frequency: Duke Database 1990-2017

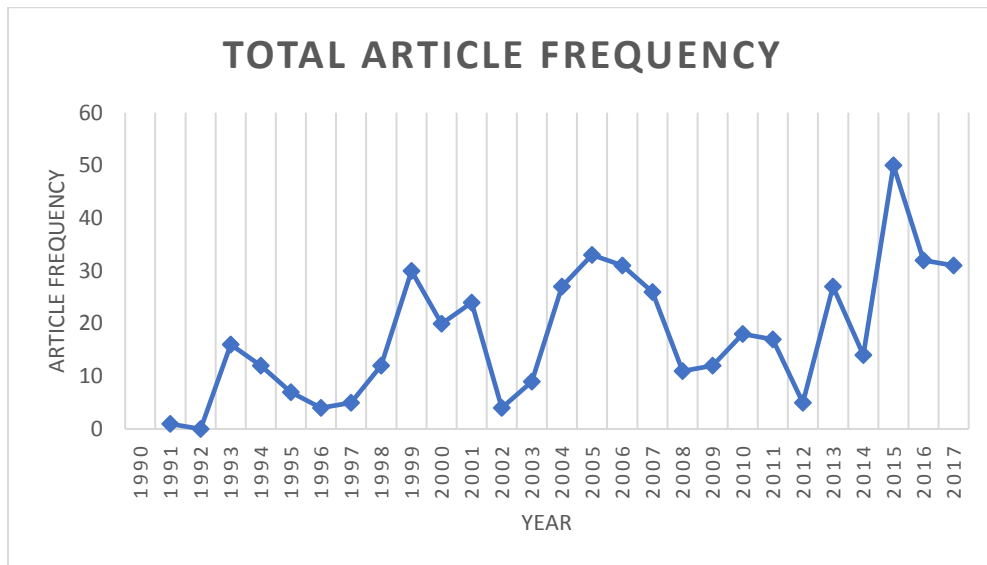


Figure 3: “Dare County Beach Nourishment” Total Article Frequency (1990-2017)

A significant spike, and the maximum value for a single year is observed in 2015. This marked the first year in a long process of evaluation, permitting, design, and implementation within the county. Other trends and peaks are observed in 1993, between 1999-2001, and between 2004-2007. Using NOAA’s Storm Database, these trends were graphed alongside storm frequency over

time (Figure 4). This database only provides storm information from 1996-present, so earlier years of article data were excluded from figures. Only 1993 was of note regarding article frequency prior to 1996, so no effect on trends is expected. No significant trends could be observed. Even years with multiple storms did not seem to reflect the same news attention. The property damage data associated with each storm for Dare County was aggregated on an annual basis and plotted alongside article frequency (Figure 5). The largest storms generated property damage several orders of magnitude larger than the smallest storms, so the logarithm of annual property damage was taken and plotted with article frequency (Figure 6).

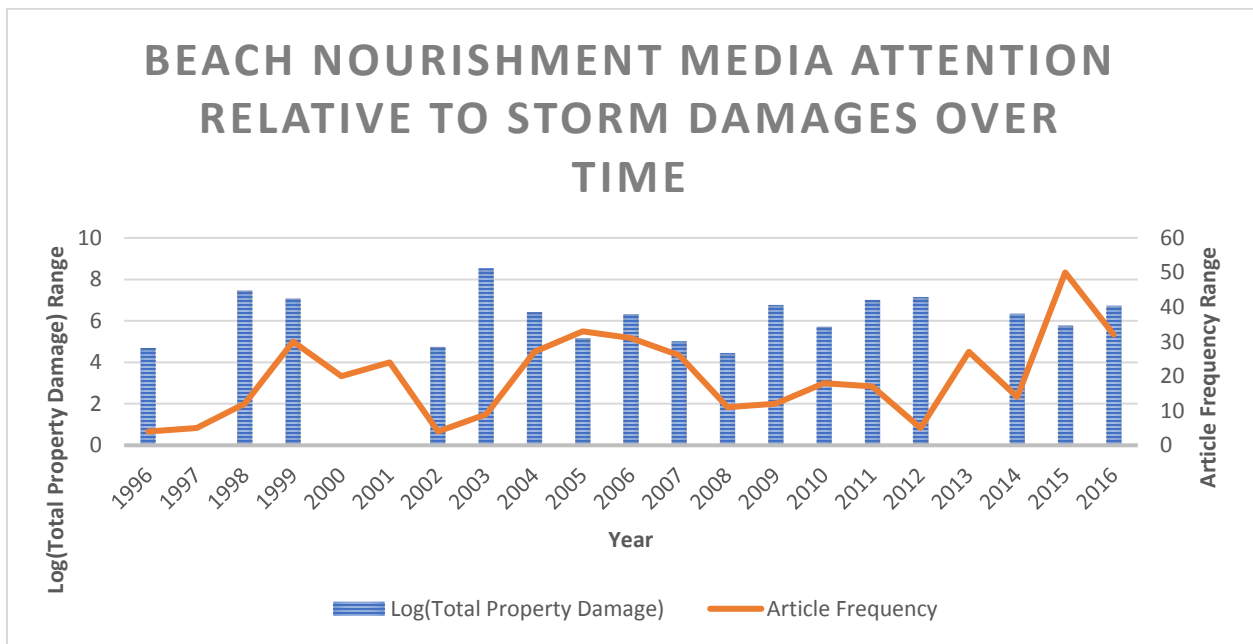


Figure 6: Article Frequency and Log(Property Damage) in Dare County (1996-2017)

While the position of the two series is seemingly random at first glance, there does appear to be some potential correlation between log(total property damage) and article frequency. Accumulation of property damages from 1996-1999 mimics a rise in article frequency that holds until 2002 despite no storm damage during the two previous years. Similarly, 2002-2006 marked five consecutive years of property damage, including the greatest year of property damage in 2003,

due to Hurricane Isabel. 2010-2012 also produced steady property damages throughout Dare County, and a corresponding rise in beach nourishment article frequency in the years that followed. Table 1 shows total property damage (\$USD) from the four most damaging storms to Eastern Dare County included in the database results. This table excludes storm surge damages from Hurricane Irene, as these largely caused damage to sound-side properties and did should not impact public concern towards beach nourishment.

Year	Storm Name	Total Property Damage (USD)
1999	Floyd	\$12,000,000
2003	Isabel	\$347,000,000
2011	Irene	\$15,000,000
2012	Sandy	\$14,000,000

Table 1: Total Property Damage From 3 Storms

To assess statistical correlation between article frequency and property damage, regressions were run on variations of the data. When only assessing levels of data (i.e. the property damage in its absolute rather than logarithmic value), simple regressions produced an r-squared of 0.041 and a p-value of 0.374, indicating no statistically significant relationship. When assessing article frequency as a function of log(total property damage), the correlation coefficient is similarly small (0.049). Finally, when assessing number of articles as a function of log(total property damage), but dropping years without any property damage, the correlation shrinks to nearly zero (r-square=0.002) and the p-value nearly rises to 1 (0.965). Table 2 summarizes these results.

Variable	Correlation Coefficient (r)	P-value
All Years: Total Property Damage	0.041	0.374
All Years: Log(Total Property Damage)	0.049	0.351

Excluding Zeroes: <i>Log(Total Property Damage)</i>	0.002	0.965
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Table 2: Correlation Coefficients for Variations of Total Property Damage Data and Article Frequency

Because beach nourishment may not be the initial concern for the public in wake of large storms, the data was also assessed using a time series analysis, the results of which can be seen in tables 3 and 4 below. Multiple models were run, the results of which can be seen in the appendix, but tables 3 and 4 represent the highest R-squared values. In short, statistical significance between article frequency and total property damage (in levels) appears on a two-year time delay, and approximately two years after the property damage occurs, but the associated coefficient is essentially zero. When using log(total property damage), the model results in no statistically significant relationship between log(total property damage) and article frequency. Conversely, both models produced strong statistical significance ($p < 0.01$) for “Number of Flood Events.” In each model, two years after a coastal flood events occurs, there is approximately a 10 unit increase in article frequency related to Dare County beach nourishment, holding all other variables in the model constant.

Levels: Two Year Time Lag, Excluding Years w/ Zero Total Property Damage (n=16)

Variable	Coefficient	P-Value
Total Property Damage	3.16E-08	0.001
Number of Flood Events	10.326	0.007
Storm Death	-0.792	0.758
Nourishment Event	-0.879	0.856
Number of Storm Events	-3.395	0.007
R-squared	0.807	

Table 3: Results from Model using Total Property Damage in Levels

Logs: Two Year Time Lag, Excluding Years w/ Zero Total Property Damage (n=16)

Variable	Coefficient	P-Value
Log(Total Property Damage)	-1.76E-01	0.951

Number of Flood Events	9.799	0.001
Storm Death	-0.677	0.887
Nourishment Event	-2.739	0.531
Number of Storm Events	-3.768	0.007
R-squared	0.744	

Table 4: Results from Model using Log(Total Property Damage)

The data was also graphed, like figure 6, but lagging the article frequencies two years. Figure 7 shows that the peaks and valleys of log(total property damage) and article frequency seem to more closely align, specifically between the 2002-2012 spread of consistent annual property damages due to storms. Simply observing trends visually does not negate the lack of statistical significance in the model, but does suggest that the model could produce different results under conditions with larger sample sizes and more explanatory variables.

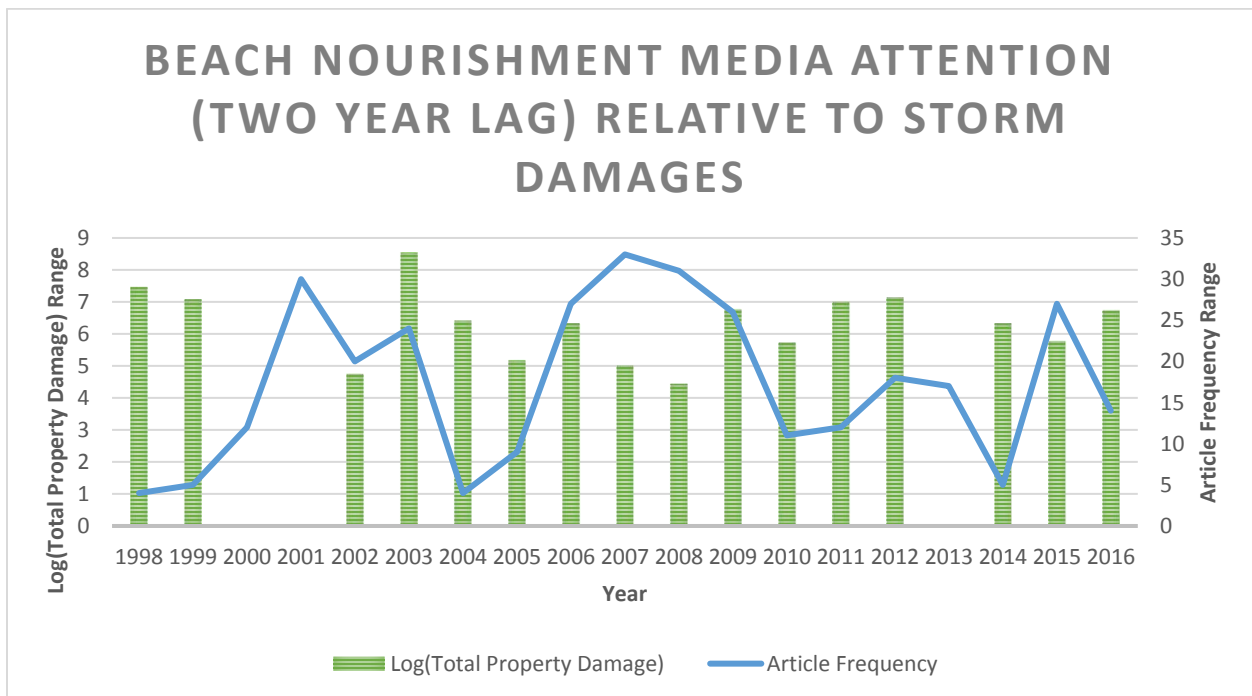


Figure 7: Two Year Lagged Article Frequency Relative to Log(Total Property Damage) in Dare Co. (1998-2016)

Articles were also aggregated across monthly across all years to illustrate patterns (Figure 8). Even when taking cumulative values across the entire 1990-2017 period, there are trends observed in the data. Article counts seem to rise and reach a maximum value in October, before falling rapidly between November and December. January starts a relatively steady frequency that carries through June. July, August, and September show low article counts.

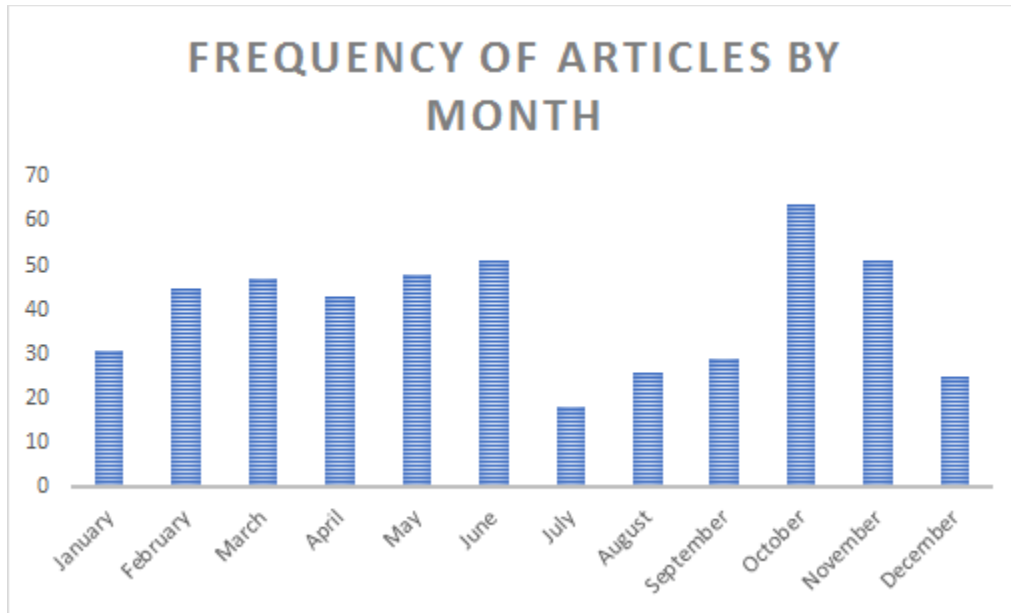


Figure 8: Frequency of Articles by Month Across Entire Time Series (1990-2017)

Tax Assessor Data Analysis

Using data from the Dare County Tax Assessor, ASPBA beach nourishment database, municipal-level project documents, and the 2010 US Census, a database was created to analyze coastal towns undergoing nourishment based on key demographics. This database is a stepping-stone towards statistical analysis regarding how characteristics of towns shape their Municipal Service District (MSD) structure. Additional data on towns that fit the criteria mentioned in the methods was also recorded. The tax data available from Dare County allowed towns within Dare County (Kitty Hawk, Duck, Nags Head, and Kill Devil Hills) to fill all variables within the

database. Given the inaccessibility of well-organized and downloadable tax assessor data for many of the chosen towns, as well as the continued federal subsidization of beach nourishment throughout the southeast, the database will continue to grow after this MP. The results of this data analysis will only include information from Dare County.

Demographically, Dare County is Republican leaning. 57% of 2012 voters chose the republican presidential candidate, Romney, while only 41% voted for Democrat incumbent Obama. The average age varies slightly by town, but ranges from a low of approximately 37.8 in Kill Devil Hills to a high of 58.2 in the Town of Duck. Conversely, the population varies widely throughout municipalities in Dare County. As the total land area and thickness of both the barrier island and associated properties changes drastically along the length of the county, this creates diversity in municipality size. For the purposes of this project, total population is not as important as a similar demographic: percent owner-occupancy, as this represents the voting population for major referendums. In Duck, only about 6% of residential properties are owner-occupied, followed by Nags Head at 17%, Kill Devil Hills at 26%, and finally Kitty Hawk at 33%.

Each municipality provides extensive information on the MSD construction and millage rate for the recent beach nourishment projects. Table 5 shows the details of these MSDs for the four municipalities within Dare County covered under the recent project. As seen, three of the four municipalities lump properties into an “oceanfront” or “everyone else” category. Essentially, everyone within the municipalities pays a small millage rate for five years, reflecting a five-year general obligation bond payback, and oceanfront property owners within the project site pay an additional millage rate for the same period. Duck, NC, does not follow this trend.

Municipality	# of MSDs	Covers Entire Municipality (Y/N)	Millage Rate (\$/\$100 assessed value) Non-Oceanfront	Millage Rate (\$/\$100 Assessed Value) Oceanfront
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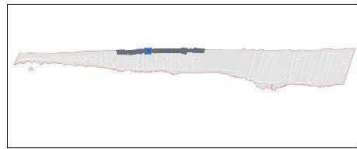
Nags Head	2	Y	\$0.027	\$0.175
Kitty Hawk	2	Y	\$0.02	\$0.12
Kill Devil Hills	2	Y	\$0.03	\$0.33
Duck	2	N	\$0.148	\$0.463

Table 5: MSD Construction by Municipality in Dare Co.

Duck, NC is fundamentally different than other towns within Dare County. As the most recently incorporated town, only founded in 2010, it is also the “thinnest” in terms of geographic area of the municipalities studied and the least populated. Only 369 people live within the town of Duck, and only 6% of homes are owner-occupied. An additional 12.2 percent of properties are owned by “local” individuals, who reside within Dare County according to Tax Assessor data. This represents a small contingency of voters/voices making decisions for a much larger tax base. Figures 9 and 10 depict the MSD structure within Duck.



Figure 9: Town of Duck MSD A (Photo Courtesy: Town of Duck)



Beach Nourishment Area
Municipal Service District B

Updated November 10, 2014



Figure 10: Town of Duck MSD B (Photo Courtesy: Town of Duck)

There are still 2 MSDs, but they only cover about $\frac{1}{3}$ of the municipality, and only the portion directly aligned with the project. MSD A has a millage rate of \$0.148/\$100 assessed value. MSD B has an *additional* millage rate of \$0.315/\$100 of assessed value, for a total millage rate of \$0.463/\$100 of assessed value. For a \$1,000,000 home, which is likely on the lower end of oceanfront property values, this represents an additional \$46,300 in property taxes each year for five years.

The projects costs are first split between Dare County's Beach Preservation Fund and the Town of Duck. The Beach Preservation Fund, supported by local occupancy taxes, covered \$7.7 Million of the \$14.58 Million project. The town of Duck was responsible for the remaining \$6.68 Million. This was paid for using a 20/40/40 split of costs. 20% was paid from the town general fund, 40% by all property owners within MSD A, and 40% by oceanfront property owners in MSD B. While MSD B covers a very small number of properties, they have the greatest assessed value within the MSD area, and thus can generate a much higher property tax revenue.

Given this unique MSD structure, the town of Duck's tax assessor data was analyzed further. New binary variables "owner-occupied," "local," and "oceanfront" were created and owner-occupied properties were mapped. Of the 143 homes that met the definition of "owner-occupied" within the dataset, only 37 are within the project area, meaning 104 owner-occupied homes lie either north or south of the project area. Of the 37 owner-occupied homes within the MSDs, 0 are oceanfront, or in MSD B. The MSDs exist in the middle 1/3 of Duck, easily delineating properties into a "North" or "South" category based on their location relative to the MSD (Figure 10).

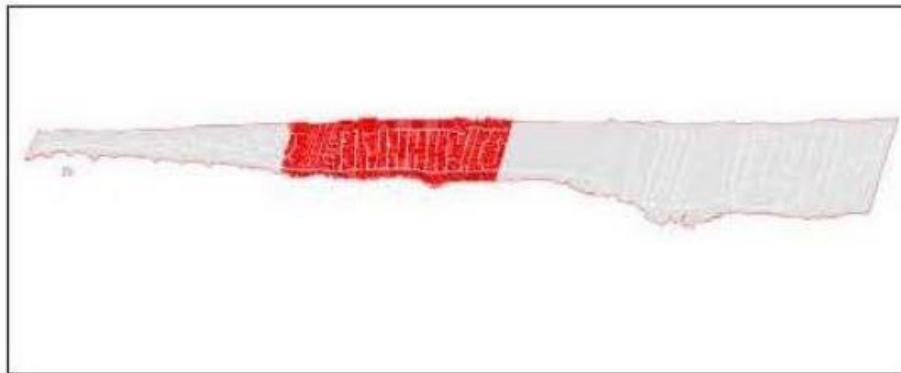


Figure 11: Town of Duck MSD (Highlighted) Relative to the Entire Municipality

82 owner-occupied properties are located south of the MSD, and 24 are located to the north. Interestingly, of the 24 northern properties, 8 properties were within two blocks of the MSD. The same analysis was conducted for "local" properties, as these individuals can still apply political pressure during the project planning and voting process. Table 6 summarizes the results of that analysis.

Total Residential Properties: 2512		
“Owner-Occupied”	143 (5.7%)	
	<i>Oceanfront</i>	6 (4.2%)
		In MSD 0 (0%)
	<i>Non-Oceanfront</i>	137 (95.8%)
		In MSD 37 (27%)
“Local”	414 (16.5%)	
	<i>Oceanfront</i>	45 (10.9%)
		In MSD 21 (47.7%)
	<i>Non-Oceanfront</i>	369 (89.1%)
		In MSD 94 (25.8%)

Table 6: Distribution of “Owner-Occupied” and “Local” Residential Properties in Duck, NC

As seen in the preceding table, the analysis of “local” properties rendered slightly contrasting results from the analysis of “owner-occupied” units. Surprisingly, of those “local” properties on the oceanfront, there is a near 50/50 split of those properties in and out of the MSD. Given the large millage rate increase for oceanfront properties, this split is not the expected result given the political power of these stakeholders. When assessing non-oceanfront “local” properties, the distribution was much less surprising. Most non-oceanfront “local” property owners own properties outside of the MSD, in a somewhat overwhelming fashion. The difference between these two values greatly outweighs that of the oceanfront properties. Most of the properties falling outside of the MSD fall to the south, on the southern side of the Army Corps of Engineers site on Scientists Drive.

In addition to the locational analysis of properties within Duck, sample statistics, simple regressions, and t-tests were run on the tax assessor data. Unsurprisingly, at a p-value of less than 0.001, welch's unequal t-tests suggest a significant difference in assessed property value for oceanfront and non-oceanfront homes. This statistical significance held for all four municipalities within Dare County.

Discussion

Newspaper Article Analysis

When the analysis began, the expectation was for frequency of storms to dictate the rise and fall of article frequency. As seen in the results, this was not the case. Awareness and concern for beach nourishment in Dare County (as assessed by media attention) followed large spikes in property damage on a two year time lag, but at a very small coefficient value. Conversely, coastal flood events did seem to correlate to an increase in article frequency across all two year lagged models. This time-lagged correlation can be explained in three ways: 1. Property damage and coastal floods likely signal serious beach and dune losses, 2. Property owners are aware, for even a moment in time, the risks to their properties in the event of large storms, and 3. Property owners must address their own property damages and individuals needs first, then community needs can be addressed.

This loss of beaches and dunes puts property owners in a vulnerable place. Storms are unpredictable and could occur many times during permitting, evaluation, and implementation of nourishment projects. During this vulnerability period, and especially at times when Dare County prohibited use of sandbags as makeshift dunes for oceanfront properties, the public is more concerned about beach nourishment, driving the media attention. Collective action is occurring during the period following large storms, generating livelier public debate and discussion of how

to solve the problem. Overtime, beaches do tend to restore back to their original state, but this restoration period depends largely on the size of the storm and the amount of overwash. These natural processes help to explain why public concern dissipates in years following large storms, even in the absence of nourishment.

In 2011, Nags Head became the first town since the early 2000's to undergo nourishment within Dare County. In 2012, when Hurricane Sandy hit, Nags Head seemed to fare best, in terms of storm damages and overwash, of any municipality within Dare County. Property damages were lower within the nourishment area, perhaps finally providing enough evidence of nourishment benefits to drive other municipalities to start the conversation (Morris, 2012). This helps explain the steep increasing slope of article frequency beginning in 2012 and continuing through 2017. This frequency increase signals both public concern in the wake of damages from Sandy and increased public buy-in given the natural experiment between Nags Head and neighboring municipality, Kitty Hawk.

Monthly patterns in article frequency are explained differently. The significant rise in article frequency in October reflects how important this issue is in local elections. Newspapers often publish pieces highlighting individuals running for public office and their stance on issues. Somewhat surprisingly, beach nourishment was often one of the six topics addressed in these short pieces. This occurred most years, but more often after the mid-2000's, likely driven by memories of Isabel, the growing division between pro- and anti-nourishment groups, and little collective action to address eroding beaches.

The approximately uniform distribute of high article frequency from January-June likely hinges on few key points. First, this is the period where elections are not of primary concern, but the tourism season is on the horizon and visitors are beginning to plan the location of their summer

vacation. Wider beaches and shoreline stabilization have been shown to encourage development in coastal communities, thus driving concern within the public sphere to nourish. Second, the town budgets are generally passed in June. This means that in order to set aside funds for nourishment in a particular year, the finance needs to be settled by June. This keeps attention spans on nourishment during the spring.

The decline in article frequency in the summer can be explained in three ways. First, the budget has been passed and the money has been allocated. Nourishment will either occur in the next fiscal year, or it will not. Second, it is the “busy season.” Competition for space exists within the news media, as only a set number of lines are published. Given the increase in visitors, events, and newsworthy material, this likely weakens the demand for nourishment articles relative to other news. Third, when summer arrives, the beach is the beach. Reservations have been made and tourism is beginning to experience an uptick. Nourishment projects take months, and if progress has not been made prior to the summer, it likely will not begin during those months.

Analysis of news articles provides some insights into public concern for nourishment. In municipalities that require use of general obligation or revenue bonds to fund projects, buy-in from potential voters and year-round occupants is necessary to ensure projects are adequately funded. This runs in tandem with seeking the interests of the majority within these communities, as much as possible, to not jeopardize political office for local decision-makers. As the media often reflects and shapes public opinion, it seems that within Dare County, public awareness and concern for nourishment, and thus successful project implementation, hinges on recent large storms and natural experiments within the county that illustrate benefits to nourishment.

Tax Assessor Data Analysis

The beach nourishment finance database provided considerable insights into the diverse scale of the problem within very small coastal communities. Much of the east coast still relies on federal subsidy of up to 65% of total project cost; specific funds exist within state and municipal budgets to meet the 35% when the money is needed. This means that most of the east coast is not comparable to towns within Dare County. While this is currently the norm, the landscape of public finance in coastal communities will shift in the upcoming years. Analysis of towns within Dare County may provide takeaways for other coastal municipalities when federal funding dissipates.

The analysis of towns within Dare County suggests that considerable variability exists. Average age ranges over nearly 20 years, populations vary by an order of magnitude, and number of properties and median home values spread across large ranges. Each of these characteristics independently provides little insight into how a municipality might shape a funding mechanism for nourishment, but together they might explain variability in MSD construction and millage rate.

The additional analysis of Duck, NC tax assessor information provides some very important takeaways. First, there are *zero* owner-occupied housing units in the oceanfront MSD. This alone is an incredible insight. These homes are responsible for an additional millage rate of \$0.463/\$100 of assessed value, a figure that greatly exceeds any other millage rate within Dare County. This rate is essentially triple what oceanfront homeowners paid in Kitty Hawk and Nags Head. While this is potentially a function of the “thin” community of Duck, NC relative to the other major municipalities in Dare, the politics of the situation suggest that the loudest voices are typically those with the most to lose. Within owner-occupied oceanfront homes in Duck, NC, these voices were not represented.

Again, regarding owner-occupied housing units, even those homeowners within the MSD were greatly outweighed, in terms of frequency, by property owners to the south. Although these

non-oceanfront property owners are paying only a fraction of the oceanfront millage rate, their voices remain outweighed by the somewhat dense owner-occupied area clustered south of the Army Corps site. Politically, this suggests that those living within the nourishment zone may have voices, but they do not represent the majority.

When analyzing “locally-owned” properties, more properties within the MSD exist than those depicted in the “owner-occupied” analysis. Some assumptions are made regarding uniform political interest amongst “local” constituents, including that these individuals are each equally likely to have a voice in local politics. Without data on an individual level, only a broad analysis of potential voice and political pressure can be made.

45 oceanfront properties are owned by “local” individuals. These properties likely present considerable rental income for the owners and are used primarily as investment properties. The associated address for many of these properties is a PO Box, making it challenging to tie the investment to an individual owner. Nevertheless, a PO Box within Dare County still requires regular visits to the area and thus, potential political voice. As mentioned in the results, the proportion of locally owned oceanfront properties was nearly an even split in and out of the MSD.

The town of Duck varies considerably in property density and island width across its length. While this nearly even split of properties was surprising initially, the understanding that only one row of oceanfront homes exists along the length of Duck, but the density of non-oceanfront properties can vary widely helps explain this result. In addition, while these local individuals paying a huge hike in property taxes are likely very loud voices in politics, it is important to remember that not every owner of the 21 properties within the MSD has the resources or the motivation to protest. There is also considerable likelihood that many of these properties are owned by a single entity.

The analysis of “locally-owned” non-oceanfront properties illustrated an unsurprising result. Given that the southern portion of the municipality is much more densely developed and wider than the MSD, the roughly 75/25 split of out/in properties is unsurprising. Most of these properties are located to the south, in the densely populated portion, and represent a great majority relative to the numbers within. Regardless of if properties are “owner-occupied” or “locally-owned,” those within the MSD represent the minority. This helps explain the unique MSD construction within Duck and lends to some conclusions regarding financing large projects.

Conclusions & Future Research

Much of this Master’s Project has lent itself to more research. As a very open-ended and under-researched topic, with considerable directions for future work, coastal climate change adaptation provides numerous paths to understanding the political, social, and economic dynamics these communities will struggle with in future years. This analysis, while only touching on a very small subset of the greater population, provided some worthwhile conclusions and avenues for future work.

As illustrated in the newspaper analysis, people care most in the wake of “shocks.” These shocks cause costs of recovery in the near term and heightened risk in the future. Shorelines require considerable time to rebuild naturally after large storms, and during this time locals are reminded of the risk when visiting beaches. The newspaper analysis also suggests that people care most when project benefits can be witnessed. The 2012 damage costs and recovery from Sandy differed widely between south Nags Head, which underwent nourishment in 2011, and the rest of Dare County. Article frequency hit a maximum value after this point, suggesting that witnessing project benefits motivates the conversation around financing the project costs.

The tax assessor data analysis of Duck suggests that modeling nourishment finance based on town characteristics may be more challenging than initially imagined. The *proportion* of owner-occupied homes matters, but perhaps not to the same degree that the *distribution* does. For towns, like Duck, with a dense area of owner-occupied and locally owned properties that are located outside the project area, analysis suggests that the MSD construction will reflect the political voice of the majority, rather than the true distribution of economic benefits. All commercial properties within Duck, most of which exist south of the MSD, benefit from widening the beach by ensuring tourism is retained and revenues can be generated. Yet, these commercial properties may not be paying any portion of the bill. In sum, those paying are the least politically represented and thus responsible for paying *all* the costs while only retaining *most* of the benefits.

Moving forward, MSD construction in Duck will be of particular interest when the beach that needs widening is adjacent to the more densely populated area. If the results of this analysis hold for this hypothetical situation, the MSD may look very different. The general scheme involves charging oceanfront homeowners more, because of the direct benefit to property value, but the details are open to manipulation. Nourishment in this area could spark serious debate, putting local interests at odds with the “status quo” established during the 2017 project.

With more time, a more thorough news analysis, using qualitative analysis of articles and including winter storms damages, could provide a greater breadth of understanding on public concern. Using qualitative analysis of certain “buzzwords” could determine how many articles fall into categories of the greater nourishment discussion, including local elections, public forums, town budgets, environmental concerns, and public outcry.

There is no shortage of additional analysis that could result from tax assessor data. Future research could involve conducting similar analyses for the other towns in Dare County and

assessing the correlation between the distribution of owner-occupied and local properties and MSD construction and project costs. In addition, by reaching out to local county governments through the southeast, the database could be built to reflect an area greater than Dare County. Finally, by incorporating information on the frequency of nourishment required, the expected project costs over time, and survey data on actual public perception of coastal climate change, realistic timelines and expectations can be set for coastal communities. As sea level rises and storms increase in intensity, beach nourishment will become more frequent and costlier. Future analysis can allow these trends to be communicated to individuals and decision-makers more clearly, so that true climate damages in coastal communities are understood and the cycle of nourishment-driven economic growth can be broken for more sustainable adaptation options.

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Appendix

Figures

Figure 1: Results of a Google Trends Search for the Key Words “Beach Nourishment” 2004-2018

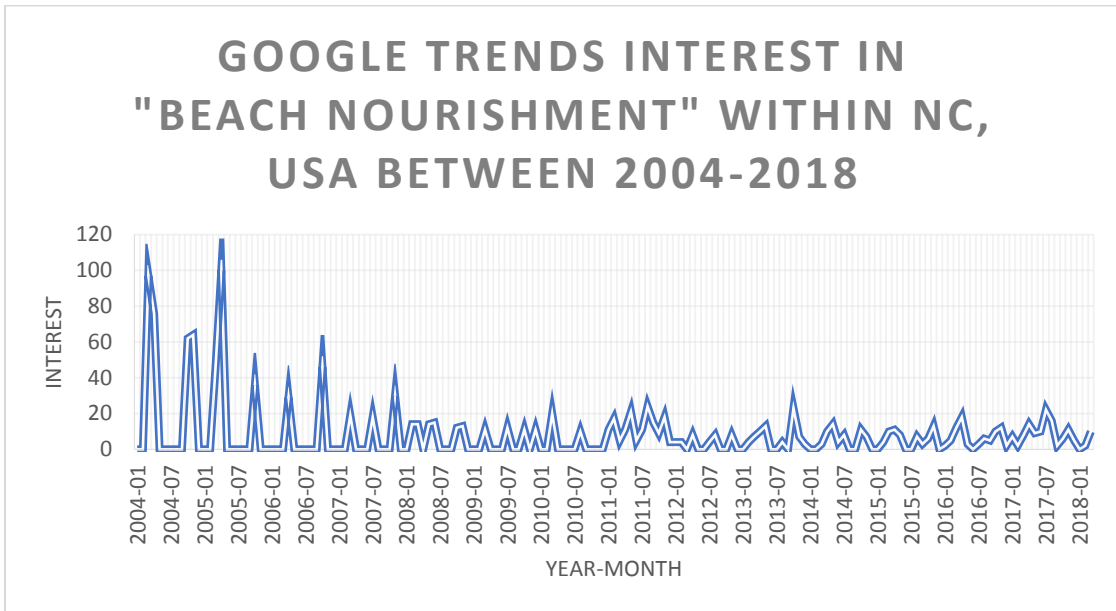


Figure 2: “Beach Nourishment Dare County” Article Frequency: Duke Database 1990-2017

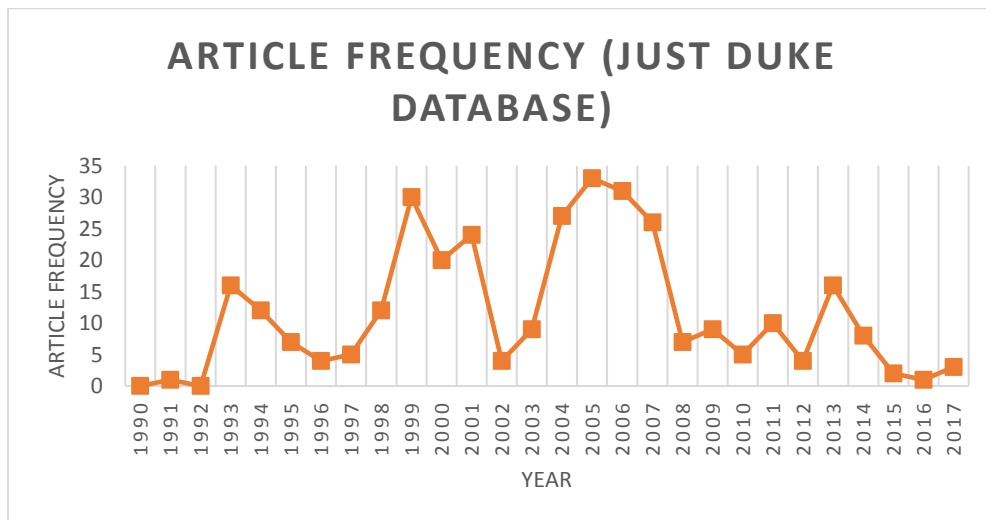


Figure 3: “Dare County Beach Nourishment” Total Article Frequency (1990-2017)

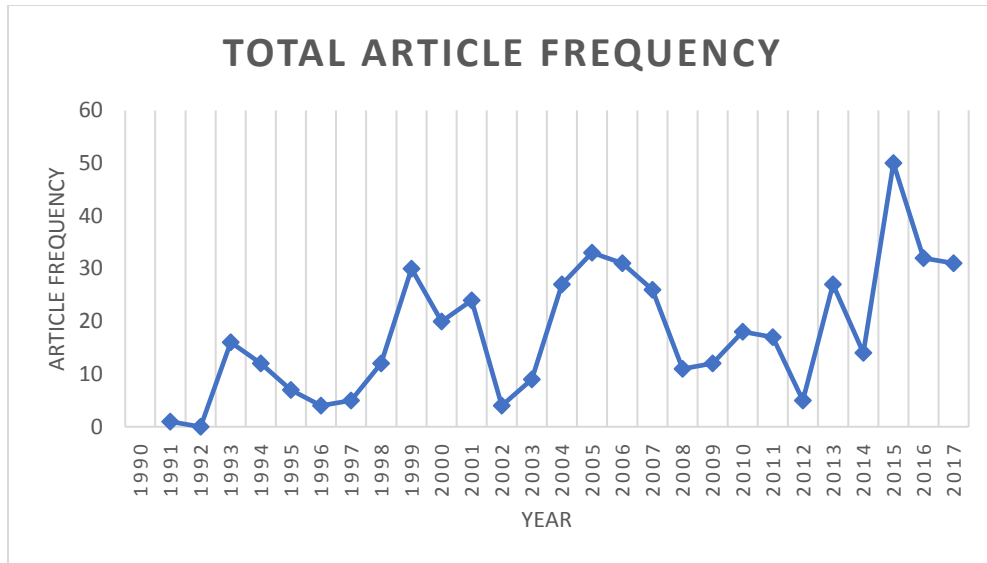


Figure 4: “Dare County Beach Nourishment” Article Frequency Relative to Storm Event Frequency

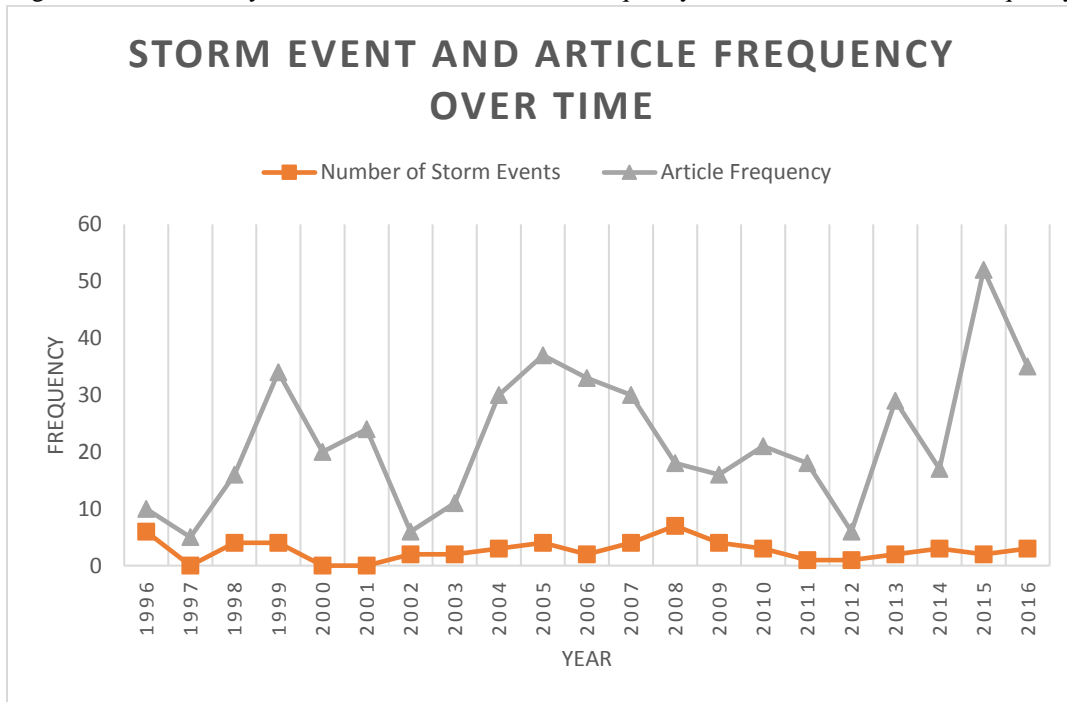


Figure 5: “Dare County Beach Nourishment” Article Frequency Relative to Storm Damages (Levels)

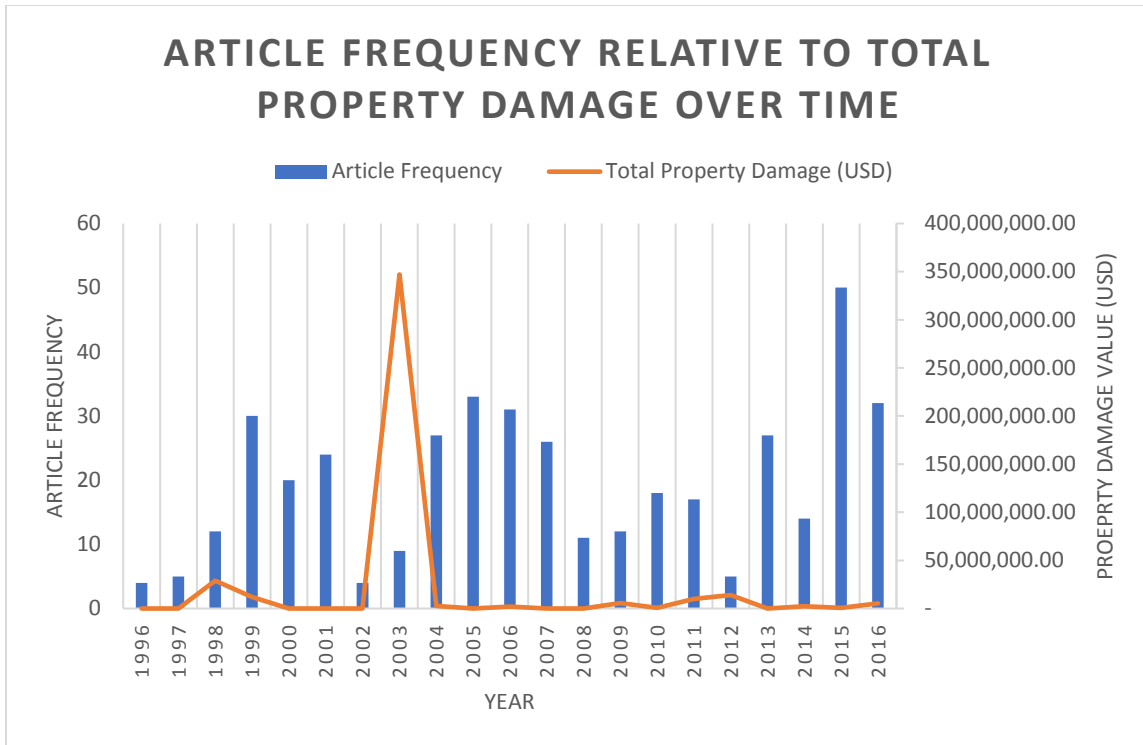


Figure 6: Article Frequency and Log(Property Damage) in Dare County (1996-2017)

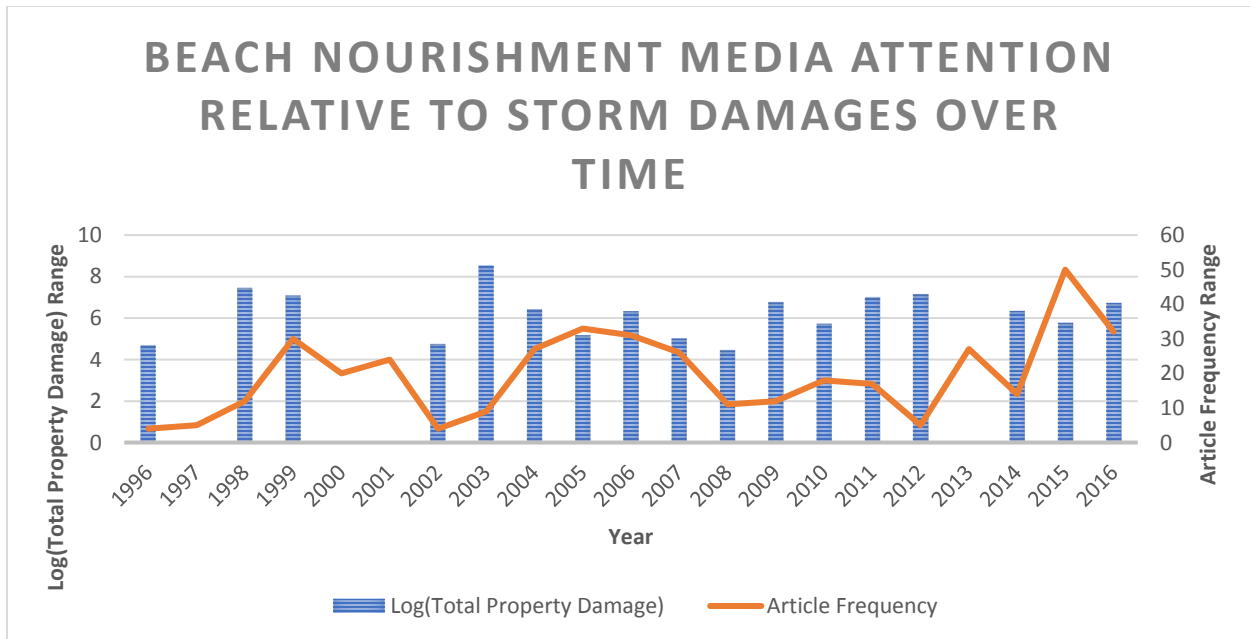


Figure 7: Two Year Lagged Article Frequency Relative to Log(Total Property Damage) in Dare Co. (1998-2016)

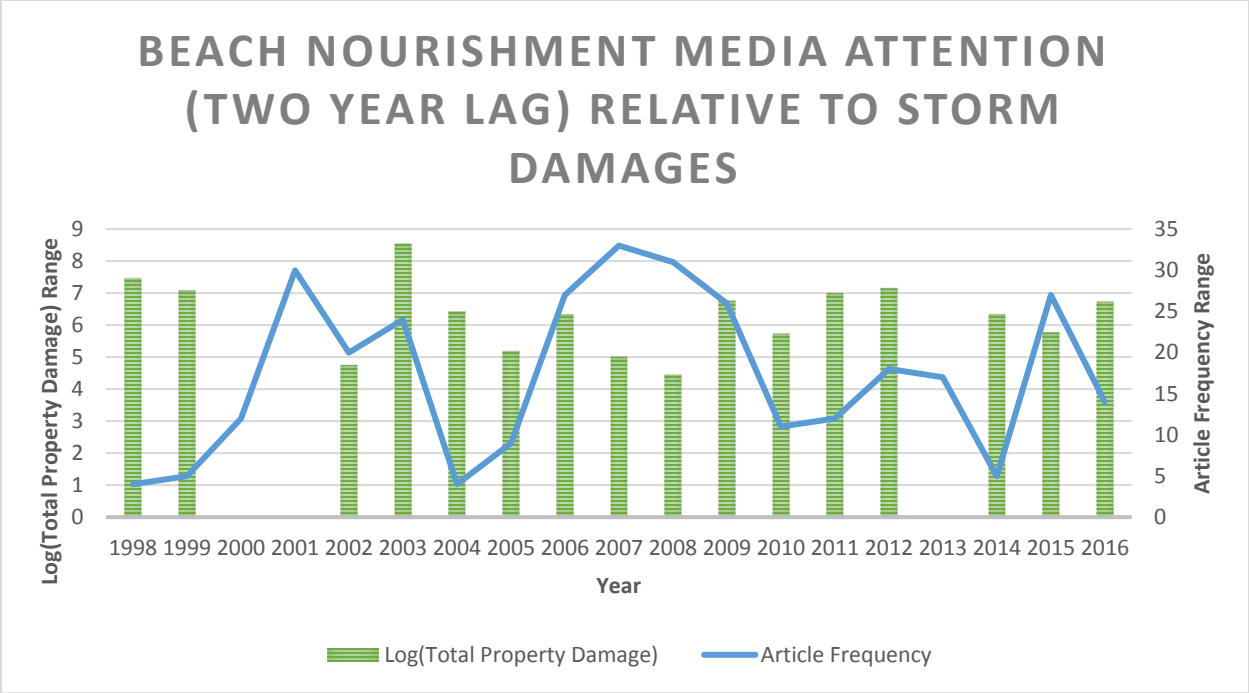


Figure 8: Frequency of Articles by Month Across Entire Time Series (1990-2017)

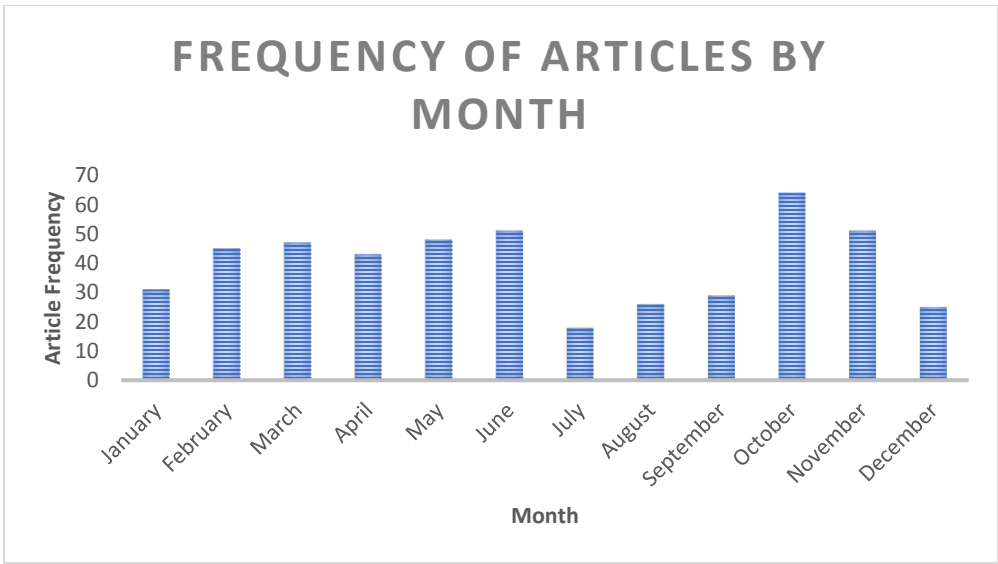
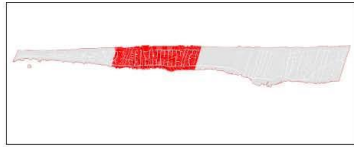


Figure 9: Town of Duck MSD A (Photo Courtesy: Town of Duck)

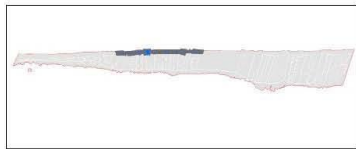


Beach Nourishment Area
Municipal Service District A

Updated November 10, 2014



Figure 10: Town of Duck MSD B (Photo Courtesy: Town of Duck)

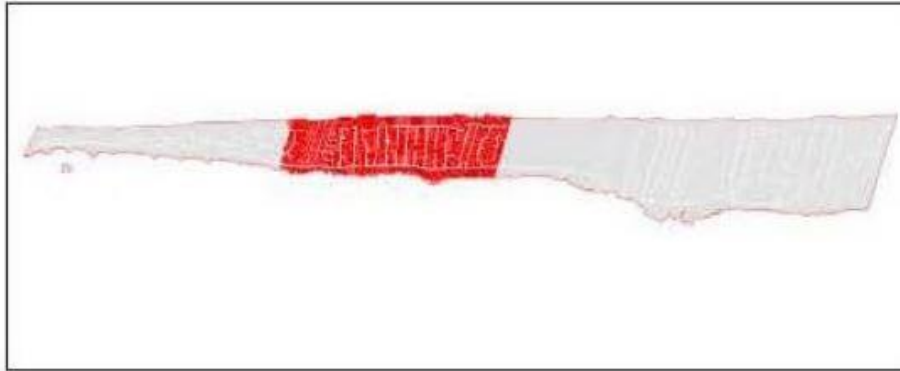


Beach Nourishment Area
Municipal Service District B

Updated November 10, 2014



Figure 11: Town of Duck MSD (Highlighted) Relative to the Entire Municipality



Tables

Table 1: Total Property Damage From 3 Storms

Year	Storm Name	Total Property Damage (USD)
1999	Floyd	\$12,000,000
2003	Isabel	\$347,000,000
2011	Irene	\$15,000,000
2012	Sandy	\$14,000,000

Table 2: Correlation Coefficients for Variations of Total Property Damage Data and Article Frequency

Variable	Correlation Coefficient (r)	P-value
All Years: Total Property Damage	0.041	0.374
All Years: Log(Total Property Damage)	0.049	0.351
Excluding Zeroes: Log(Total Property Damage)	0.002	0.965

Table 3: Results from Model using Total Property Damage in Levels

Levels: Two Year Time Lag, Excluding Years w/ Zero Total Property Damage (n=16)

Variable	Coefficient	P-Value
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Total Property Damage	3.16E-08	0.001
Number of Flood Events	10.326	0.007
Storm Death	-0.792	0.758
Nourishment Event	-0.879	0.856
Number of Storm Events	-3.395	0.007
R-squared	0.807	

Table 4: Results from Model using Log(Total Property Damage)

Logs: Two Year Time Lag, Excluding Years w/ Zero Total Property Damage (n=16)

Variable	Coefficient	P-Value
Log(Total Property Damage)	-1.76E-01	0.951
Number of Flood Events	9.799	0.001
Storm Death	-0.677	0.887
Nourishment Event	-2.739	0.531
Number of Storm Events	-3.768	0.007
R-squared	0.744	

Table 5: MSD Construction by Municipality in Dare Co.

Municipality	# of MSDs	Covers Entire Municipality (Y/N)	Millage Rate (\$/\$100 assessed value) Non-Oceanfront	Millage Rate (\$/\$100 Assessed Value) Oceanfront
Nags Head	2	Y	\$0.027	\$0.175
Kitty Hawk	2	Y	\$0.02	\$0.12
Kill Devil Hills	2	Y	\$0.03	\$0.33
Duck	2	N	\$0.148	\$0.463

Table 6: Distribution of “Owner-Occupied” and “Local” Residential Properties in Duck, NC

Total Residential Properties: 2512		
“Owner-Occupied”	143 (5.7%)	
	<i>Oceanfront</i>	6 (4.2%)
		In MSD 0 (0%)
	<i>Non-Oceanfront</i>	137 (95.8%)
		In MSD 37 (27%)
“Local”	414 (16.5%)	
	<i>Oceanfront</i>	45 (10.9%)
		In MSD 21 (47.7%)
	<i>Non-Oceanfront</i>	369 (89.1%)
		In MSD 94 (25.8%)

Additional Tables of Statistical Models

Levels: No Time Lag, Including Years w/ Zero Total Property Damage (n=21)

Variable	Coefficient	P-Value
Total Property Damage	-3.69E-08	0.013
Number of Flood Events	1.387	0.613
Number of Deaths	-14.553	0.027
Number of Nourishment Events	-0.816	0.870
Number of Storm Events	0.068	0.972
R-squared	0.1763	

**Levels: Two Year Time Lag,
Excluding 2003 (n=16)**

Variable	Coefficient	P-Value
Total Property Damage	-6.44E-08	0.671
Number of Flood Events	9.988	< 0.001
Storm Death	0.351	0.872
Nourishment Event	3.203	0.523

Number of Storm Events	-2.982	0.026
R-squared	0.726	

Levels: Two Year Time Lag, Excluding Years w/ Zero Total Property Damage & 2003 (n=15)

Variable	Coefficient	P-Value
Total Property Damage	-1.21E-07	0.419
Number of Flood Events	9.688	< 0.001
Storm Death	-0.123	0.960
Nourishment Event	-1.469	0.759
Number of Storm Events	-3.265	0.009
R-squared	0.810	

Logs: Two Year Time Lag, Including all Years (n=19)

Variable	Coefficient	P-Value
Log(Total Property Damage)	3.99E-01	0.645
Number of Flood Events	10.318	< 0.001
Storm Death	-0.9053704	0.765
Nourishment Event	2.1892	0.674
Number of Storm Events	-3.573	0.009
R-squared	0.660	

Logs: Two Year Time Lag, Excluding Years w/ Zero Total Property Damage (n=16)

Variable	Coefficient	P-Value
Log(Total Property Damage)	-1.76E-01	0.951
Number of Flood Events	9.799	0.001
Storm Death	-0.677	0.887
Nourishment Event	-2.739	0.531
Number of Storm Events	-3.768	0.007
R-squared	0.744	

**Logs: Two Year Time Lag, Excluding
2003 (n=18)**

Variable	Coefficient	P-Value
Log(Total Property Damage)	-6.19E-02	0.941
Number of Flood Events	10.212	< 0.001
Storm Death	0.170	0.952
Nourishment Event	3.395	0.493
Number of Storm Events	-3.025	0.020
R-squared	0.724	

**Logs: Two Year Time Lag, Excluding Years w/ Zero Total Property
Damage & 2003 (n=15)**

Variable	Coefficient	P-Value
Log(Total Property Damage)	-3.03E+00	0.071
Number of Flood Events	8.541	< 0.001
Storm Death	3.549	0.247
Nourishment Event	-3.035	0.380
Number of Storm Events	-3.765	0.004
R-squared	0.841	