Global Environmental Change in Coastal North Carolina: Public Opinion and Impact Mitigation

By

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Abstract

As research progresses the observed or anticipated impacts of global warming become more pronounced and the projections more precise. Impacts along coastlines include sea level rise (SLR) and increasing proportion of strong tropical storms, which in turn amplifies significant wave height. When combined with an increase in coastal stressors climate change can have deleterious impacts on coastal areas; exacerbating erosion, land loss, destruction of property and loss of life. Physical characteristics in the Tidewater region of North Carolina make it vulnerable to climate change, especially when combined with human population increases. To assess the awareness of likely effects of SLR, storms, waves, development, erosion and land loss in North Carolina the following study was completed from November 2005 through May 2007.

The study used two methods of investigation. The first used surveys to determine the state of knowledge concerning global change impacts on the coast and assess the publics’ willingness to accept impact reduction mechanisms. The second approach used case studies of two North Carolina counties, Carteret and Dare County, to determine how and if prevalent local environmental issues are affected by global change.

Survey results indicate that North Carolinians are largely convinced that global warming is a) happening and b) exacerbated by human activities. There is more knowledge of widespread impacts of climate change than those experienced locally, although coastal residents displayed more knowledge than piedmont residents. Responses suggest North Carolinians believe global warming is exacerbating coastal stressors and is a serious problem. Despite this, there is little faith in the local governments’ ability to manage for potential impacts. Case study results showed the majority of local issues involved land use/access and were further stressed by climate change impacts.

Various mitigation efforts are available to manage the potential impacts of global climate change, although few of them are incorporated into policy and planning. There are many management tools available for coastal managers and planners, but until policy mandates protective measures on the coast there will be little effective mitigation. To mitigate the increasing impacts of global climate change research must influence proactive policies.

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Acronyms
AEC- Area of Environmental Concern
CAMA- Coastal Areas Management Act
CHNS- Cape Hatteras National Seashore
CLNS- Cape Lookout National Seashore
Corps- Army Corps of Engineers
CZMA- Coastal Zone Management Act
DCM- Division of Coastal Management
EESLR- Ecological Effects of Sea Level Rise
GHG- Greenhouse Gas
FAR- Fourth Assessment Report
IPCC- Intergovernmental Panel on Climate Change
NC- North Carolina
OBX- Outer Banks (Northern)
RSLR- Relative Sea Level Rise
SCP- Strategic Conservation Plan
SLR- Sea Level Rise
SST- Sea Surface Temperature
1.0 Introduction

The release of the Fourth Assessment Report (FAR) from the Intergovernmental Panel on Climate Change (IPCC) significantly altered the foci of the climate change debate. Instead of questioning the existence of climate change and assigning blame we are now placed with the challenge of finding routes to mitigation. The IPCC FAR finds that the current warming of the climate system is undeniable; observations indicate a mean global temperature increase of 0.74°C (± 0.18°F) since the early 1900s, which is significant against a background of climate variability. Contributing scientists to the FAR determined that this accelerated warming is very likely a consequence of anthropogenic activities that have increased GHG concentrations, principally carbon dioxide, in the atmosphere (IPCC 2007). Subsequently, instead of trying to determine whether or not climate change is real, most scientists, policymakers and governments have accepted the reality and severity of the situation and are looking for ways to combat anthropogenic warming of our Earth and its potentially devastating impacts.

Observations suggest that impacts of global warming will not be felt equally across the planet and that certain regions will be affected more than others. Areas particularly sensitive to climate change include the Arctic Circle, high altitude forests, drylands, urban centers and cities, and, perhaps the most poignant of examples, the extensive coastal zones of the world (Houghton 2004; IPCC 2007; Sawin & Hughes 2007). Coastal zones are like land barriers from the high energy ocean environment that buffer inland areas as they dissipate the force of the water and waves. The proximity to the ocean presents a threat perhaps more immediate and tangible to
coastal communities than other areas as the effects of global warming manifest as sea level rise (SLR) and changing wave and storm behaviors.

Although the sea level has been rising for the past 18,000 years following the recession of the last glacial period, contributing to an estimated total SLR of about 130 m, the rate of SLR is accelerating, increasing to 0.3 m/century (± 0.07 m) in 1993-2003, or about 3 mm per year, from the lower rate of 0.18 m/century (± 0.05 m) in 1961-2003 (IPCC 2007). Fluctuations in sea level are the result of several forces, human and natural, including climate change, continental rebound and sediment compaction. Climate change has positive feedback effects on the sea level, the warming air will induce accelerated glacial melt and warming oceans will experience thermal expansion, contributing to a total sea level increase greater in proportion to the increase in air temperatures. A warming of 3°C (according to some estimates this could be the year 2030) could cause a SLR of 5 m (Davis & Fitzgerald 2004)! Projections for SLR by the year 2099 range from 0.3-6.4 m depending on the GHG emission scenario, with the lower ranges being the best case scenario for emission reductions and the higher ranges representing a worst case scenario. If emissions were kept at 2000 concentrations the oceans would still experience a SLR of 0.3-0.9 m (IPCC 2007).

Warming temperatures are likely increasing the frequency of strong storms. Debate still infuses this issue; there is a background of variability on smaller, decadal timescales, making it difficult to discern any distinctive linkage between increasing GHG in the atmosphere and changes in hurricane trends (Trenberth 2005). However, recent studies indicate a global trend toward more
intense hurricanes, in terms of wind speed and duration, and a greater proportion of hurricanes that are stronger, category 4 and 5, hurricanes over the past 30 years as the oceans warm (Emanuel 2005; Webster et al 2005).

Additional coastal stresses come in the form of unparalleled development and the human population explosion. The current global population is estimated to be over 6.5 billion, with about 3.2 billion of these people residing in cities; all of whom must have somewhere to live, often leading to unimpeded and often unsustainable development (US Census Bureau 2007; Flavin 2007). These phenomena are by no means restricted to inland areas; half of the world population lives densely packed (twice the global average at 80 people km$^2$, reaching up to 100 people/km$^2$ in poor regions of India and Africa) within 200km of the coast (Creel 2003). In the United States over half the population (about 53%) lives in coastal counties that make up a less than one fourth of the total land mass, about 17% excluding Alaska, and many more are migrating seaward every year (Crosset et al 2004). Increasing coastal populations and developments result in mounting natural disaster and hazard risks for the people living there; proximity to the ocean increases vulnerability to physical conditions and events exacerbated by SLR and storms (Chafe 2007; Pielke et al 2005).

1.1 Global Change in North Carolina

Although the consequences of global change are not necessarily the result of state activities all states and countries in the developed world must accept some responsibility for anthropogenic climate change. Ultimately, it is up to the states to manage for climate change impacts as well as
protect their citizens from events and situations that increase their vulnerability to such occurrences. More than 78% of energy used in the state of North Carolina is derived from fossil fuels (Munger & Shore 2005); certainly North Carolina has contributed her share of GHG emissions and plays a part in global warming. Low estimates for temperature rise over the next century in the Southeastern states hover around 2.3°C, and could potentially be much higher if actions, namely federal and international policies, to reduce GHG emissions (National Assessment Synthesis Team 2001). The State Climate Office of North Carolina has observed a warmer and wetter NC over the past 10 years, with observable and significant increases in minimum temperatures and numbers of days between spring thaw and fall freeze (Boyles & Ramun 2003). Population growth is evident in the state as well; the state grew by over 2% from 2005 to 2006 and is currently ranked seventh in population growth in the country (NC State Demographics 2007). Although most of state is feeling the temperature and population pressures of global change, due to its unique topography and geography, North Carolina is particularly vulnerable to coastal stressors like SLR, changing storm and wave behaviors and increasing populations and development.

1.2 Goals of Paper

While it may not be reasonable to expect the state or local governments of North Carolina to take on responsibility for curbing climate change without federal assistance, it is the responsibility of the governments to minimize the potential harm induced as a consequence of them. This could include many different policies, laws and actions, largely authorized through state legislature and enforced by local governments. Policies to combat climate change impacts, manage land and
restrict development mandated by state governments are adapted for local management and will undoubtedly reflect the culture and traditions of the people in the state or county. For this reason it is critical to assess the prevalent attitude of the people impacted by coastal management policies and mandates to determine the best possible avenue for mitigating the impacts of a changing climate, veritably, a changing world. The following study was conducted to evaluate the opinions of North Carolina citizens on climate change and their options for mitigation of potentially dangerous global change impacts. Survey questionnaires were given to obtain public opinions of climate change and case studies on two counties were performed to gain perspective on local symptoms of global change and how they relate to specific issues in each county.

2.0 North Carolina Coast Background

The state of North Carolina is divided into four physiographic regions: Mountain, Piedmont, Inner Coastal Plain and Tidewater. For the purposes of this study we will be primarily concerned with the physical characteristics of the 20 counties that comprise the Tidewater region (Figure 1). The Coastal Plain (Inner and Tidewater) makes up about 45% of the states total land area; beginning in the middle of the state and bordered on the west by the fall line where the harder rocks of the Piedmont give way to the softer sedimentary rocks of the Coastal Plain. This lowland (generally less than 10m above sea level) area of the state is makes up one of the largest areas of wetland resources on the Atlantic Coast, including salt marshes, swamp forests, freshwater marshes and bogs, and acres of Carolina Bays and pocosins endemic to the Southeast (Figure 2). These wetlands provide invaluable services to the entire state; including water
filtration, storm buffering and shoreline stabilization for erosion control to name only a few (Bobyarchick & Diemer 2000; Forsythe 2000; Richardson & Gibbons 1993).

Figure 1: North Carolina Physiographic Regions

Figure 2: North Carolina Wetlands

The North Carolina coast is considered a drowned-river estuary system; as sea levels rose lowlands and ancient river basins were submerged and the irregularly shaped coast and estuarine started to evolve. As the ocean encroached inland the ancestral rivers flooded and became large
basin shaped estuaries behind the thin ribbons of barrier islands. The deep estuarine basins or sounds trap sediment carried from inland, removing it from the littoral system along the coast and creating a sediment starved nearshore environment. Estuaries in North Carolina support a complex array of habitats, assisted by the regularity of astronomical tides, irregularity of wind tides (storms) and changing salinity concentrations. The interplay among these factors will determine if a particular estuarine shoreline segment will accrete or erode and is subsequently responsible for the formation and persistence of important salt and fringe marshes which stabilize the shoreline and support vegetation (Riggs & Ames 2003).

The underlying geology of the state creates major differences in the Northern and Southern coastal regions and is responsible for the shape and number of barrier islands that are able to form along the coast. The Northern Province is made up of soft materials like unconsolidated mud, peat and sand that transformed over time to layers of sedimentary rocks. This produces a gently sloping land surface and creates long barrier islands with large estuaries and few inlets (4) over 180 miles. The Southern compartment consists of older and harder rocks like limestone and sandstone, a steeper slope and short, stubby barrier islands with many inlets (18) and narrow estuaries. In either province the barrier islands are critical inland buffers that protect the delicate Tidewater and Inner Coastal Plain regions from high energy ocean conditions including storms. Because of the northeastern facing barrier islands the Northern Province is vulnerable to long lasting, fierce winter storms, or Nor’easters. The Southern region generally receives more hits from tropical storms and hurricanes, generally shorter in duration but just as powerful as their Northern counterparts (Riggs & Ames 2003).
To fully understand how global environmental change impacts the NC Coast we must examine the natural processes responsible for the genesis and persistence of NC’s barrier islands. After the end of the last ice age sea level began to rise at a catastrophic rate (~1cm/year) until it eventually decelerated to a characteristic rate of about 1mm/year (Davis & Fitzgerald 2004). Although barrier islands tend to form in a time of rising sea level, they were likely unable to develop until the rate slowed. Once formed in times of rising sea level an island will migrate landward maintaining a minimum width and elevation.

During landward barrier island migration (hereafter, referred to as island migration): 1) the front (ocean) side moves landward via shoreline retreat (erosion), 2) the back (sound) side moves landward by landward growth (accretion) and 3) the island builds up to maintain elevation above rising sea level. In addition 4) the mainland (estuarine) shoreline tends to retreat (erode), keeping pace with the migrating island (Pilkey et al 1998). Barrier islands also migrate up or down the coast via alongshore sediment transport, a phenomena particularly evident at inlet sites.

In some way (discussed below) each of these separate processes will be affected as increasing populations and climate change are expressed in North Carolina, but Step two requires further investigation. There are two possible mechanisms for sound-side widening to occur: 1) tidal delta incorporation and 2) overwash. Tidal delta incorporation occurs on the sound-side of deltas; as water floods into the estuary through the inlet and the velocity drops, sand is deposited and large masses form on the sound-side of the inlet. Eventually this flood delta is incorporated
into the island as the inlet migrates via alongshore transport and the island is widened over the entire back or sound side (Pilkey et al. 1998). Overwash occurs as waves overtop the high elevations of the barrier island, carrying sediments with them that are deposited on the backside of the island, essentially transferring sediments from the front side of the island and preserving the total sediment volume of the island (Donnelly et al. 2005). These processes are unique; usually there is little interaction between estuarine and oceanic processes (particularly in the Northern Province where inlets are sparse) but at inlets and overwash sites estuarine environments are periodically dominated by oceanic processes, allowing for landward migration (Riggs & Ames 2003).

2.1 Sea Level Rise

Before the termination of the last glacial period the sea level in North Carolina was between 100 and 130m lower than it is today, translating loosely into a shoreline position that was 24-96km (15-60miles) farther in the Atlantic Ocean (Riggs & Ames 2003). Local or relative sea level rise (RSLR) in North Carolina is estimated at 0.3-0.5m/100 years, or 3-5mm/year (Munger & Shore 2005). The rate of this increase is variable over time and controls changes in the natural processes (Section 2.0, the aforementioned four Steps) that exist in a dynamic equilibrium with one another; as one component is altered the others will shift accordingly, dictating the movement of the estuarine and ocean shorelines. Furthermore, these rates of SLR will vary regionally and locally; affecting coastal processes that change the shape of the shoreline and the location of inlets over time (Davidson-Arnout 2005; Slott et al. 2006). Generally, the Northern Province will suffer greater impacts from SLR than the Southern Province because of the low
regional land slope. Local affects include accelerated coastal erosion and land loss, increased loss of infrastructure, increased economic losses due to flooding and storm damage and the increased loss of estuarine wetlands and other coastal habitats (Riggs & Ames 2003).

### 2.2 Storms and Waves

Sometimes called “Hurricane Alley”, North Carolina is no stranger to hard hitting storms and waves; perhaps the most active hurricane season ever recorded was in 1827, when 11 hurricanes either made landfall or came very close to shore (Pilkey et al 1998). Historically, the frequency with which North Carolina was affected by Atlantic Basin hurricanes has been highly variable on multi-decadal, decadal and even annual timescales and trends toward more or less hurricanes has been difficult to discern. However, Emanuel (2005) has shown that since 1949 the annual duration of North Atlantic and Western North Pacific storms that impact the East Coast has increased by about 60%, and in the same period the average wind speed has increased by 50%. Concurrently, stronger hurricanes seem to have doubled in proportion, although globally the total number of hurricanes has remained approximately the same. Particularly in the North Atlantic, a correlation between increasing sea surface temperatures (SST) has been observed simultaneously with a significant increase in tropical storm duration and frequency (Webster et al 2005). Although tropical storms and hurricanes receive much of the spotlight with respect to global warming it is also possible that extratropical, or winter storms may change in frequency, duration, intensity and direction.
Since the busy hurricane season of 1827, the North Carolina coast has seen her share of busy summers (Figure 4). In the 1950s, there was Hurricane Hazel that completely destroyed sections of the coast. An Army Corps of Engineers (Corps) report noted that “hardly a vestige of human habitation remained” on the Brunswick County shore. After Hazel there was Hurricane Hugo in 1989 and although much of the damage was centralized in Charleston, South Carolina, the impacts were felt far inland and up the coast. Damages from Hugo were sustained in Charlotte, North Carolina and again in the Brunswick County area, causing approximately $1 billion in damages to the state. Another big year was 1996, when Hurricanes Arthur, Bertha and Fran followed a similar path along the coast, the eye of Hurricane Fran actually passing through the Piedmont area of the state accruing billions of dollars in damages and resulting in a death toll of 23. In 1999, Hurricanes Floyd and Dennis caused most of their damage as flooding, both in the Inner Coastal Plain and the Tidewater regions of NC, killing 45 people and demolishing homes, crops and causing a virtual public health crisis as wastewater treatment operations were flooded (Pilkey et al 1998; Robinson 2000). In 2003 Hurricane Isabel cut a breach on the southern end of Hatteras Island, followed by the slow moving Hurricane Ophelia that camped out over the Core Banks.

Waves may play the most important part in barrier island processes that shape the coastline of sand dominated coasts; they the true “beach-builders” and shapers of the NC coast. The waves along the East Coast are primarily generated from wind; storms producing any significant amount of wind will generate waves that will propagate themselves until reaching the nearest shoreface. Just like individual weather produces a long-term climate, individual storm events
combine over time to produce a long-term wave climate along coastlines. The wave climate felt by a coastline segment will depend upon the approaching wave angle, determined by the origin and path of the storm, influencing the shape and evolution of the coast via the movement of sediments; erosion and accretion. A shift in storm patterns, either direction, frequency or intensity, will result in a similar shift in the energy and dominant angle of the wave climate, thus altering the equilibrium of the geomorphological processes that govern barrier island migration and shoreline position accordingly (Davis & Fitzgerald 2004; Slott et al 2006).

Although no shift in mean wave angle has been discerned as of yet on the North Carolina Coast, there has been an observable increase in mean wave height in the North Atlantic for over a decade (Bacon & Carter 1991; Bouws et al 1996; Carter & Bacon 1998; Hayden 1975; Kushnir et al 1997). There is an evident seasonal trend in storms and wave direction; in the winter there are more Nor’easters and waves from the left, and in the summer there are more tropical storms and hurricanes and waves from the right (Zhang et al 2000). Clearly, the wave climate adjusts as the predominant storm direction shifts, if this pattern is altered as the SSTs warm and storm behaviors change then the evolution NC coastline will also shift.

In short, it is likely that global warming has lead to an increasing trend in tropical storms, either in intensity or frequency, a worrisome development which would lead to a substantial increase in storm related damages, particularly when combined with increasing coastal populations. Moreover, the increase in mean wave height is indicative of such a shift, although the precise causal factor of this trend is not yet certain.
2.3 Development

To this point, processes and events impacting the North Carolina coast have been natural in origin, but have been indirectly exacerbated by human activities (burning of fossil fuels) that have caused global warming. On the other hand, development of coastal areas is far from being an indirect process affecting the shoreline; human modifications and development of the coastline are possibly the most dangerous of the threats and certainly the most challenging for coastal management.

In the 1980s, North Carolina experienced a significant change in patterns of population growth; the overall growth rate of the Tidewater region exceeded the state average of 12.6%, reaching 21%, lead by Dare and Brunswick counties (Ives & Stuart 2000). Accompanying this growth is development; as residential, commercial, municipal buildings and roads are built in the Tidewater region pressures on the natural resources increase disproportionately and the carrying capacity of the land is stretched to its limits. Development and population increases on the coast
not only put the natural environment at risk; coastal development puts people in harms way (Pielke et al 2005). The NC coast has always been faced with hazards, overwash, storms waves, high winds, storm surge etc., but these were natural occurrences and not a problem until people began settling in these dynamic environments. Hazards which will increase resultant of global warming are estimated to cause in excess of $7 billion in property damages and almost $2 billion in damages to the agricultural and forestry business sectors in NC (Bin et al 2007).

Development of the North Carolina Coast has not been limited to the conventional types of development seen in inland areas. In order to combat the natural processes of island and inlet migration (via tidal delta incorporation and overwash) undesirable to human structures, various agencies have practiced different forms of shoreline stabilization since the early 1930s. Efforts to prevent overwash and “stabilize” the OBX by the Civilian Conservation Corps originated with artificial dune construction in the 1930s authorized by the state (Dolan 1972; Pilkey et al 1998). Since then other forms of beach stabilization have been engineered, led largely by the Corps, including hard stabilization (groins, jetties, seawalls and breakwaters) and soft stabilization (beach nourishment and artificial dune construction), although no method has been discovered to permanently stabilize the shoreline and prevent migration or shoreline retreat (Davis & Fitzgerald 2004; Riggs & Ames 2003).

2.4 Erosion and Land Loss

Contrary to popular belief, erosion is not a natural disaster. In fact, erosion is a natural process which occurs over long and short timescales that shapes the coastline in both ocean and estuarine
environments, and is responsible for the perpetuation of barrier islands via migration. Two wave processes stimulate erosion; long duration, fair weather processes that are determined by SLR and sediment supplies and short duration, high energy processes, namely storm events. Each process can be treated separately; long term coastal erosion occurs in response to alongshore transport gradients and to a lesser extent SLR (Slott et al 2006). Short term and severe erosion and inlet creation are caused by singular storm events that induce overwash and island breaching (Zhang et al 2002). These processes will tend to complement each other until equilibrium is established on the shoreface slope; the higher the sea level, the farther distance the waves can travel along the shoreface and storms will have a greater impact. In nature these erosive processes are in balance with the coastal ecosystem and as SLR and storms increase or change in direction, more sediment is supplied to the coast and the back barrier system and total sand volume is maintained. However, when placed in a human context island migration becomes erosion and has significant environmental, societal and economic consequences. Further, the processes that govern erosion (migration) will be significantly altered by global warming.

As we are currently in a rising sea level period, many of North Carolina’s barrier islands are in a landward migration phase. As human activities prevent the beach from returning to its state of dynamic equilibrium, preventing the shoreface from adjusting and overwash events occurring the natural process of landward shoreline migration becomes shoreline erosion, and is brought about by increasing wave heights due to increasing depth as the water rises. As sea level rises, overwash occurs more frequently, building up the backside of the island and simultaneously increasing elevation until the island returns to its original height and width, just slightly farther
inland from its previous location, but the same distance from the mainland shoreline as it erodes (Step 4). If the oceanic processes that deposit sediment to the backside of the island (Step 2) are prevented by increased elevation or vegetative growth the island will no longer be able to maintain its previous width or elevation, overall, narrowing and decreasing in height (Riggs & Ames 2003).

Since 1938, overwash events on the North Carolina Coast have steadily decreased, presumably as a result of increasing dune heights in the OBX (Boc & Langfelder 1977) and other forms of shoreline stabilization (Donnely et al 2005). This represents an enormous disruption in natural barrier island processes; reducing the width of barrier islands, increasing the threat of total collapse and causing accelerated erosion on oceanic and estuarine shorelines. This is often the case in NC; total estimated land loss for the estuarine shorelines from 1975-2000 is about 110km² (Riggs 2003) and erosion rates on the oceanside range from 5m to 7m per year (Pilkey et al 1998)! Assisting SLR and storms in erosion is the increase in boat traffic in estuarine environments, as coastal populations flock to the coast, boat traffic increases proportionally. It should be noted that although most of the NC coastline is actively eroding (migrating) some segments are accreting via alongshore transport and wave action, although the dominant trend is toward erosion.

In the event of a shift in dominant storm direction on the North Carolina Coast the wave climate governing alongshore transport of sediment and the ultimate shape of the coast will respond accordingly. Recent models have investigated this phenomenon on the NC coast using
comparative simulations. The simulations compared increased tropical storms, more waves from the right with respect to the coast and increased extratropical storms, more waves from the left as well as a scenario with decreased storminess in general. In the increased storminess scenarios large areas of accretion and erosion occurred, changing the long term evolution and shape of the coastline dramatically (Murray et al 2006). Possibly the most pivotal point of this new study is that erosion rates on the NC coast could be several times greater than current rates of shoreline retreat, and greater than the projected effects from SLR alone.

Land loss from erosion is not limited to North Carolina’s coastlines. Although the coastlines of the Southern Province are largely protected from severe impacts of erosion as sea level rises, the extensive estuaries are dominated by storm and tidal processes that can lead to serious erosion in many estuarine shoreline segments (Riggs & Ames 2003). The extensive wetlands found in the Tidewater region will experience changes in acreage and location as SLR and storm patterns change water levels and accelerate erosion. Like the barrier islands, wetlands have also evolved over time in response to changes in sea level, variations in sediment supply and patterns in storm frequency, intensity and duration. Wetlands maintain elevation above sea level by vertically accreting sediments, either from an outside source (overwash) or by the decomposition of on site plant material. As the sea level rises, wetlands must keep up with the rising water level by accretion, and if the supply of sediment is insufficient to maintain elevation, the wetlands are likely to become open water habitat (Michener et al 1997).
Most of the wetlands along the southeastern seaboard are expected to decrease in size as SLR accelerates. The unique wetlands of the Tidewater region are particularly vulnerable. Were it not for the vertical accretion of plant material, peat, in the low sloping Northern Province, many wetlands would have already subsided below sea level. It is unlikely that peat accumulation will be sufficient to maintain elevation in North Carolina’s coastal wetlands. In the future we can expect a dramatic change in wetland distribution and a decrease in total acreage of wetlands throughout the coastal plain (Moorhead & Brinson 1995).

3.0 Methodology

3.1 Survey Questionnaires

To determine the level of knowledge and potential response to global change mitigation policies, survey questionnaires were given out to NC citizens (See Appendix A). The format was adapted from a statewide telephone survey given to Alaskan residents in 2006 titled “Alaskan Opinions on Global Warming” (Leiserowitz 2006). Questions from the Alaskan survey were transformed to suite the coastal environment of NC and, in addition, included specific questions particular to this project concerning storms and SLR. These surveys were given out by hand and filled out and returned on site in approximately 10 minutes over a period of several months in the spring and summer of 2007. No scientific background information was given to the respondents concerning the questions to get an accurate idea of previous knowledge and honest opinions. Respondents were from several counties in the state, restricted to the Piedmont and Tidewater regions, and included Brunswick, Carteret, Chatham, Dare, Durham and Orange counties in NC.
Basic statistical analyses were run on the results to determine trends in answers. Results were grouped into three sections, NC Total, NC Piedmont and NC Coast, to highlight differences and similarities among the regions.

3.2 Case Studies/Site Description

To illuminate the connections and complexities between global warming impacts and local issues, case studies were performed on 2 coastal counties in NC (Figure 3): Carteret and Dare County. Research performed for the case studies included literature and policy reviews, personal interviews and on site investigations by the primary researcher conducted from November 2005 to May 2007.

Carteret County is located in the Southern Province of the state and includes Cape Lookout National Seashore and the Southern barrier islands of North Carolina: Bogue Banks, Core Banks, Portsmouth Island and Shackleford Banks. Of all the barrier islands in the Southern banks only Bogue Banks is developed and harbors the towns of Atlantic Beach, Pine Knoll Shores, Indian Beach and Emerald Isle, the county line terminating at Bogue Inlet. Inland, estuarine towns include Beaufort, Morehead City, New Bern and Cape Carteret.
Much of the Northern barrier islands are in Dare County. These islands, called simply the Outer Banks (OBX), are representative of Northern Province barrier island formation and are long and narrow with few inlets to separate them. The primary crossover point from the mainland to the northern barrier islands is located near the town of Manteo. This is facilitated by the causeway at Whalebone Junction, the site of the now closed Roanoke Inlet which separated Roanoke Island,
and the Northern towns of Duck, Southern Shores, Kitty Hawk and Kill Devil Hills, from Bodie Island. The causeway intersects four major highways, including the only road traveling south toward Cape Hatteras, the infamous Highway 12, splitting the town of Nags Head into northern and southern components. Highway 12 South crosses over the Oregon Inlet onto Hatteras Island and through the undeveloped Pea Island Wildlife Sanctuary and the back barrier towns of Rodanthe, Waves, Salvo and Avon before reaching its easternmost point. Cape Hatteras extends east from the wide relict dunes and maritime forests of Buxton, before the shoreline turns abruptly southwest through Frisco and Hatteras before reaching Hatteras Inlet and the beginning of Hyde County.

**4.0 Results**

**4.1 Survey Results**

A total of 141 completed surveys were received from both the Piedmont and Tidewater regions. Of the total number 83 of the respondents were Piedmont residents and 58 were Coastal residents. Results for the survey questions are all given as percentages of the total number of respondents, divided either into NC Total, NC Piedmont or NC Coast (See Appendix B for raw data). According to the sample size of the three categories at the 95% confidence level there is range of confidence intervals (CI) or percentage points for our regions; NC Total has a confidence interval of ±11.7%, the three counties in the NC Piedmont have range of ±10.8 and the NC Coast counties have ±13.1 for the categories individual CI. All CI’s are given at the 95% confidence level. In the future a larger sample size would be desirable for a smaller range of CI but for preliminary investigatory purposes this is acceptable.
**Question: “How convinced are you that global warming is happening?”**

<table>
<thead>
<tr>
<th></th>
<th>NC Total</th>
<th>NC Piedmont</th>
<th>NC Coast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convinced</td>
<td>86.5</td>
<td>90.4</td>
<td>81.0</td>
</tr>
<tr>
<td>Completely</td>
<td>58.2</td>
<td>60.2</td>
<td>55.2</td>
</tr>
<tr>
<td>Mostly</td>
<td>28.4</td>
<td>30.1</td>
<td>25.9</td>
</tr>
<tr>
<td>Unconvincing</td>
<td>9.2</td>
<td>6.0</td>
<td>13.8</td>
</tr>
<tr>
<td>Not very</td>
<td>9.2</td>
<td>7.2</td>
<td>12.1</td>
</tr>
<tr>
<td>Not at all</td>
<td>2.1</td>
<td>1.2</td>
<td>3.4</td>
</tr>
<tr>
<td>Don’t know</td>
<td>2.1</td>
<td>1.2</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Table 1: Global Warming Opinions

This question show that people in NC, both Piedmont and Coastal residents, are largely convinced that global warming is occurring. Confidence intervals for the percent of NC Total that are convinced global warming is occurring are ± 5.6% at the 95% confidence level.

**Question: “Why do you think global warming is occurring?”**

<table>
<thead>
<tr>
<th></th>
<th>NC Total</th>
<th>NC Piedmont</th>
<th>NC Coast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Activity</td>
<td>67.4</td>
<td>68.7</td>
<td>65.5</td>
</tr>
<tr>
<td>Normal Cycles</td>
<td>18.4</td>
<td>14.5</td>
<td>24.1</td>
</tr>
<tr>
<td>Both human activity and</td>
<td>9.2</td>
<td>13.3</td>
<td>3.4</td>
</tr>
<tr>
<td>normal cycles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Don't know</td>
<td>6.4</td>
<td>3.6</td>
<td>10.3</td>
</tr>
<tr>
<td>Not happening</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 2: Causes of global warming

North Carolina residents are in less agreement about the causes of global warming than they are concerning the whether it is occurring or not. Overall, North Carolinians believe humans are largely responsible for a warming climate with a confidence interval at ± 7.7% at the 95% confidence level.
Question: “Some people say that global warming is already impacting North Carolina. Do you agree or disagree that global warming is making the following things worse?”

Figure 5: NC Total Global Warming Impacts
Overall, North Carolinians are in agreement that global warming is creating more frequent overwash, higher ocean temperatures, stronger winter and summer storms and making winters warmer. NC residents also think global warming is exacerbating coastal erosion, the loss of roads and infrastructure, inlet breaching, shrinking of barrier islands, accelerating island migration and changing fish migrations. More knowledge seems to exist where temperatures are concerned and less regarding barrier island processes. Confidence intervals range from ±6.68-8.19% at the 95% confidence level.
Regarding the potential worsening of coastal responses in the event of global warming, there is typically less knowledge (more “don’t know” responses) in situations that have more disagreement and more agreement where knowledge is greater (less “don’t know” answers.)
Figure 8: NC Piedmont Response for Potential Global Warming Impact Responses

Figure 9: NC Coast Response for Potential Global Warming Impacts Responses
In a comparison between Piedmont and Coastal residents responses, residents living at the coast seem to have greater knowledge about the potential worsening impacts of global warming. Particularly with respect to overwash and barrier island migration processes and changing fish migrations.
Question: “How serious of a threat is global warming to:”

![Bar chart](image)

Figure 11: NC Total Response to Seriousness of Global Warming Threat

Most of the respondents in NC obviously consider global warming to be a serious threat to plants and animals and people in the state, US and other countries (over 80% with a CI of ±5.76%), but less of a threat to their local communities (about 60%).

![Bar chart](image)

Figure 12: Regional Comparison for Seriousness of Global Warming Threat
While coastal residents believe global warming to be a serious occurrence, there is a greater level of not serious responses in the coastal region than in the Piedmont.

**Question:** “When do you think global warming will start to have dangerous impacts on North Carolina?”

![Figure 13: Global Warming Timeframe](image)

Responses indicate that North Carolinians believe global warming to be a problem either in the present or in the near future, or about 50%. However, there is a clear uncertainty evident by the high “don’t know” responses, approximately 20% and a wide range of confidence intervals.
Question: “Do you think global warming is an urgent problem that requires immediate government action, or a longer term problem that requires more study before government action is taken?”

Overall, global warming is considered to be an urgent problem by NC residents. In the Piedmont region slightly more residents, 69%, believe it is an urgent problem that needs attention now, than coastal residents, 53%. However for the coastal category the CI at a CL of 95% is ±13% and ±10, leaving a large margin for error.
Question: “Do you feel that your local government is prepared to deal with the impacts of global warming on your community?”

According to the results of this question, people in NC have little faith that their local government has the capabilities to deal with global warming impacts. A staggering 0% of respondents believed their local government was very prepared and only about 8% of total NC respondents thought the government was somewhat prepared. In several cases, respondents that did not in fact believe global warming was happening did not believe that the government was prepared to deal with the ghostly impacts. However for the NC Total category the percentages are almost equal for very unprepared, 51.1%, and don’t know, 54.1%. With CI’s at
approximately ±8.2% this is indicative of some variability and prevalent uncertainty of residents in their governments.

**Question:** “Many towns and villages in the NC Outer Banks are experiencing more frequent flooding and are in danger of coastal erosion. Do you think the state of NC should help to:”

![State Involvement in Local Disasters](image)

**Figure 16: State Involvement in Local Disasters**

![Regional Comparison of State Involvement in Local Disasters](image)

**Figure 17: Regional Comparison of State Involvement in Local Disasters**
We can see a divergence between NC Piedmont and Coastal resident responses more so in this survey question than any of the previous, 32.5% of Piedmont residents think the towns should move (±10.0% CI) and only 10.0% of Coastal residents (±8.0% CI). This is a sensitive topic to coastal residents, who believe that the local government should be allowed to maintain and protect coastal areas from erosion as they see fit and largely oppose state involvement in community planning.

**Question: “Do you think the relationship between global warming and coastal erosion is:”**

![Figure 18: Strength of Global Warming/Coastal Erosion Connection](image)

There is a sense that climate change is connected to coastal erosion, 70.2% of NC residents believe there is a strong connection at CI of ±7.6%, 29.1% believe it is very strong and 41.1% believe it is somewhat strong.
Question: “Overall, do you think that storms hitting the NC Coast have:”

![Bar chart showing storm patterns and percentages](chart.png)

Figure 19: Global Warming Impact on Storm Patterns

Although there is a sense that storm patterns have not become less destructive from NC residents, we can see a large amount a variability concerning storm patterns along the coast.

Over 30% of folks in the Piedmont were unsure of any storm pattern and although there was less uncertainty in the coastal region, about 22% of coastal residents were not sure.
Question: “In August 2005, Hurricane Katrina struck the Gulf Coast of the United States and had devastating impacts. Do you think the likelihood of a storm of this magnitude hitting the NC Coast is:”

![Chart showing likelihood of storm impact](image)

Figure 20: Likelihood of Storm with Katrina-like Damages in NC

Almost 66% of NC residents think it is likely that a storm with Hurricane Katrina like impacts will strike the NC Coast, 44.0% think it is somewhat likely and 22.0% believe it is very likely with CI’s of ±7.8%. Piedmont residents are more convinced that a storm of this impact will likely hit the NC coast than coastal residents; 86% of Piedmont respondents thought it was a likely event with ±7.5% CI’s (37% very likely and 49% somewhat likely). The consensus is that the likelihood of this storm hitting is inevitable.
Question: “If this type of a storm hit the NC Coast do you think the state of North Carolina should help to:”

<table>
<thead>
<tr>
<th>Option</th>
<th>NC Total</th>
<th>NC Piedmont</th>
<th>NC Coast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rebuild the areas destroyed in the same locations</td>
<td>15%</td>
<td>20%</td>
<td>10%</td>
</tr>
<tr>
<td>Relocate the areas in less hazard prone areas (but still on the coast)</td>
<td>30%</td>
<td>35%</td>
<td>25%</td>
</tr>
<tr>
<td>Relocate the areas in less hazard prone areas (but NOT on the coast)</td>
<td>10%</td>
<td>15%</td>
<td>5%</td>
</tr>
<tr>
<td>Nothing, let the towns take care of themselves</td>
<td>5%</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>Don’t know</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
</tbody>
</table>

Figure 21: Post-disaster State Involvement

None of the responses for this question exceeded 35%, either regionally or from all of NC, indicating a clear lack of consensus among residents on this issue. More frequently, NC residents, 30.5% with CI’s of ±7.6%, think that in the event of mass destruction from a storm the state should assist in rebuilding the structures damaged still on the coast but in a less hazardous area of the coast.
Question: “For each of the following, do you favor or oppose it as a way for the government to reduce the impacts of global warming?”

Figure 22: NC Total Response to Potential Impact Reduction Mechanisms
North Carolinians are clearly in favor of regulating polluting industry for the production of GHGs; 91.5% of the respondents were in favor of restricting power plant emissions with CI’s of ±4.6%. The state citizens understand the extent of the problem and recognize the need to sign international treaties (89.7% were in favor, CI ±5.0%) to reduce GHG emissions. Opposition to increased taxes is higher than regulatory restrictions for polluting; 31.9% opposed increasing taxes in the transportation sector and 44.7% opposed increased taxes in the electricity sector with CI’s of ±7.7% and ±8.2% respectively. Many people (about 80%) believe that development should be restricted in hazard prone areas and that modifications should be made to existing developments to minimize potential warming impacts along the coast at a CI of ±6.3%. People in NC are less in favor of coastal retreat as these impacts manifest and worsen.
Regulate greenhouse gas emissions from power plants
Sign international treaties to reduce greenhouse gas emissions
Increase taxes to people either drive less or buy cars that use less gas
Increase taxes on electricity so people use less of it
Restrict development in hazard prone areas
Make modifications to existing developments to resist flooding and erosion impacts (bridges, highways, dunes)
Start slowly retreating from the coastline

**Figure 24: NC Piedmont Response to Potential Impact Reduction Mechanisms**

Regulate greenhouse gas emissions from power plants
Sign international treaties to reduce greenhouse gas emissions
Increase taxes to people either drive less or buy cars that use less gas
Increase taxes on electricity so people use less of it
Restrict development in hazard prone areas
Make modifications to existing developments to resist flooding and erosion impacts (bridges, highways, dunes)
Start slowly retreating from the coastline

**Figure 25: NC Coast Response to Potential Impact Reduction Mechanisms**
Regulate greenhouse gas emissions from power plants
Sign international treaties to reduce greenhouse gas emissions
Increase taxes to people to either drive less or buy cars that use less gas
Increase taxes on electricity so people use less of it
Restrict development in hazard prone areas
Make modifications to existing developments to resist flooding and erosion impacts (bridges, highways, dunes)
Start slowly retreating from the coastline

Figure 26: Regional Comparison for Potential Impact Reduction Mechanisms
<table>
<thead>
<tr>
<th>Impact Reduction Mechanism</th>
<th>NC Piedmont Favor</th>
<th>NC Coast Favor</th>
<th>NC Piedmont Oppose</th>
<th>NC Coast Oppose</th>
<th>NC Piedmont Don’t Know</th>
<th>NC Coast Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulate greenhouse gas emissions from power plants</td>
<td>91.6</td>
<td>91.4</td>
<td>2.4</td>
<td>1.7</td>
<td>6.0</td>
<td>6.9</td>
</tr>
<tr>
<td>Sign international treaties to reduce greenhouse gas emissions</td>
<td>88.0</td>
<td>89.7</td>
<td>6.0</td>
<td>3.4</td>
<td>6.0</td>
<td>6.9</td>
</tr>
<tr>
<td>Increase taxes to people either drive less or buy cars that use less gas</td>
<td>56.6</td>
<td>60.3</td>
<td>32.5</td>
<td>31.0</td>
<td>10.8</td>
<td>8.6</td>
</tr>
<tr>
<td>Increase taxes on electricity so people use less of it</td>
<td>33.7</td>
<td>41.4</td>
<td>41.0</td>
<td>50.0</td>
<td>13.3</td>
<td>8.6</td>
</tr>
<tr>
<td>Restrict development in hazard prone areas</td>
<td>85.5</td>
<td>77.6</td>
<td>4.8</td>
<td>13.8</td>
<td>9.6</td>
<td>8.6</td>
</tr>
<tr>
<td>Make modifications to existing developments to resist flooding and erosion impacts (bridges, highways, dunes)</td>
<td>78.3</td>
<td>81.0</td>
<td>14.5</td>
<td>5.2</td>
<td>7.2</td>
<td>13.8</td>
</tr>
<tr>
<td>Start slowly retreating from the coastline</td>
<td>33.7</td>
<td>31.0</td>
<td>19.3</td>
<td>41.4</td>
<td>22.9</td>
<td>27.6</td>
</tr>
</tbody>
</table>

Table 3: Percent Response Regional Comparison for Potential Impact Reduction Mechanisms

We can see that there is a convergence of answers among the two regions when the reducing mechanism of taxes is brought up (Table 3). The greatest dissimilarity between the Piedmont and Coastal regions is in the last impact reducing mechanism that asks if we should start slowly retreating from the coastline. Coastal residents oppose this mechanism much more (41.4% of respondents are in opposition) than do Piedmont respondents (19%), but this may not be a significant difference considering the large coastal CI of ±12.9%.
Question: “Do you think the state of NC should stop rebuilding in coastal areas when damages exceed:”

<table>
<thead>
<tr>
<th>NC Piedmont Favor</th>
<th>NC Coast Favor</th>
<th>NC Total Favor</th>
</tr>
</thead>
<tbody>
<tr>
<td>90%</td>
<td>16.9</td>
<td>19.0</td>
</tr>
<tr>
<td>75%</td>
<td>19.3</td>
<td>32.8</td>
</tr>
<tr>
<td>50%</td>
<td>21.7</td>
<td>22.4</td>
</tr>
<tr>
<td>25%</td>
<td>10.8</td>
<td>5.2</td>
</tr>
<tr>
<td>ANY</td>
<td>9.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Don’t know</td>
<td>20.5</td>
<td>13.8</td>
</tr>
<tr>
<td>Oppose</td>
<td>1.2</td>
<td>6.9</td>
</tr>
</tbody>
</table>

Table 4: Regional Comparison for Rebuilding in Coastal Areas

![Figure 27: Regional Comparison for Rebuilding in Coastal Areas](image-url)
Responses for this question are highly variable. Interestingly, coastal residents were typically more in favor of rebuilding restrictions than Piedmont residents, especially when damages exceed 75% of a structure 31.0% versus 18.1% with CI’s of ±12.1% and ±8.3% respectively. Opposition to setting rebuilding limitations were low overall; generally respondents were in favor of setting such limitations but were unsure of the degree of damage that would necessitate these restrictions.

4.2 Case Study Results

In North Carolina coastal counties are regulated by the Coastal Area Management Act (CAMA). Authorized in 1974 by the federal Coastal Zone Management Act (CZMA), CAMA mandates that each of NCs 20 coastal counties, including Carteret and Dare, develop a county Land Use Plan (LUP). Although the individual LUPs of the counties will vary, consistency with the state CAMA is required. Pertinent statewide CAMA regulations to the case studies include the banning of hardened structures from the shoreline, not the estuarine environment, and that each local government must define those issues which will affect the community in a 10 year planning period. The individual LUPs for Carteret and Dare Counties are discussed in the Section 5.3 (DCM 2005).
The portion of Carteret County that includes the Cape Lookout National Seashore (CLNS) is the most isolated of the barrier islands on the NC Coast, largely because of the vast undeveloped portions of the coast. Although Bogue Banks is the only developed island in Carteret, the now empty Shackleford Banks and Portsmouth Island were once bustling communities. Originally created in 1753, Portsmouth Island was once an important unloading point for sailing ships coming through Ocracoke Inlet. During the Civil War Federal forces invaded Hatteras Island to the North and residents of Portsmouth Island fled in fear of the Union forces. After the war, ships began to use Hatteras Inlet to get their heavy cargo inland and Portsmouth’s use as an unloading point was no longer required. Only half the population returned to their homes following the evacuation, the rest slowly moved inland, until eventually, in 1971, when the last
male resident of Portsmouth Island died. The island is currently part of the CLNS and although parts of the town are maintained for historic value, the island has no permanent residents. The evacuation of Shackleford Banks was less complicated; after a strong hurricane hit the island in 1899 and the community sustaining maritime forest was drowned in salt water, residents permanently relocated farther inland (Schoenbaum 1998).

The south-facing barrier islands of Carteret County are familiar with frequent hits by hurricanes that intermittently open inlets and cause extensive overwash. Characteristic of the Southern Province, Carteret County has several inlets, most of which have been opened by storms and will migrate, widen, narrow and, possibly, close over time. Separating Carteret County from Hyde County, and Ocracoke Island from Portsmouth Island, is Ocracoke Inlet, a stable, deep inlet that has been open since at least 1585. Moving south along the county brings us to New Drum Inlet, a manmade inlet created to replace Old Drum Inlet which intermittently opened and closed (finally closing in 1971) over the past century in response to storm activity and alongshore transport, inducing a southwestern inlet migration route that continues today. The Old Drum Inlet site (only a short distance from the New Drum Inlet) has presented a tendency for overwash and recently reopened in response to the 1999 Hurricane Dennis. Farther south Barden Inlet, reopening after remaining closed for some 50 years in a 1933 hurricane, divides Shackleford Banks from the Core Banks. Separating the undeveloped islands from Bogue Banks is Beaufort Inlet which is a natural inlet that has existed since the 17th century, but is assisted with dredging activities by the Corps. Developed from an ancient river channel and marking the termination of Carteret County is Bogue Inlet. Considered to be a “breathing” inlet, Bogue Inlet has narrowed
and widened drastically in the past 60 years, ranging from 400m to almost 2km (Cleary & Marden 2004; Pilkey et al 1998; Schoembaum 1998).

Due to its steep slope and wide islands the bulk oceanside Carteret County is largely unaffected by the overwash and erosion caused by storms and SLR. Which is not to say that these things are not occurring; overwash fans are evident in many areas, islands are eroding and inlets are migrating all along the North Carolina shoreline, but in Carteret County the only place where it matters is the developed island of Bogue Banks. Bogue Banks remained virtually empty until the 1950s when large portions of the island were sold in small lot sizes (Schoembaum 1998). Although the 25 mile stretch is considered to be a relatively safe area for small scale development due to the high elevation dunes and dense forests, the island is bordered by two migrating inlets. The migration and periodic widening of Beaufort and Bogue Inlet creates erosion risk on either side of the island, exacerbated by boat traffic into the Morehead City and Beaufort Harbors and compounded by an oceanfront erosion rate of about 0.6m/year (~2ft/year) (Pilkey et al 1998).

Although back barrier erosion rates are unavailable, it can be inferred that the Southern Banks primary mechanisms for island widening is via flood delta incorporation. Restricting these processes by removing sediment from the littoral system (inlet dredging) and preventing migration (stabilization of primary inlet channel) has contributed to increased erosion rates on the front and back side of these inlet littered Southern banks. Efforts to battle erosion on Bogue Banks include the construction of a seawall on Atlantic Beach in 1954 following Hurricane
Hazel and frequent beach nourishment projects along the majority of the coastline. Such beach replenishment projects are performed by the Corps using “free” sand; largely material dredged from either of the proximate inlets (Pilkey et al 1998).

Significant environmental issues in Carteret County include the loss of the fishing economy, conflict over beach nourishment methods and, most importantly, rapid and uncontrolled development throughout the coastal and inland estuarine environments.

Although it was not a primary research objective for this particular study, the loss of the fishing base in Carteret towns is reflective of another global environmental issue. The global reduction and loss of marine and coastal fisheries is a far reaching societal and environmental problem, with cascading effects on the natural, economic and cultural components of local fishing communities. With respect to Carteret, the reduction in fisheries has manifested as an allocation issue; who gets the fish. Along the Beaufort waterfront, we can still see the old Menhaden processes factory, a once flourishing business in the town and along the rest of the banks. The combination of a catch reduction, industrialization and globalization of the fishing sector and the increase in recreational fishing interest groups in the area has prompted the close of the last Beaufort Menhaden fishery. Conflicts between the commercial Menhaden netters and the recreational fishermen stem from the a few basic points: 1) there are fewer Menhaden around the NC coastal areas and 2) if these few Menhaden are captured by commercial fishing nets, they are unavailable for the recreationally desirably sportfish to eat, and their numbers will decline. In
addition, the globalization and industrialization of fishing fleets has created a huge financial
constraint for smaller, local companies.

The conflict concerning beach nourishment on Bogue Banks centers around two main
components: the quality of the sand used to nourish the beach and the cost of nourishment. The
first concern stems from the fact that because this sand comes from material dredged by the
Corps to maintain Beaufort and Bogue Inlets, it is very different from the sand typically found on
an Atlantic Coast beach. After the top coating of fluffy, white sand was eroded away,
beachgoers continually found themselves forced to contend with hardened slabs of mud, fist-
sized cobbles and sharp shells. All this compounded by the knowledge that any replenishment is
temporary and costly. These endeavors are costly despite the free sand, and much of the cost is
born by the public via state and federal taxes. In 2003, the state matched government aid,
totaling $3.6 million, to fund small beach nourishment projects on the coast, many of which
included the bad sand (Barrett 2004). To the outrage of many beachgoers, residents of many of
these state funded nourishment projects have repeatedly taken steps to bar public access on the

There is a visible disconnect between the attitude of preservation and conservation toward the
town of Beaufort and the CLNS and the actions encouraging development in the rest of Carteret
County. This highly contentious issue centers largely around rebuilding areas along Bogue
Banks to facilitate a larger carrying capacity and the new development of “Down East” Carteret
County. Most of the beaches were developed to capacity by 2000, and subsequently much
concern is focused on water quality issues (due to septic system overload) and other municipal problems. The Down East area refers to slightly higher elevation, isolated, lowland region northeast of Beaufort bordered by the Neuse River and the outstanding resource waters of Core Sound (Figure). Historically, this area of the county was lightly inhabited by small fishing and farming towns of Marshallberg, Harkers Island, Atlantic, Sea Level, Cedar Island, Bertie and Smyrna (DET, 2007). Developers are flocking to this once rural area with the intention of building subdivisions, condominiums and high end housing developments.

Much of the Down East area is unincorporated and thus not under control by Carteret County municipal planning responsible for zoning, although some activities require permits from various agencies there is very little control for development activities Carteret County LUP, 2005). Residents of the Down East communities are alarmed that developments will destroy and stress environmentally fragile areas as well as degrade the culture and tradition of their communities. Attempts have repeatedly been made to enact various types of regulatory development restrictions in the area, including temporary moratoriums on development in the Down East areas and the adoption of conservation ordinances to address environmental concerns (Carteret Co. Planning Commission Meeting Notes, 2006). Unfortunately, there has been little success, at least in any permanent sense, in finding a medium between residents, developers and the local government.
When the term the “Graveyard of the Atlantic” is used to describe the North Carolina Coast, folks are largely referring to the area offshore of Dare County. Although each of the North Carolina Capes have their own set of shoals (Lookout Shoals to Cape Lookout and Frying Pan Shoals to Cape Fear, the 10 mile submerged “tail” of Cape Hatteras’, Diamond Shoals is possibly the most treacherous of the three cuspate embayments. This is largely because Cape Hatteras represents the eastern most point on the United States mainland and is therefore the first
landmass ships traveling west would encounter (Figure). To warn incoming ships in the past was Bodie Lighthouse, rebuilt three times beginning in 1848, near the now closed Roanoke Inlet site, and the Cape Hatteras Lighthouse built in 1873. Some of the first settlements after the Native Americans were US Lifesaving Stations built to warn ships and rescue the crewman trapped on the Shoals (Riggs & Ames 2003; Schoenbaum 1998).

The northeastern orientation of Cape Hatteras and the shoreline above it has made this section of the coast particularly vulnerable to strong nor’easters as well to tropical storms passing along the Atlantic. These storms frequently cause large overwash events over thin segments of the shore and often create breaches in the islands and rapidly create inlets. Additionally, the huge Albemarle and Pamlico estuaries behind the thin northern OBX are subjected to storm surge and extreme wind tides during storms. The return flow of overwash pushed into the back barrier system, or seawash, by storms is equally, sometimes more, likely to induce a breach as the overflow of water from the ocean (Donnelly et al 2006). Because of their close connection to the ocean, these estuaries display many processes that are reflective of the proximate high energy ocean dynamics and are subject to similar forces, high waves, wind and rapid erosion, in response to storm events (Riggs & Ames 2003).

Naturally, the tendency for inlets to suddenly appear and then close up in response to the high energy shoreline has persisted through time as storms approach the OBX. Most recently, Hurricane Isabel made land fall on the NC coast, the eye passing over the Southern islands near Cape Lookout. The Category 2 hurricane created a storm surge on the Oceanside that was 2-
2.5m (6.5-8ft) above normal tide levels and breached Hatteras Island about 6 miles from Hatteras Inlet. This segment of the island was characterized by high rates of shoreline erosion and low elevation, characteristics that encourage overwash. In 1933, a storm created a breach (an inlet in the early stages) in almost the exact same place. Before construction of a bridge over the site was completed the inlet closed naturally and the work was abandoned. The inlet created by Isabel in 2003 was mechanically closed in about two months by the Corps (Wamsley & Hathaway 2004).

This pattern of appearing and disappearing inlets is a pattern the OBX are accustomed to. Roanoke Inlet once separated Roanoke Island from Bodie Island near the Whalebone Junction, but closed long ago. In 1730 a storm opened up the New Inlet, dividing Pea Island from Hatteras Island, until its closure in 1846 after a hurricane opened Oregon Inlet and changed the alongshore transport of sediments, temporarily filling up the old inlet site. New Inlet reopened in 1933 and bridges were built over it to access Hatteras Island, and left to rot after the inlet shoaled up and closed again in 1945. The long forgone wooden bridge is still visible from the Pea Island section of Highway 12 (Schoenbaum 1998). Hatteras Inlet was opened during the same hurricane as Oregon Inlet in September 1846; each of these inlets were opened near the location of previous inlets dating back to 1585 that had closed several hundred years later, if only to reopen again (Cleary & Marden 2004). In 1962, the Ash Wednesday winter storm overwashed most of the Atlantic coast, opening an inlet north of Cape Hatteras, Buxton Inlet, which took about 2 years to close by the Corps (Riggs & Ames 2003).
Oregon Inlet is one of the most interesting inlets along the OBX. This inlet is the primary route through which most of water and sediment enters and exits the Albemarle-Pamlico estuarine basin in response to tidal flux. Following its last opening in 1846 it has migrated about 4km south at a rate of about 15m/year (Cleary & Marden 2004). This southern migration and the influx of ocean sediment has accumulated sand on the north end of Hatteras Island as tidal delta incorporation processes widen the island across the migration zone of the inlet since opening in 1846. Following the construction of the Herbert Bonner Bridge in 1962, the steady migration of Oregon Inlet presented a problem for coastal managers and engineers. The creation of the bridge necessitated that the inlet stay in place on both ends, a feat not easily undertaken. Proposals for jetty construction projects to stabilize or halt the migration of Oregon Inlet and protect the bridge have occurred over the years but have not been passed due to serious concerns. Plans submitted by the Corps to create 2 jetties on each side of the inlet were approved by Congress in the 1970s, but have been kept in the planning stages as concerns arise. Primarily, the construction of this hardened structure will likely increase wave energy within the inlet channel and significantly disrupt sediment transport along the shoreline, contributing to accelerated erosion rates, especially as sea level increases (Pilkey et al 1998). It is also likely that the inlet will continue to migrate despite the presence of the jetties, resulting in the complete loss of $100 million for initial construction estimates, and another $15 million a year for maintenance (Cleary & Marden 2004).

In addition to the hard stabilization proposed for Oregon Inlet, various forms of soft stabilization have been conducted along much of the OBX. Beginning in the 1930s with the Civilian
Conservation Corps funded by the depression era federal works program created by Franklin D. Roosevelt soft stabilization on the beach was considered a valiant attempt to save the OBX. By 1940, the CCC had created an artificial frontal dune system along most of the Northern OBX 15-25 feet high. This type of management persisted long into the 1970s when coastal managers noticed that although the dunes had been maintained, there was no longer any beach in front of them, and new soft stabilization methods, beach nourishment, were conducted. The National Park Service bore this cost of $20 million. Around the same time, coastal researchers began to understand the complexities of shoreline dynamics and barrier island processes. This illumination made it clear that the manmade dunes were not only responsible for the loss of the beach but were the cause of barrier island narrowing by preventing overwash events and inducing sound-side erosion. As the coastal scholar Thomas Schoenbaum (1998) puts it, “We may have inadvertently found the formula for washing away the OBX in our effort to preserve them.” (Dolan 1972; Pilkey et al 1998)

Long term erosion rates from wave activity, both on the sound-side and ocean-side, exacerbates the effects of storm events. In many cases coastline segments are eroding on the Oceanside and the sound-side due to sediment deprivation and lack of overwash. However, erosion on the sound-side of the OBX is muted by a shallow sand platform under the barrier islands, Hatteras flats, that extends into Pamlico Sound for about 2 miles, protecting the back barrier side of the islands by dispersing wave energy (Riggs & Ames 2003). One such area is the town of Rodanthe where erosion rates are in excess of 4.5m/year (15ft/year) on the ocean side (Pilkey et al 1998) and 0.2-2.4m/year on the sound-side (Riggs & Ames 2003). North of Rodanthe in the
Pea Island Wildlife Sanctuary erosion rates are rapid and variable; this areas has the makings of
an inlet site, reaching almost 7m/year in some areas. It is a fairly regular occurrence to see
bulldozers and other beach moving equipment left at the site in anticipation of the next storm,
and overwash, event. The stretch between Avon and Buxton is another overwash frequented
area, home to Buxton Inlet and all its predecessors (Pilkey et al 1998).

Unlike the Southern barrier islands, all of the Northern OBX is developed. Large portions of the
ocean facing sections of the islands are within the Cape Hatteras National Seashore (CHNS) and
are undeveloped. The Pea Island Wildlife Refuge between Oregon Inlet and Avon protected on
the back barrier side as well as on the shoreline; the Alligator Wildlife Refuge and the Buxton
Woods Coastal Reserve are largely restricted to estuarine environment. Luckily, a great deal of
the land in Dare County is managed by state or federal agencies and the regulations therein
largely restrict, if not prohibit, development. Development in the coming years will primarily
consist of vacation homes and other seasonal residences; in peak season the population of Dare
County increases from about 30,000 to 200,000, encouraging the growth of such developments
(Dare County LUP 2003).

Current local issues in Dare County reflect years of conflict and animosity between the federal
government, specifically the National Park Service (NPS), and local residents. Following the
realization that their efforts to stabilize the OBX via dune construction the NPS announced that
their new policy to let natural processes occur without interference. However, this was easier
said than done. When CHNS was designated in 1953 one of the primary components of its
creation was the commitment to protect local communities from ocean hazards and preserve the traditional way of life for Islanders. Some residents believed that the NPS 1973 policy to stop dune fortification was a failure to take responsibility for the communities at risk, and felt that they were being left by the NPS to “wash out to sea” (Schoenbaum 1998).

The modern battle of Islander versus NPS has taken an interesting turn from an natural resources perspective and can be summed up as a parallel battle; ORVs versus Piping plovers. Recent years on the CHNS have presented a beach access and user group conflict; if Piping plovers are there, the people and their ORVs must move. Piping plovers are protected under the federal Endangered Species Act and are summer visitors to the OBX. When the birds move in and show signs of breeding and nesting, sections of the beach are closed off to vehicle access.

On most beaches ORV access is prohibited. The fact that this is not the case on the CHNS is a large draw for many visitors and is considered by locals to be an important cultural tradition, if not a necessity for fisherman that gain their livelihoods from the sea. The tip of Cape Hatteras, referred to simply as “The Point”, is a fishing spot that draws crowds from all over the East Coast. The Point is located near 2 huge ocean currents; the frigid Labrador Current and the balmy Gulf Stream. The union of these ocean convectors produces conditions highly desirable for many types of recreational surf fish species, including Jack Cravelle, Bluefish, Cobia, Pompano, Spanish Mackerel and the jewel of the group, Red Drum. Driving on the beach at Cape Hatteras predates the designation of the CHNS, before Highway 12 was paved in 1953, beach driving was the primary mode of transport on the OBX (NPS New Release 2007).
When the NPS closes a section of the beach to protect the nesting birds, it is generally a small area restricted to the large dune systems offshore. However, recent years and shoreline changes have resulted in the closing of bigger and bigger sections of the beach, culminating in the summer of 2007 the closure of the Southern “hook” of The Point. This closure extended all the way to the mean high tide line and therefore the NPS was required to construct an additional beach road to circumvent the closure through the maritime forest abutting the sandy shores of the Cape. Additional closures were made throughout the busy tourist season, and many locals and visitors were extremely upset at the loss of “their beach” to so few birds. Local tackle shops began selling bumper stickers that read “I love Piping plovers fried with coleslaw”, and other anti-bird/anti-NPS slogans.

The turmoil has heightened in the late summer months of 2007. Various environmental groups have threatened to sue CHNS for years for their lack of an official ORV plan on the shore. Several interim plans have been in place since the 1970s but on account of the unique situation at the CHNS, driving on the beach is a local tradition that has not, historically, caused significant damage to the beach, a permanent plan has yet to be designed. The Piping plover dispute has added fuel to the fire for those seeking to ban beach driving and prompted US District Judge Terrance Boyle to issue a court order in July 2007, citing the NPS for non-compliance with legal requirements to have an ORV plan (NPS New Release 2007).
Now the birds are finished nesting and the Endangered Species closures have reopened, but CHNS users are in danger of losing their rights to drive on the beach. Cape Hatteras National Seashore Superintendent Mike Murray has agreed to allow the use of ORVs on CHNS while the NPS develops a final plan (Kozak 2007). However, private beach access proponents, bird conservation organizations and various other environmental agencies continue to oppose the use of ORVs on the CHNS.

Another growing concern for the OBX Islanders lies with the Herbert C. Bonner Bridge that connects Roanoke and Hatteras Island (the previous Bodie and Pea Island, before the inlets closed). As discussed above, the rapid migration of Oregon Inlet has compromised the stability of the bridge and plans to stabilize the area with jetties are either dead or dying in the planning stages. Users of the bridge are increasingly concerned for their safety crossing the bridge for normal commutes and during storm evacuations. New plans have been proposed to build an entirely new bridge over the area. The first option is a “short bridge” over the inlet that will follow approximately the same course as the Bonner Bridge, terminating at the beginning of Hatteras Island and entering the Pea Island Wildlife Sanctuary. The second option is a “long bridge”, also called the “Pamlico Bridge” that would span over 17 miles and pass Pea Island completely. Problems with the short bridge lie with permitting; the construction would impact wetlands and other environmentally sensitive areas but take much less time to finish than the long bridge. On the other hand, the long bridge is predicted to receive necessary permits, but will be very costly for the state and could potentially impede access to the Pea Island Wildlife Sanctuary (replacethebridgenow.com 2007; Vandever & Miller 2003).
5.0 Discussion

5.1 Survey Implications

It is clear that North Carolina residents believe that global warming is indeed occurring and that it is most likely because of human activities. Gaps of knowledge include impacts of global warming that will affect barrier island processes; residents are more knowledgeable concerning broad-scale, global impacts of warming but are lacking a clear understanding of how their local communities will be affected. There is a clear lack of faith in the local governments’ ability to handle these potential impacts, an attitude encouraged by the terrible post-Katrina response in the Gulf Coast. People are not confident that the government can or will protect them in the event of a Katrina-like storm impacting the coast, but nonetheless think that such a disaster event in NC will occur. There was also the belief that there was nothing that local governments could do to prepare to global change, climate or otherwise, and that it was the responsibility of the federal government to respond.

North Carolinians are largely undecided about how to handle coastal development scenarios, folks don’t want to retreat from the coastline but they don’t want to place people and property in an unreasonable risk scenario. Many respondents stated that they believed there should be certain exemptions for long-term coastal residents and criticized programs and government subsidies that encouraged development in coastal hazard areas. Accurately so, it turns out that federal subsidies for flood protection and disaster relief may in fact raise the cost of storm damage by increasing the amount of property located in harms way (Cordes 1998). As expected, reducing impacts of global warming through taxes was a largely
unpopular mechanism unless it was directed at sectors that people believed were primary GHG polluters.

Coastal residents were less concerned about impacts overall than Piedmont residents. In a personal interview when a DCM employee was asked how people at the coast felt about SLR he responded that because these folks lived with the thought of life threatening storms they were not terribly concerned about a few millimeters a year. As far as policymaking is concerned, Piedmont residents may have as much of an impact on decisions impacting coastal areas as those who live in the Tidewater region. In a land economics study authors found that growth in beachfront communities reflected the increased demand for recreation as income and employment rose in inland areas (Cordes 1998).

Confidence intervals demonstrate a need for a larger sample population particularly for the coastal regions. To be 95% confident that the results generated in this study were significant necessitated CI’s ranging from 5-13 percentage points. This is a fairly large margin of error that could be remedied by a larger sample, to generate CI’s of ±2.0% for the NC Total category we would need approximately 2,400 surveys to achieve a CL of 95%, and over 4,000 for a 99% CL. However, for the purposes of this paper, to get a general idea of the attitude of North Carolinians concerning global warming, the CI’s found were useful.
5.2 Case Study Implications

The case studies on the two NC Coastal counties highlight the diversity and complexity of the North Carolina Coastal area. Although Carteret and Dare County are separated by less than 50 miles of coastline, with Ocracoke Island, the processes that are impacted by global change are quite divergent.

Dare County is predominately at risk from shoreline erosion and island breaching. The thin barrier islands have been modified by human activities for over 70 years, making them more vulnerable to erosion on the Oceanside and accelerating erosion. Although the estuarine environment in the Northern OBX is somewhat protected from erosion by the shallow Hatteras flats, close interaction with the ocean environment and the prevention of overwash from dune fortification has induced sound-side erosion. As SLR accelerates overwash events will become more frequent on the OBX. In a natural environment this rate of SLR would not the capabilities for the barrier islands to maintain themselves. Unfortunately, overwash is highly undesirable to towns and manmade structures and is prevented whenever possible. The continued effect of overwash prevention along the OBX will produce and overall narrowing of the islands and accelerate sound-side erosion.

Tangential to increasing overwash on the OBX is the increased vulnerability to island breaching. As the islands narrow and decrease in elevation inlets will tend to form around the lowest and thinnest shoreline segments, near previous inlet sites and high erosion areas as demonstrated with
the Hurricane Isabel breach. As storms get stronger and wave heights increase in the Atlantic the OBX will be progressively more exposed to storm impacts and breaches will increase.

Since most of the land in Dare County is state or federally owned there is little room for further development on the islands. The areas that are available for development are regulated by CAMA and the Dare County LUP and in most cases property is already developed. The major development concern in Dare County is that in the event of a storm, and in the future increasing in strength, many areas of the county are damaged or destroyed. Highway 12 is particularly vulnerable; the Corps must frequently rush in to push heaps of sand and water off the sole land route out of Hatteras Island.

The concern then becomes, after a storm, is it reasonable to rebuild areas that are damaged or destroyed? What degree must a structure be damaged to forgo rebuilding? More importantly, how many times will the state and local governments pay to rebuild areas that are time and time again damaged by overwash and storms? An example is the Hurricane Isabel breach; the area is prone to overwash and has been presumably trying to recreate past inlets in the area. Can coastal managers and engineers combat so strong a force of nature?

In Carteret County much of the vulnerability to global change is confined to the estuarine and wetland areas in the northeastern part of the county, of Down East Carteret. As coastal populations increase and development comes to these fragile and largely natural areas of the county, pressures on the natural resources of the land multiply exponentially. Developments in
Down East threaten to pollute freshwater resources, damage the Outstanding Resource Waters of the state, degrade wetland habitats and fisheries, as well as perhaps forever ruining the tradition and culture of the community. Along the estuarine waterfront, hardened structures will be constructed to protect the new developments from any erosion, but in the long run this will simply exacerbate and accelerate the situation. Additionally, activities that drain wetlands for development will result in the compaction and subsidence of the land, increasing the RSLR of the area, potentially resulting in greater vulnerability to SLR and erosion.

On the Carteret County coastline the problem is not so much new development as it is bad management decisions. The development of Bogue Banks has relied largely on the premise that this is a “safe” island stretch to build on, perhaps contributing to the staggering rate of development that has taken place in the past 20 years. To accommodate new residents, visitors and their accompanying development, managers have began a course soft stabilization that will not be easily reversed. Nourishment of the beaches of Bogue Banks has been surrounded by criticism already, imagine the conflict that would come to be should coastal managers decide to stop nourishing, as recommended by many scientists, and allow the beaches to disappear. Truly the only way to preserve the beaches in the long run is to pull away from the shoreline. This does not mean that North Carolinians would be denied access to the coast, but rather that a select few (oceanfront property owners) would have to make tough sacrifices for the benefit of the many.
5.3 Policy Mitigation

Common law principles in NC charge the state with protecting coastal areas for the benefit of the public under the Public Trust Doctrine (Clark 2003). It is the responsibility of the state to ensure protection and preservation of coastal resources but it is usually up to the local governments to manage activities that impact these areas through land use planning, zoning and building codes. In North Carolina CAMA is one of the strongest forms of locally enforced coastal protection in the state; regulating activities impacting the coast and assisting coastal managers. Each of the 20 CAMA counties in NC has a LUP that is designed to reflect the needs of the local community, anticipating future changes in the natural and human environment and plan management response accordingly. Local LUPs can be more restrictive that the state allows but must be consistent with state mandates, allowing local governments to express their own priorities for protection. It can be assumed that a communities’ LUP is an intrinsic political value judgment regarding the protection of the counties coastal resources (Schoenbaum & Rosenberg 1976).

A wonderful regulatory tool restricting development, CAMA identifies the suitability of undeveloped land for future development is based on several constraints including physical limitations for development (shoreline areas with high erosion potential and watershed that drain into ORW of the state), fragile areas or Areas of Environmental Concern (AEC) and areas with resource potential. Development in many of these areas necessitates a CAMA permit. Areas of Environmental Concern include coastal wetlands, estuarine waters, renewable resources areas, ORWs, primary nursery areas and natural hazards areas. Identification of AECs is determined
by a land classification map and designation of such is an ongoing process involving public participation.

Individual LUPs in NC are required under CAMA to make statements of local policy that address issues over a 10 year planning period including resource protection, resource production and management, economic and community development, public participation in the policy process and storm hazard mitigation (DCM 2003). This is the primary conduit through which local governments attempt to anticipate future changes in the community, both environmental and societal. Particular to this research are policy statements concerning shoreline erosion and disasters or storms. Shoreline erosion policy statements in CAMA mandate that erosion response measures that include beach nourishment are considered economically feasible and that this is a reasonable alternative to relocation or loss of oceanfront development. Following the Bogue Banks beach nourishment fiasco, new policies have been put in place by CAMA regulating the size of sediment used in beach nourishment (DCM 2006).

Prior to the event of a disaster NC CAMA policy requires the coordination of all state agencies to mitigate the effects of coastal disasters, including preparation and relocation of development that has been impacted post-disasters, although the mitigation effort is largely the responsibility of the local government. Post-disaster policies allow the issuance of an emergency general permit to allow immediate replacement of structures, reconstruction of frontal dune systems, excavation of channels, basins or ditches that have been impacted by storms. This includes the
replacement of previously existing hardened shoreline stabilization structures, assuming that the structures were functioning as intended.

Policy statements in the Carteret County LUP focus heavily on development, water quality, beach access and beach nourishment, reflecting the occurrence of local issues found in the case study. Carteret Counties’ attitude toward development in the LUP indicates the encouragement of development in many areas, and although policies are consistent with CAMA they are not additionally restrictive. Interestingly, the LUP states that the Down East area of the county is expected to remain a low density, undeveloped area. However, water quality is of major importance in the community and the LUP contains more restrictive policies than CAMA concerning sewer systems in developments and activities impacting ORWs, primary nursery areas and coastal wetlands. Beach nourishment is supported in the LUP and maintains beaches to assist in future nourishment efforts. Additionally, attention to beach access gravitated to the creation of more access points for non waterfront owners to access the beach, by boat (docks and marinas), car (parking lots) and on foot (access trails) (Carteret County Planning Department 2005).

Because of the high percentage of public land unavailable for development, the Dare County LUP directs development to focus on existing patterns of the village communities as “nodes” of development along the largely natural coast. A significant promulgation of CAMA requires a minimum 30-foot buffer along all estuarine waters, severely limiting development along the thin stretches of land in Dare County. Additionally, the LUP states that development should fit the
natural capacities of the landscape rather than trying to alter the landscape to fit development.
To this end, the Dare County Board of Commissioners established a moratorium on all
commercial structures greater than 20,000 square feet in 2001, resulting in the adoption of this as
a limitation on development in 2003. There is an evident preference for residential development
over commercial development, reflecting the seasonality of the OBX and the use of vacation
homes.

In Dare County, virtually all of the ocean shoreline is classified as a high hazard flood AEC. In
the ocean erodible AEC development is restricted to 60x the average annual erosion rate for the
island segment plus the distance that the shoreline is expected to erode in the event of a 100-year
storm. Development on the ocean shorelines of Dare County is heavily regulated, restricting
development the County reserves the right to oppose any regulations that may affect ocean
hazard AECs. Development in the estuarine environment is less restrictive; Dare County
supports the use of hard structures for stabilizing the estuarine shoreline and promotes the use of
offshore breakwaters and rip-rap to minimize wave energy. On estuarine shorelines the Dare
County LUP is consistent with the CAMA requirement of 30-feet, but encourages a larger buffer
from the shoreline.

Like Carteret County, the Dare County LUP supports beach nourishment as a way to stabilize
portions of the shoreline. The LUP discusses the barrier island processes described in Section
2.0, acknowledging that shoreline erosion versus shoreline migration is a manmade occurrence.
Believing coastal retreat to be an unfeasible option, for coastal management, the LUP uses beach
nourishment as the best alternative to hardened shoreline stabilization. Related to the advocacy of beach nourishment is the policy statement that current data quantifying SLR is insufficient and for this reason the Dare County LUP will rely on CAMA standards for development in AECs and will not be more restrictive in flood prone areas.

In the policy statements regarding disaster reconstruction, Dare County presents several recovery and reconstruction scenarios, ranging from complete, catastrophic damage to minor structural damage and flooding. In the event of a catastrophic event the Board of Commissioners can declare a moratorium on all building permits and rezoning requests in the county depending on an evaluation of reconstruction strategies that may assist in the mitigation of future storm damage or repetitive losses. Finally, the current policy statements fully support the use of ORVs on the CHNS, citing the long standing history and tradition, but recognize the need for an official ORV plan.

Although CAMA is the most pertinent, a few other policies regulate activities in some areas of the NC Coastal region: Section 404 of the Clean Water Act protects wetlands and certain activities are regulated by the NC Environmental Policy Act.
5.4 Other Mitigation Efforts

Although regulations limiting development in coastal areas using land use plans is a critical tool in mitigating impacts of SLR, changing storm/wave patterns and development, areas of research provide the important tools with which coastal planners, policy-makers and managers use to make policy decisions.

One of the most forward thinking acts of the state in recent years is Senate Bill 1134, in which the NC General Assembly established the Legislative Commission on Global Climate Change in 2005. The Commission is directed to study the issues surrounding climate change, the emerging carbon economy and decide whether or not it is appropriate to establish a global warming pollution reduction goal for the state. This is a giant step in the right direction for the state, as the only real way to fight global warming is by requiring mandatory carbon emission reduction, LUPs manage for the already occurring impacts. The Commission has a counterpart, the Climate Action Plan Advisory Group, which is charged with providing recommendations for a future state climate action plan and looks at various ways that NC can reduce their carbon footprint on the globe. The last meeting was held in the spring of 2007; at that point no decision had been reached regarding a state reduction goal but research continues (NC General Assembly 2007).

Another organization that thinks it is important for NC to establish a global warming reduction goal is Environmental Defense. A 2005 report by the organization makes several recommendations for the state to address global warming: establish a goal to reduce global warming pollutants, develop an action plan to reduce global warming in NC and encourage state
Senators to pass the McCain-Lieberman Climate Stewardship Act. This plan focuses policy on
the actions that cause global warming and not on how to manage the impacts (Environmental
Defense 2005).

The introduction of a plan that will directly manage for impacts of global warming on the NC
Coast is the Beach and Inlet Management Plan (BIMP). Recognizing the potential impacts of
increased storms and development the plan is designed to approach beach and inlet management
from a regional perspective. To this end, the BIMP will attempt to mitigate coastal hazards and
decrease the risk to life and property in the context of conserving natural resources. Funding for
the BIMP was received in July of 2006, and the results should be evident sometime in 2009
(DCM 2006).

The Division of Coastal Management and the NC Estuarine Biological and Physical Processes
Work Group prepared a series of recommendations for shoreline stabilization methods. The
shoreline stabilization study found that in all cases the best way to stabilize shorelines is through
land planning. Land planning for stabilization leaves the land in its natural state; property is
designed around the existing conditions if the shoreline segment. The second best stabilization
option for shorelines was typically using vegetated buffers (DCM 2006).

In addition to the BIMP, the NC Department of Environment and Natural Resources (DENR)
has created a statewide conservation plan aimed at identifying current and future conservation
areas of the state. The Strategic Conservation Plan (SCP) has undertaken efforts to prioritize
natural resource areas in the state and identifying gaps in the network of essential nature preserves. This is done largely using Geographic Information Systems (GIS) data layers to rank and prioritize areas of the state, including sensitive coastal areas (Figure). The STP final product will result in a set of NC conservation maps of evaluated ecosystems ranked to highlight conservation opportunities. In the future the ecosystem evaluation will include a vulnerability assessment to further refine the prioritization scheme used to rank areas. The vulnerability assessment includes climate change, population growth and growth patterns and will be extremely important to coastal areas that are impacted by SLR, storms and anthropogenic growth. The maps will be updated every 6 months and represents a huge wealth of information on the states rich coastal resources (NC DENR 2007?).

Further contributing to NCs mitigation of global change impacts is the National Ocean and Atmospheric Administration (NOAA) Center for Sponsored Coastal Ocean Research (NCSCOS). This center is involved in several research projects focusing on SLR in NC funding such projects and programs as Shore-Zone Modification in Response to SLR in NC Estuaries, Ecological Effects of SLR on Coastal NC Marshes ((EESLR) and Modeling Estuarine Habitat Response to Rising Water Level. These are multi-disciplinary and multi-institutional research efforts that address SLR impacts from scientific and technical approaches. The EESLR program is developing both maps and models to predict SLR impacts that could be used as a critical management tool for effective policy development (NCSCOS 2005).
In response to local issues of concern to Carteret and Dare Counties citizens have formed action groups addressing local problems. Carteret County citizens have formed an organization called Downeast Tomorrow to combat the rampant development that is occurring in the Down East section of the county. The focus of the group is to gain community involvement in the planning process that ultimately determines how the LUP is designed and how the community will grow in the coming years (DET 2007). In Dare County there are two organizations aimed at giving a voice to local residents. The Outer Banks Preservation Association boasts over 3,000 members in over 20 states and Canada and was created in the 1970s to work with the NPS to preserve the tradition and culture of the OBX. This largely consists of working with the NPS to ensure public access on the CHNS and develop and ORV plan to guarantee such access for fishermen (OBPA 2005). To encourage citizen involvement in the Bonner Bridge replacement over Oregon Inlet is the citizen action committee, replacethebridgenow.com, working to expedite the bridge replacement process before more serious problems arise (replacethebridgenow.com 2007).

5.5 Modifications and Recommendations for Mitigation Efforts

Policy Improvements

1) The North Carolina General Assembly should set target GHG emission reduction goals.

On a national level reducing GHG pollutants is the primary foundation for truly fighting climate change and would show that the US is ready to accept accountability and responsibility for contributing to global warming. Reducing state GHG emissions by policy action would solidify the legislative commitment to fixing the source of the problem and take advantage of the
economic opportunities in the upcoming carbon market. Although the world will be locked into many of the impacts of climate change even if emissions were to stop today, steps must be taken at higher levels of government to combat further acceleration of the warming climate.

Acceptance of this responsibility at the legislative level of state government will translate into better preparation to manage for potential global warming impacts. If the state were to mandate GHG reductions from polluting sectors it would show the federal government and NC residents that the state is on board to start making sacrifices in order to protect our plant. Possibly more convincing is that the survey results show that North Carolinians would support this policy action in the General Assembly.

2) Restructuring of CAMA on a state and local level

Although each of the CAMA counties frequently make updates to their individual land use plans and there are amendments to the state CAMA made in the General Assembly, the original document was created in 1976. Information and research concerning the coastal environment and management therein in the past 30 years has progressed significantly. Many of the management themes addressed in CAMA are outdated and the document is completely lacking in any climate change impacts on coastal areas. For example, in the entire state document there is no mention of climate change or how the impacts will affect coastal stressors like erosion, disasters and flooding. The absence of these coastal connections is substantial to the application of CAMA in local LUPs and to the management of the NC Coast.

Policy outputs are typically the result of the political climate in which local governments operate. However, in states that have LUP mandates planners can rely less on the local political demands
of the community and the mandate itself is a key source in limiting development in response to hazard mitigation (Burby & Dalton 1994). It is the responsibility of the government to mitigate these potential hazards; linking natural hazards to other high priority local issues that are confronting decisionmakers could be a valuable conduit for progressive, proactive policies. Bogue Banks could benefit the most from making this linkage. The relative width of the island and the length of time since the last major storm strike has lulled the communities on Bogue Banks and inland into a false sense of security. As development continues in the area and permeates into Down East the potential damage accrued by the next tropical storm or hurricane strike increases exponentially; by permitting and encouraging development, the Carteret County LUP may be setting the county up for disaster.

a. Longer time horizon

For LUPs CAMA mandates a 10 year planning horizon for statements of local policy and to define those issues which are predicted to affect the community. This is an extremely short time frame with respect to geologic and climate processes. However, in high energy coastal systems like the OBX and the rest of the NC Coast dramatic changes in the shape and structure of the coastline can be seen in a very short period of time (Riggs & Ames 2003). Researchers investigating long-term erosion on the East coast found that long-term (SLR) and short-term (storm events) erosion on the shoreline should be treated separately in coastal management (Zhang et al 2002). If all estimates concerning local policies on erosion on shoreline segments are made in a 10 year timeframe the benefits of foresight in coastal management are lost. Considering the timeframe in which many coastal processes take place there is clearly a need for a long term, 50-100 years, component in the CAMA mandate for local LUPs. Including a
prediction and/or statement of policy for long term erosion rates and subsequent coastline
evolution in addition to the short term planning horizon will yield more effective and well
planned LUPs for coastal communities.

b. **Remove loopholes**

Certain aspects of CAMA have shown to be counterproductive loopholes that allow undesirable
forms of development to occur in coastal areas. An instance of particular note is the temporary
allowance of sandbags to stabilize a shoreline segment during development. Sandbags function
as a sort of temporary hard structure on the shoreline and can have severely erosive effects
downshore and are only permitted to be in place for 2 years. Unfortunately the enforcement of
sandbag removal has left much to be desired and in many areas these semi-hardened structure
abound on shoreline segments and adversely impacting the nearshore environment.

Additionally, following damage to the coast following hurricanes or tropical storms NCDENR
has discretion to issue an emergency general permit, allowing the replacement of structures and
the reconstruction of frontal dunes. This is strong incentive for coastal managers to rush in after
a disastrous storm event and potentially replace structures that are not needed or undergo such
repetitive loss that replacement is futile in the long-term.

c. **Need more protection for estuarine environment (possibly banning hardened
structures)**

Currently, CAMA has extensive use standards for the estuarine environment, but they are
significantly less restrictive to development and other human activities that are banned on the
ocean shoreline. As discussed above, in many segments of the NC Coast the estuarine shoreline and the ocean environment are closely linked. This is not taken into account in the protection of estuarine areas and allowed developments include hardened structures, canal construction, boardwalks, development over existing impervious surfaces and development within buffers if they are under certain size and septic limits. Much of this leeway is given to ensure the preservation and continuing creation of urban waterfronts in the state. In the event of increasing storminess on the coast these urban waterfronts are increasingly exposed to dangerous waves and high erosion. Following Hurricane Ophelia in 2005 virtually every estuarine structure in Emerald Isle was pushed onto the shore. This included decks, boardwalks, boats and anything else in the water. This pattern will surely increase in the future and the damages will be exponential if steps aren’t taken to protect property and the environment.

3) **Translate proactive research into proactive policy to mitigate effects of stressors**

Although current research on the impacts of climate change and population growth is proactive, trying to anticipate future problem areas and mitigate impacts where possible, policy is lacking. This is surely due to the intrinsic holds involved in the policy-making process and the desire to be absolutely certain about how an area will be impacted before making and policy decision regarding its management. We can see this in Dare County at Oregon Inlet with the Bonner Bridge. Uncertainties regarding future stability of the area have held up the process and potentially endangered the lives of hundreds of visitors and residents daily. Policy that manages the coast and impacts of climate change has similarly experienced a stagnation that only a category 5 hurricane may disrupt.
4) **Improve citizen participation in planning**

The Carteret County case study illuminated that citizen involvement in local LUPs is waning in many areas. Residents of Down East feel that they are largely ignored by the Board of Commissioners and the Planning Department in setting development restrictions in their communities and in the creation of LUP updates. CAMA mandates public participation in the planning process but aside from mandating public meeting there is little specificity as to what this public involvement might entail. In Dare County there is significantly more attention to local preference in planning. To prepare the 2003 LUP updates the Dare County Board of Commissioners adopted a public participation plan in 2000 which included a questionnaire that was mailed to all property owners, residents and non-residents in the county. If Carteret County were to adopt a similar plan locals may have a better chance at control in their communities.

**Research and Technical Assistance**

1) **Evaluate coastal vulnerability at high resolution**

Obtaining a high resolution, fine scale assessment of how coastal ecosystems will respond to changes in climate and population will be a critical management tool for future coastal managers. This would involve the integration of physical, biological, chemical, societal and economic factors. Physical factors should include both long-term and short-term erosion rates. Long-term erosion rates would reflect the dominant wave climate and RSLR, short-term should include potential for breaching in response to storm events and potential storm surge. A combination of Geographic Information Systems (GIS) and current models (like those used in EESLR) would allow managers to assess vulnerability and determine areas where there is overlap of high
vulnerability to climate changes from SLR, storms, waves, erosion and land loss and high population growth or increasing development trends. The spatial assessment should be aimed at determining the risk from two separate perspectives, the natural environment and the human environment and yield two separate assessments. The overlap between the two would present different avenues and opportunities for management. The uses of such an assessment in the state are multiplicative and could be shared with various agencies and organizations to further development of proactive research and make informed policy decisions.

2) **Apply data obtained from EESLR to SCP**

The SCP aims in the future to produce a vulnerability assessment for conservation prioritization in the entire state. In the coastal area, model outputs from the EESLR will be an important component in assigning a rank to coastal areas. If combined with the above technical recommendations the SCP could function as both a conservation tool and a vulnerability assessment.

3) **Implement new land classification component or system in CAMA**

There are new pressures to land in the state that the current land classification system in CAMA can’t assess. A new system could take advantage of the new land assessments in the state including the EESLR, SCP, the hypothetical high resolution assessment recommended above and many, many more. Additionally, the dynamic nature of the coastal system in the state should be evaluated frequently to anticipate changes in land classifications. Priority for frequency assessments should be given to high energy areas that are capable of experiencing rapid change.

4) **Provide technical support in development of LUP**
A clear example of this inadequacy in the planning process was evident in the Carteret County case study. During planning meetings important decisions were made concerning development and property buffers from ORWs and wetlands, storm water treatment and management, shoreline stabilization and restrictions in environmental areas. During these meetings developers brought professionals from engineering, water treatment and construction areas who presented technical information concerning the proposed development before the Board of Commissioners. There was a clear under-representation of environmental agencies present and residents who commented on environmental technicalities and requirements were apparently considered an unviable source of information. Many important decisions were made with technical or scientific information given by an extremely biased and questionable source, only after hours of fruitless debate on the topic. A technical advisor who provided an un-biased opinion on important environmental issues in the county would expedite the planning process immensely and prevent unnecessary environmental degradation.

Other Recommendations

1) Educate residents on global change impacts on a state and local level

It appears that although North Carolinians have a good understanding of how climate change impacts the planet in general there is a gap of knowledge concerning local impacts. This could relate back to the lack of climate connections made in CAMA. This is already underway in many areas; the Coastal Studies Institute under construction in Manteo, the Institute of Marine Sciences and the Duke University Marine Lab are continuously working to educate and inform the public about coastal issues.
6.0 Conclusions

There are four distinct conclusions that can be made from this study:

1. Coastal stressors are accelerating.

2. Local issues are primarily a result of land (use) conflict and are exacerbated by climate change and population growth.

3. North Carolina residents are ready for government policy action that addresses the source of global warming, but are hesitant to make significant local changes to address climate change impacts.

4. Local action but state policy is the primary conduit for impact mitigation and pre-disaster planning.

As climate change and shoreline developments arrive at the coast the natural equilibrium in which the land exists shifts. This shift can be less than commodious for the communities living near the active shore zone and include accelerated erosion, overwash and flooding. In the future the capabilities of coastal communities to exist in sync with the natural environment will become a critical component for the persistence of the beach and the properties on the coast.

Because regional projections of and observed responses to climate change are uncertain best management practices and land use patterns remain unclear. Currently, most land management decisions have little basis in ecological science and are influenced more strongly by economics, values, traditions and politics. This management approach is dismally inadequate and does not take natural physical processes nor the implied carrying capacity of ecosystems into account whatsoever. We have to assume that the impacts of climate change on the land will be
substantial, we know this to be true in the coastal region of NC, and that changes are inevitable. The ability of ecological systems to respond to changes in climate will depend upon the patterns of land use and management in an ecosystem, particularly the human response to SLR and changes in the frequency and intensity of storms and hurricanes (Dale et al 2000; Michener et al 1997).

The management tools to deal with the upcoming problems presented by climate change are available to coastal planners and are improving every year. The lack of political commitment impacting management regimes in state mandates must be addressed if there is to be a significant attempt to mitigate the impacts of climate change. This will surely include restrictions that will be met with opposition, but perhaps not as much as politicians fear. Indeed, fear of backlash can no longer hinder the responsibility of the government to protect its citizens from hazards. In North Carolina it is possible to preserve access to coastal resources and ensure their availability to everyone if a few are restricted from development in sensitive areas.

Local projections of climate change impacts will see much improvement in the coming years. As modeling and GIS techniques advance so will the potential for sound management decisions on our nations’ coasts. To ensure and encourage best management practices on our coastlines will require higher level policy action as well as cutting edge research and technology. The facts of global warming and population growth impacts on coastal areas must be reflected in policy. Attaining this goal should be a focal point for state level environmental advocacy in upcoming years.
7.0 References


8.0 Appendices

Appendix A- Surveys

Are you a resident of:

North Carolina
The North Carolina Coast
Other

How convinced are you that global warming is happening?

Completely
Mostly
Not very
Not at all
Don’t know

If global warming is happening, do you think it is due more to the normal cycles in the Earth’s environment, or more due to human activity such as burning of fossil fuels?

Human Activity
Normal Cycles
Both (Human Activity and Normal Cycles)
Don’t know

Some people say that global warming is already impacting North Carolina. Do you strongly agree, somewhat agree, somewhat disagree, or strongly disagree that global warming is already causing or making the following things worse?

<table>
<thead>
<tr>
<th>Topic</th>
<th>Strongly agree</th>
<th>Somewhat agree</th>
<th>Somewhat disagree</th>
<th>Strongly disagree</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>More frequent overwash</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of roads and infrastructure</td>
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<tr>
<td>Inlet breaching</td>
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<tr>
<td>Coastal erosion</td>
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<tr>
<td>Island migration</td>
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<tr>
<td>Decrease in overall barrier island size</td>
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<tr>
<td>Higher ocean temperatures</td>
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<tr>
<td>Winter storms (Nor’easters)</td>
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<tr>
<td>Summer storms</td>
<td></td>
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<tr>
<td>Warmer winters</td>
<td></td>
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<td></td>
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<tr>
<td>Changing fish migrations</td>
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</tbody>
</table>
How serious of a threat is global warming to:

<table>
<thead>
<tr>
<th></th>
<th>Very serious</th>
<th>Somewhat serious</th>
<th>Not very serious</th>
<th>Not at all serious</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plants and animals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>People in North Carolina</td>
<td></td>
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<tr>
<td>People in the United States</td>
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<tr>
<td>People in other countries</td>
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<tr>
<td>Your local community</td>
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<tr>
<td>You and your family</td>
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</tbody>
</table>

When do you think global warming will start to have dangerous impacts on people in North Carolina?

- It is dangerous now
- In 10 years
- In 25 years
- In 50 years
- In 100 years
- Never
- Don't know

Do you think global warming is an urgent problem that requires immediate government action, or a longer term problem that requires more study before government action is taken?

- Urgent problem
- Longer-term problem
- Not a problem
- Don't know

Do you feel that you local government is prepared to deal with the impacts of global warming on your community?

- Very prepared
- Somewhat prepared
- Very unprepared
- Somewhat unprepared
- Unsure
Many towns and villages on the North Carolina Outer Banks are experiencing more frequent flooding and are in danger of coastal erosion. Do you think the state of North Carolina should help to:

| Move these towns and villages to safer ground |
| Maintain these towns in their current locations |
| Let the local governments take care of themselves |

Do you think the relationship between global warming and coastal erosion on the North Carolina coast is:

| Very strong |
| Somewhat strong |
| Very weak |
| Somewhat weak |
| Unsure |

Overall, do you think that storms hitting the North Carolina Outer Banks have:

| Become more intense |
| Become more frequent |
| Stayed about the same |
| Become less intense |
| Become less frequent |
| Not sure |

In August 2005, Hurricane Katrina struck the Gulf coast of the United States and had devastating impacts; causing billions of dollars of damages and the loss of life and property. Do you think the likelihood of a storm of this magnitude hitting the North Carolina coast is:

| Very likely |
| Somewhat likely |
| Very unlikely |
| Somewhat unlikely |
| Don’t know |
If this type of a storm hit the North Carolina coast do you think the state of North Carolina should:

<table>
<thead>
<tr>
<th>Option</th>
<th>Strongly favor</th>
<th>Somewhat favor</th>
<th>Strongly oppose</th>
<th>Somewhat oppose</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rebuild the areas destroyed in the same locations</td>
<td></td>
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<tr>
<td>Relocate the areas in less hazard prone areas (but still on the coast)</td>
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<tr>
<td>Relocate the areas in less hazard prone areas (but NOT on the coast)</td>
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<tr>
<td>Nothing, let the local governments take care of themselves</td>
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<tr>
<td>Don’t know</td>
<td></td>
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</tbody>
</table>

For each of the following, please tell me whether you strongly favor, somewhat favor, strongly oppose or somewhat oppose it as a way for the government to reduce the impacts of global warming.

<table>
<thead>
<tr>
<th>Option</th>
<th>Strongly favor</th>
<th>Somewhat favor</th>
<th>Strongly oppose</th>
<th>Somewhat oppose</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulate greenhouse gas emissions from power plants</td>
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<tr>
<td>Sign international treaties to reduce greenhouse gas emissions</td>
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<td></td>
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<tr>
<td>Increase taxes so people either drive less or buy cars that use less gas</td>
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<tr>
<td>Increase taxes on electricity so people use less of it</td>
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<tr>
<td>Restrict development in hazard prone areas</td>
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<td></td>
</tr>
<tr>
<td>Make modifications to existing developments to resist flooding and erosion impacts (bridges, highways, dunes)</td>
<td></td>
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</tr>
<tr>
<td>Start slowly retreating from the coastline</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Stop rebuilding when damages exceed 90%</td>
<td>90%</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>75%</td>
<td></td>
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<tr>
<td></td>
<td>50%</td>
<td></td>
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<tr>
<td></td>
<td>25%</td>
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<tr>
<td></td>
<td>any</td>
<td></td>
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</tr>
</tbody>
</table>
### Appendix B - Raw Data

#### Table 1

<table>
<thead>
<tr>
<th>Convinced</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completely</td>
<td>NC=50; NCC=32</td>
</tr>
<tr>
<td>Mostly</td>
<td>NC=25; NCC=15</td>
</tr>
<tr>
<td>Unconvincled</td>
<td></td>
</tr>
<tr>
<td>Not very</td>
<td>NC=6; NCC=7</td>
</tr>
<tr>
<td>Not at all</td>
<td>NC=1; NCC=2</td>
</tr>
<tr>
<td>Don't know</td>
<td>NC=1; NCC=2</td>
</tr>
</tbody>
</table>

#### Table 2

<table>
<thead>
<tr>
<th>Human Activity</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC=57; NCC=38</td>
<td></td>
</tr>
<tr>
<td>Normal Cycles</td>
<td>NC=12; NCC=14</td>
</tr>
<tr>
<td>Both (HA and NC)</td>
<td>NC=11; NCC=2</td>
</tr>
<tr>
<td>Don't know</td>
<td>NC=3; NCC=6</td>
</tr>
<tr>
<td>Not happening</td>
<td>NC=0; NCC=0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Event</th>
<th>Strongly agree</th>
<th>Somewhat agree</th>
<th>Somewhat disagree</th>
<th>Strongly disagree</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>More frequent overwash</td>
<td>NC=23; NCC=15</td>
<td>NC=20; NCC=23</td>
<td>NC=7; NCC=6</td>
<td>NC=2; NCC=1</td>
<td>NC=31; NCC=12</td>
</tr>
<tr>
<td>Loss of roads and infrastructure</td>
<td>NC=20; NCC=12</td>
<td>NC=26; NCC=27</td>
<td>NC=8; NCC=6</td>
<td>NC=3; NCC=1</td>
<td>NC=26; NCC=12</td>
</tr>
<tr>
<td>Inlet breaching</td>
<td>NC=22; NCC=20</td>
<td>NC=29; NCC=22</td>
<td>NC=3; NCC=6</td>
<td>NC=3; NCC=1</td>
<td>NC=26; NCC=9</td>
</tr>
<tr>
<td>Coastal erosion</td>
<td>NC=35; NCC=23</td>
<td>NC=27; NCC=21</td>
<td>NC=3; NCC=6</td>
<td>NC=3; NCC=1</td>
<td>NC=16; NCC=7</td>
</tr>
<tr>
<td>Island migration</td>
<td>NC=21; NCC=17</td>
<td>NC=23; NCC=23</td>
<td>NC=4; NCC=7</td>
<td>NC=3; NCC=1</td>
<td>NC=32; NCC=10</td>
</tr>
<tr>
<td>Decrease in overall barrier island size</td>
<td>NC=20; NCC=23</td>
<td>NC=29; NCC=20</td>
<td>NC=4; NCC=6</td>
<td>NC=3; NCC=1</td>
<td>NC=27; NCC=4</td>
</tr>
<tr>
<td>Higher ocean temperatures</td>
<td>NC=40; NCC=27</td>
<td>NC=24; NCC=21</td>
<td>NC=2; NCC=4</td>
<td>NC=4; NCC=1</td>
<td>NC=13; NCC=5</td>
</tr>
<tr>
<td>Winter storms (Nor’easters)</td>
<td>NC=26; NCC=21</td>
<td>NC=29; NCC=17</td>
<td>NC=4; NCC=8</td>
<td>NC=4; NCC=4</td>
<td>NC=20; NCC=8</td>
</tr>
<tr>
<td>Summer storms</td>
<td>NC=30; NCC=20</td>
<td>NC=25; NCC=22</td>
<td>NC=6; NCC=7</td>
<td>NC=4; NCC=2</td>
<td>NC=18; NCC=7</td>
</tr>
<tr>
<td>Warmer winters</td>
<td>NC=45; NCC=26</td>
<td>NC=18; NCC=22</td>
<td>NC=3; NCC=5</td>
<td>NC=3; NCC=2</td>
<td>NC=14; NCC=3</td>
</tr>
<tr>
<td>Changin fish migrations</td>
<td>NC=25; NCC=22</td>
<td>NC=15; NCC=18</td>
<td>NC=3; NCC=6</td>
<td>NC=3; NCC=2</td>
<td>NC=36; NCC=11</td>
</tr>
<tr>
<td></td>
<td>Very serious</td>
<td>Somewhat serious</td>
<td>Not very serious</td>
<td>Not at all serious</td>
<td>Don’t know</td>
</tr>
<tr>
<td>--------------------------</td>
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<td>--------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Plants and animals</td>
<td>NCC=31; NC=52</td>
<td>NCC=18; NC=16</td>
<td>NCC=4; NC=6</td>
<td>NCC=2; NC=2</td>
<td>NCC=3; NC=7</td>
</tr>
<tr>
<td>People in North Carolina</td>
<td>NCC=27; NC=38</td>
<td>NCC=23; NC=29</td>
<td>NCC=4; NC=3</td>
<td>NCC=2; NC=3</td>
<td>NCC=2; NC=10</td>
</tr>
<tr>
<td>People in the United States</td>
<td>NCC=24; NC=43</td>
<td>NCC=26; NC=27</td>
<td>NCC=4; NC=5</td>
<td>NCC=2; NC=2</td>
<td>NCC=2; NC=6</td>
</tr>
<tr>
<td>People in other countries</td>
<td>NCC=29; NC=53</td>
<td>NCC=20; NC=19</td>
<td>NCC=5; NC=2</td>
<td>NCC=1; NC=2</td>
<td>NCC=3; NC=7</td>
</tr>
<tr>
<td>Your local community</td>
<td>NCC=28; NC=39</td>
<td>NCC=21; NC=27</td>
<td>NCC=6; NC=3</td>
<td>NCC=1; NC=3</td>
<td>NCC=2; NC=8</td>
</tr>
<tr>
<td>You and your family</td>
<td>NCC=27; NC=41</td>
<td>NCC=22; NC=25</td>
<td>NCC=5; NC=4</td>
<td>NCC=2; NC=2</td>
<td>NCC=2; NC=3</td>
</tr>
</tbody>
</table>

**table 6**

<table>
<thead>
<tr>
<th></th>
<th>NCC=18; NC=26</th>
<th>NCC=15; NC=17</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is dangerous now</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In 10 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In 25 years</td>
<td>NCC=4; NC=14</td>
<td></td>
</tr>
<tr>
<td>In 50 years</td>
<td>NCC=4; NC=5</td>
<td></td>
</tr>
<tr>
<td>In 100 years</td>
<td>NCC=2; NC=0</td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>NCC=4; NC=5</td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td>NCC=12;</td>
<td>NC=16</td>
</tr>
</tbody>
</table>

**table 10**

<table>
<thead>
<tr>
<th></th>
<th>NCC=31; NC=57</th>
<th>NCC=22; NC=20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urgent problem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longer-term problem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not a problem</td>
<td>NCC=1; NC=4</td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td>NCC=4; NC=2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>NCC=0; NC=0</th>
<th>NCC=5; NC=6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very prepared</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Somewhat prepared</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very unprepared</td>
<td>NCC=29; NC=43</td>
<td></td>
</tr>
<tr>
<td>Somewhat unprepared</td>
<td>NCC=10; NC=11</td>
<td></td>
</tr>
<tr>
<td>Unsure</td>
<td>NCC=14; NC=23</td>
<td></td>
</tr>
<tr>
<td>Move these towns and villages to safer ground</td>
<td>NC=27; NCC=6</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td>Maintain these towns in their current locations</td>
<td>NC=22; NCC=20</td>
<td></td>
</tr>
<tr>
<td>Let the towns take care of themselves</td>
<td>NC=27; NCC=26</td>
<td></td>
</tr>
<tr>
<td>Unsure</td>
<td>NC=6; NCC=6</td>
<td></td>
</tr>
</tbody>
</table>

| Become more intense                            | NC=20; NCC=6  |
| Become more frequent                           | NC=15; NCC=14 |
| Both (more intense and less frequent)          | NC=6; NCC=6   |
| Stayed about the same                          | NC=13; NCC=17 |
| Become less intense                            | NC=2; NCC=0   |
| Become less frequent                           | NC=0; NCC=1   |
| Not sure                                       | NC=26; NCC=13 |

| Very strong                                    | NC=21; NCC=20 |
| Somewhat strong                                | NC=36; NCC=22 |
| Very weak                                      | NC=6; NCC=1   |
| Somewhat weak                                  | NC=2; NCC=3   |
| Unsure                                         | NC=17; NCC=12 |

<p>| Rebuild the areas destroyed in the same locations | NC=13; NCC=12 |
| Relocate the areas in less hazard prone areas (but still on the coast) | NC=24; NCC=19 |
| Relocate the areas in less hazard prone areas (but NOT on the coast) | NC=7; NCC=6   |
| Nothing, let the towns take care of themselves | NC=11; NCC=9  |
| Don't know                                     | NC=19; NCC=11 |</p>
<table>
<thead>
<tr>
<th>Topic</th>
<th>Strongly favor</th>
<th>Somewhat favor</th>
<th>Strongly oppose</th>
<th>Somewhat oppose</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulate greenhouse gas emissions from power plants</td>
<td>NC=54; NCC=42</td>
<td>NC=22; NCC=11</td>
<td>NC=0; NCC=1</td>
<td>NC=2; NCC=0</td>
<td>NC=5; NCC=4</td>
</tr>
<tr>
<td>Sign international treaties to reduce greenhouse gas emissions</td>
<td>NC=55; NCC=39</td>
<td>NC=18; NCC=13</td>
<td>NC=2; NCC=1</td>
<td>NC=3; NCC=1</td>
<td>NC=5; NCC=4</td>
</tr>
<tr>
<td>Increase taxes to people either drive less or buy cars that use less gas</td>
<td>NC=25; NCC=17</td>
<td>NC=22; NCC=18</td>
<td>NC=15; NCC=12</td>
<td>NC=12; NCC=6</td>
<td>NC=9; NCC=5</td>
</tr>
<tr>
<td>Increase taxes on electricity so people use less of it</td>
<td>NC=12; NCC=8</td>
<td>NC=26; NCC=16</td>
<td>NC=24; NCC=18</td>
<td>NC=10; NCC=11</td>
<td>NC=11; NCC=5</td>
</tr>
<tr>
<td>Restrict development in hazard prone areas</td>
<td>NC=54; NCC=31</td>
<td>NC=17; NCC=14</td>
<td>NC=2; NCC=2</td>
<td>NC=2; NCC=6</td>
<td>NC=8; NCC=5</td>
</tr>
<tr>
<td>Make modifications to existing developments to resist flooding and erosion impacts (bridges, highways, dunes)</td>
<td>NC=32; NCC=27</td>
<td>NC=33; NCC=20</td>
<td>NC=9; NCC=2</td>
<td>NC=3; NCC=1</td>
<td>NC=6; NCC=8</td>
</tr>
<tr>
<td>Stop rebuilding when damages exceed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90% ONLY FAVOR</td>
<td>NC=14; NCC=11</td>
<td>ONLY OPPOSE</td>
<td>NC=1; NCC=4</td>
<td>NC=17; NCC=8</td>
<td></td>
</tr>
<tr>
<td>75% ONLY FAVOR</td>
<td>NC=15; NCC=18</td>
<td></td>
<td>NC=0; NCC=0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50% ONLY FAVOR</td>
<td>NC=18; NCC=13</td>
<td></td>
<td>NC=0; NCC=0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25% ONLY FAVOR</td>
<td>NC=9; NCC=3</td>
<td></td>
<td>NC=1; NCC=0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>any</td>
<td>NC=6; NCC=0</td>
<td></td>
<td>NC=6; NCC=0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start slowly retreating from the coastline</td>
<td>NC=28; NCC=6</td>
<td>NC=20; NCC=12</td>
<td>NC=10; NCC=15</td>
<td>NC=6; NCC=9</td>
<td>NC=19; NCC=16</td>
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</tbody>
</table>