ABSTRACT

USING VULNERABILITY AND PLANNING DATA TO MEASURE RESILIENCE IN COASTAL NORTH CAROLINA

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Along the coast of North Carolina, development has put tremendous stress on already delicate natural systems. Consisting almost entirely of barrier islands, this region is highly dynamic and subject to a variety of acute and chronic natural hazards. In order to continue to enjoy these areas for recreation and reap the economic benefits that they bring, it will be essential to strike a balance between human activity and nature. This can only be accomplished through effective planning and coastal management. It is argued here that resilient coastal communities result from the combination of relatively low natural vulnerability as well as planning and management strategies aimed at effectively adapting to different types of hazards. Taking both vulnerability and planning into account, a resilience index has been devised and is used to compare three different communities along the North Carolina coast. The results suggest that traditional mitigation strategies are insufficient and that more adaptive approaches will be necessary to sustain these communities.

USING VULNERABILITY AND PLANNING DATA TO MEASURE RESILIENCE IN COASTAL NORTH CAROLINA

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CHAPTER 1: INTRODUCTION AND PROBLEM STATEMENT

Introduction

People have been drawn to the coast for both economic and recreational reasons throughout history. Coastal regions are some of the most alluring places, but they are also amongst the most hazardous. As of 1999, about 75 percent of Americans lived within 50 miles of the coast (this includes the Great Lakes) (Klee, 1999). Historically, people in coastal communities have viewed the benefits in terms of defense and trade/commerce to outweigh the risks of developing in hazardous environments (Ewing et al., 2010). As a result, coastal development has put tremendous stress on already delicate natural systems. Given the fact that the United States' economy is intricately tied to the coast, it is essential to strike a balance between human activity and nature. This is best accomplished through effective planning and coastal management.

Coastal areas are amongst the most vulnerable places on Earth and the hazards facing coastal communities abound. Acute hazards include damage from coastal storms (wind, storm surge, flooding, and rapid beach erosion), while chronic hazards are more long-term and involve a greater amount of uncertainty in terms of their measurement and prediction, making them more difficult to plan for. These include gradual beach erosion, sea level rise, climate change, pollution, and loss of habitat. It is important to note that these are only considered "hazards" once these areas are inhabited by humans (Pilkey et al., 1998). It is often discussed how our coasts are "disappearing" due to erosion and sea level rise. Oftentimes, they are not disappearing, they are simply moving. Human property (homes, businesses, industries, etc.) is what is truly at risk of disappearing. We try to create artificially static environments out of systems that are naturally dynamic, resulting in variability that is as much due to human activity as it is to natural hazards.

The coast of North Carolina is no stranger to these issues. Like the majority of the United States' Atlantic and Gulf coasts, North Carolina's coast is extremely flat and dominated by barrier islands. Of all coastal systems, barrier islands are perhaps the most dynamic, as they tend to migrate and change location over time. In North Carolina, the barrier islands typically migrate landward due to the combination of wave action, wind-blown sand transport, and sea level rise (Inman and Dolan, 1989). Human activities often disrupt these natural migration processes through development and the emplacement of artificial control structures.

Coastal hazards present exceptionally difficult challenges for planners, ones for which there are no simple solutions. Traditional approaches have generally focused on mitigation as opposed to adaptation. These methods, such as hard or soft stabilization (beach nourishment) are costly, temporary, and oftentimes only exacerbate the problem in the long-term. Attempts to stabilize beaches and barrier islands also disrupt natural processes and ecosystems. Thus, these practices cannot be considered sustainable or contributing to community resilience. In order to be resilient, coastal communities must be able to adapt to a naturally changing environment while altering or disrupting it only minimally or not at all. How to accomplish this is a critical issue.

Objectives and Significance of the Proposed Research

Achieving resilience is more difficult in some places than others, and is particularly difficult in vulnerable coastal settings. This research does not address all of the factors that contribute to resilience, which include both physical and social vulnerability. Instead, the goal of this research is to measure the resilience of the natural and built environment in a coastal setting, which is a very important indicator of overall resilience and sustainability. In this context, three coastal communities in North Carolina are compared according to how they are presently addressing vulnerability and how they plan to address it in the future. This is accomplished through critical examination of each community's Coastal Area Management Act (CAMA) land use plan and hazard mitigation plan. The goal of this research is to address the following questions:

1) Are differences in physical vulnerability reflected in land use planning?
2) How do planning strategies differ amongst three communities along the North Carolina coast?
3) Can these three communities be used to make generalizations about North Carolina's coast as a whole?
4) Are communities better at planning for acute or chronic hazards?
5) Which communities (if any) are employing adaptive strategies to deal with natural hazards?
6) Which communities are most resilient and why?
7) Can we build a high level of resilience in these communities with good planning, or is their natural vulnerability simply too great to overcome?

Problem Statement

This research has been devised as a first step towards determining how resilient and ultimately, how sustainable different North Carolina coastal communities are when considering their current hazards and in the face of future environmental change. As the literature indicates, building resilience involves a complete understanding of hazards and vulnerability, as well as the relationships between their different components. Building resilience also necessitates comprehensive and ongoing planning strategies aimed at adapting to vulnerability and future uncertainty. The literature on resilience typically assumes it to be a qualitative concept that is not measurable. However, from political and economic perspectives, it is important that some sort of quantitative measure of resilience, albeit perhaps imprecise, be devised. This will provide direction for communities, giving them a sense of where they currently stand overall, in relation to other communities, and what they can improve upon to be more resilient.

It is apparent that the ability to manage both natural environments and human societies requires the recognition of the dynamic interdependency between the two. When the concern is with the interactions between human and natural systems, environmental issues arise (Handmer and Dovers, 2009). While it is true that both biophysical and human vulnerability are required to gain a complete measurement of community resilience, this research focuses solely on the resilience of the natural and built environment as opposed to human populations. Thus, this research only considers biophysical hazards in its vulnerability assessment and not socioeconomic factors which may contribute to vulnerability. Although still important and perhaps useful for a subsequent analysis, human resilience was chosen to be left out, in part due to the following general demographic characteristics of the study communities: 1) low year-round population and population density (see Tables 1.1 and 1.2 for 1999 and 2000 populations of study communities), 2) high socioeconomic status (see Table 1.1 for 1999 poverty status of study communities as compared to the rest of the state), and 3) the homogenous racial and ethnic makeup of the population (See Table 1.2 for the 2000 White population of the study communities as compared to the rest of the state).

	North Carolina, State	**Kitty Hawk, North Carolina**	**Sunset Beach, North Carolina**	**Topsail Beach, North Carolina**
Total Population (1999):	7,805,328	2,962	1,898	404
Income below poverty level (1999):	958,667	193	79	27
% Below Poverty	***12.28***	***6.52***	***4.16***	***6.68***

Table 1.1: 1999 year-round population and poverty status for study communities (U.S. Census Bureau, 2000).

	North Carolina, State	**Kitty Hawk, North Carolina**	**Sunset Beach, North Carolina**	**Topsail Beach, North Carolina**
Total Population (2000):	8,049,313	2,974	1,898	404
White Population (2000)	5,802,165	2,916	1,856	398
% White	***72.08***	***98.05***	***97.79***	***98.51***

Table 1.2: 2000 year-round population and percentage of White population (U.S. Census Bureau, 2000)

CHAPTER 2: CURRENT STATE OF KNOWLEDGE

This project brings together two areas that are closely related: the physical/geographical context that defines limits to development and resilience, and the planning context in which decisions about appropriate development, mitigation and adaptation are made.

The Physical Context: Barrier Island Systems

Extensive research has been done on barrier islands, which comprise almost the entire North Carolina coast, and the dangers of development on them. An understanding of both the natural and anthropogenic processes affecting barrier islands is essential in order to make sustainable planning decisions.

Barrier islands are naturally dynamic systems which require four conditions for their formation: a sufficient supply of sand, sea level rise, wave action, and a coastal plain and continental shelf of modest slope. The resulting coastline consists of elongate bodies of sand of varying width which are separated from the mainland by an estuary and from each other by tidal inlets from the open ocean (Pilkey et al., 1998). Under natural conditions, these barrier islands typically migrate landward. As sea level rises, the seaward side of the barrier islands and mainland side of the estuaries are eroded and inundated. Simultaneously, sand deposited on the beach is transported to the back (estuary) side of the island by overwash, inlets, and aeolian transport in a process called "roll-over", resulting in accretion (Brass, 2009). These processes must be sufficient enough to produce substantial dunes and maintain the islands' elevation above the rising sea level (Pilkey et al., 1998).

There is inherent complexity in defining how combinations of these variables affect the behavior of coastal systems (McFadden, 2010). Indeed, whenever humans interact with naturally dynamic environmental systems, there are associated hazards. These hazards can be either natural or anthropogenic, but they are all anthropogenic in a sense since natural "hazards" are not considered disasters if there are no impacts to the human-valued environment (Ewing et al., 2010). In the context of the North Carolina coast, hurricanes and sea level rise are natural processes which contribute to barrier island formation and migration. However, when humans enter the mix, lives, property and livelihoods are affected. It can also be argued that humans have exacerbated these processes by contributing to global climate change. Hazards facing North Carolina's coast can be characterized as either chronic or acute, as described below.

Acute Hazards

Acute hazards are short-duration, high intensity events which cause immediate impacts to the built environment and threaten human lives. Acute hazards facing North Carolina's beaches are generally manifested in the form of coastal storms such as hurricanes and nor'easters which result in wind damage, overwash from storm surge, rapid beach erosion, and flooding. Hurricanes and nor'easters are responsible for the greatest short-term losses and possibly the most long-term losses on a global scale (Pilkey et al., 1989). Storms play an important role in washover sedimentation, windblown sand transport, inlet formation, and infilling of estuaries. Approximately 85% of North Carolina's coast has been inundated by overwash from storms since 1938 (Inman and Dolan, 1989).

Chronic Hazards

Chronic hazards are processes that occur gradually over an extended period of time which may negatively impact human property and the built environment. Although the impacts are gradual and are not high intensity, the threat is ever-present. Chronic hazards may also occur on varying timescales. The primary chronic hazards facing North Carolina's beaches are sea level rise and associated beach erosion. The effects of sea level rise are often very difficult to predict or quantify due to the complexity of processes affecting coastal areas, the regularity of coastal changes and the relationships between sea level rise and other processes (Gutierrez et al., 2007). There is no standard method for predicting sea level rise although a number of predictive approaches have been used, including extrapolation of historical data and trends, static inundation modeling, simple geometric modeling, application of sediment dynamics/budget modeling, and probabilistic simulation based upon parameterized physical forcing variables. However, all of these approaches have their own shortcomings and associated drawbacks for certain applications (Thieler and Hammar-Klose, 1999).

While most areas of beach are eroding, some areas are actually accreting. A complicating factor with respect to planning has to do with the fact that certain areas experience net erosion during years with increased storm, wind, or wave activity, but will experience net accretion during years with minimal activity. This may make it difficult to establish long-term trends. Erosion rates can also be very localized, meaning that while a certain spot may be experiencing net erosion, another spot half a mile away may be experiencing net accretion. On the Outer Banks, physical erosion/accretion rates range from accretion of 4 ft/yr. to erosion of 26 ft/yr., with an average net landward migration of 4 ft/yr. (Inman and Dolan, 1989). In 2004 within the town of Sunset Beach alone, erosion/accretion rates ranged from net erosion of 4 ft/yr. to net accretion of 31 ft/yr. (North Carolina Division of Coastal Management, 2011b).

Coastline changes in response to sea level rise are affected by underlying geology, physical processes, sediment budget, and human activity (Gutierrez et al., 2007). According to Inman and Dolan (1989), it is estimated that average sea level rise along the east coast of the

United States is 31 cm/100 yrs. and along the Outer Banks is 35 cm/100 yrs. Assuming a continuation of sea level rise at a rate equal to that of the 20th century, it is almost certain that wave-dominated barrier islands of the mid-Atlantic region (including the Outer Banks) will continue to experience changes through erosion, overwash, and inlet formation. Under more extreme scenarios, these islands may reach a geomorphic threshold in which they become unstable. As a result, the aforementioned changes could happen at a much faster rate, such that a barrier island would decrease in width and height (Gutierrez et al., 2007).

Within North Carolina, relative sea level rise rates vary between different regions of the coast. According to the 2010 North Carolina Sea Level Rise Assessment Report, relative sea level rise varies according to latitude along the North Carolina coast, with higher rates along the northern coast and lower rates along the southern coast. This is the result of differing underlying geology and higher rates of land subsidence in the northern region (North Carolina Coastal Resources Commission, 2010).

Anthropogenic Hazards

Many of the hazards coastal communities in North Carolina face are exacerbated by anthropogenic processes. According to Pilkey et al., (1989), the activities causing the most anthropogenic land loss worldwide are coastal construction, shoreline protection, and resource extraction. Yet, there is some uncertainty regarding the impacts of humans on regional shoreline change, resulting from a lack of accurate data on the sediment budget and relative sea level conditions prior to human habitation (Pilkey et al., 1989). Highly developed coasts are considered to be modified to such a great extent that they can no longer be examined in comparison to undeveloped coasts (Brass, 2009). Development and emplacement of beach and dune stabilization structures prevent the transport of sand to the back of the island. Inlet stabilization also increases erosion and does not allow the island to migrate laterally. As the beach erodes from storms and sea level rise, the back of the island cannot accrete and the island as a whole narrows (Inman and Dolan, 1989).

The Planning Context: Options for Vulnerable Coastal Communities

Pethick and Crooks (2000) define vulnerability as the exposure of social and environmental systems to stress as a result of the impacts of environmental change, which may be some combination of natural and anthropogenic hazards. The exposure of environmental systems to these hazards is known as biophysical vulnerability. Social vulnerability considers the demographic and socioeconomic characteristics of a population that affect their ability to cope with and respond to an event or disaster.

> We see the concept of coastal vulnerability as based on human value judgments concerning risk to various elements of the natural and human environment from a variety of sources, not as an absolute. Therefore, the vulnerability of a coastal community is a function of the state we wish the community to be in, its relations with other communities, the relevant governance arrangements at the coast in question, and linkages or integration with the natural environment of the space it occupies (McFadden, 2010, 217).

To this end, numerous ways to measure vulnerability have been devised. Some focus mostly on the natural environment. For example, Pethick and Crooks' (2000) index considers vulnerability equal to return interval/relaxation time. In this case, relaxation time is the amount of time required for a natural system to recover after a disturbance and return interval is the average amount of time between disturbances of similar magnitude. Intuitively, the higher the score, the more resilient (or less vulnerable) the system.

In a national assessment of coastal vulnerability, Thieler and Hammar-Klose (1999) devised a coastal vulnerability index (CVI) highlighting the regions expected to experience the greatest impacts from sea level rise. The index ranks six physical variables (geomorphology, coastal slope, rate of relative sea level rise, shoreline erosion/accretion rate, mean tide range, and mean wave height) on a scale from 1 to 5, with 1 indicating very low impact and 5 indicating very high impact. Each score represents a range of values for each variable (for example a score of 1 represents a coastal slope of >.2% or a relative sea level rise of <1.8mm/yr.). The CVI was calculated by taking the square root of the product of the ranked variables divided by the total number of variables (Thieler and Hammar-Klose, 1999). Figure 2.1 shows the CVI for the section of the east coast of the United States from North Carolina to Georgia, as calculated by Thieler and Hammar-Klose. Focusing on North Carolina, it is evident that relative sea level rise is highest along the northern part of the coast (north of Cape Lookout). Even though this map is somewhat dated, it is consistent with the findings of North Carolina Coastal Resources Commission (CRC) (2010).

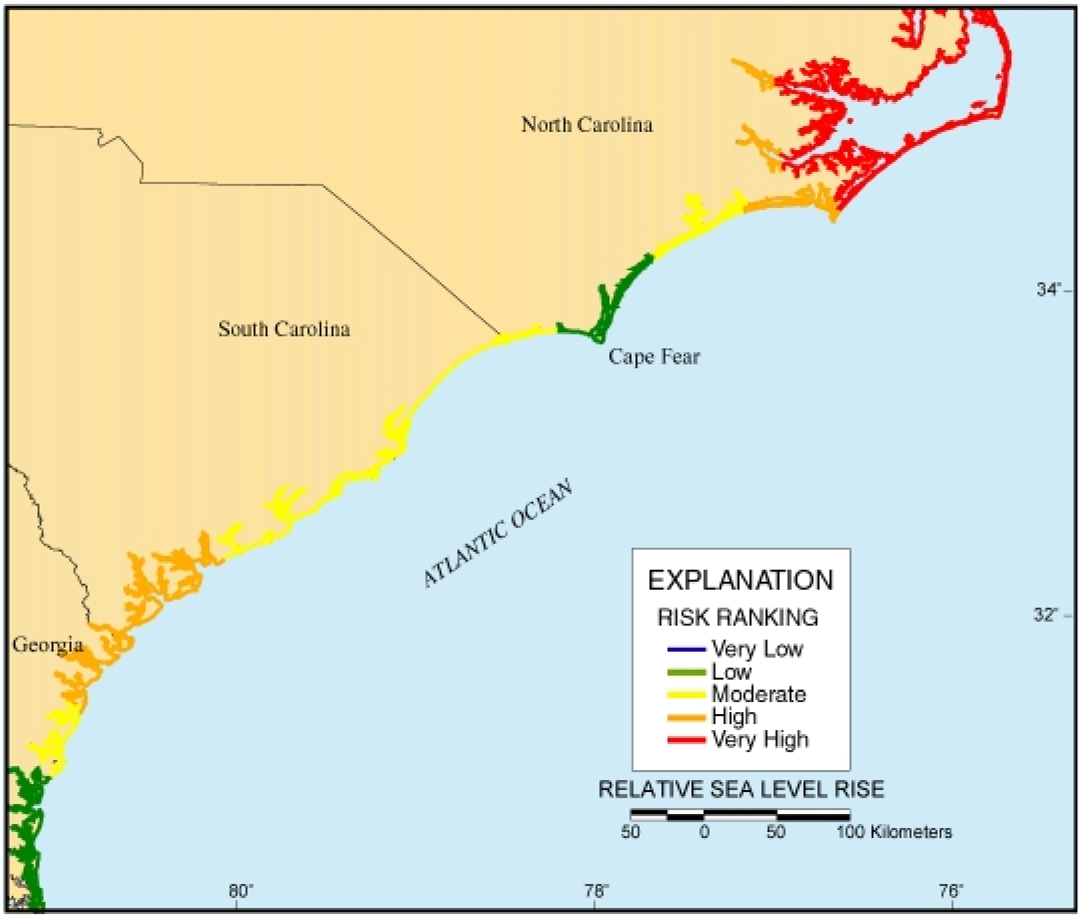

Figure 2.1: CVI for Southeast U.S. Coast (Thieler and Hammar-Klose, 1999)

A more comprehensive vulnerability index provided by Boruff et al., (2005) adapts the same index used by Thieler and Hammar-Klose (1999) to measure CVI and combines it with a measure of social vulnerability. Analysis of the relative contributions of social and physical characteristics led to their conclusion that physical characteristics are the greater overall indicator of vulnerability (Boruff et al., 2005). Building on this work, McLaughlin and Cooper (2010) devised their own vulnerability index upon which the scoring system for the index used in the analysis presented here is loosely based. Their work is discussed in greater detail in Chapter 3.

Given the fact that vulnerability is partially, though not exclusively, defined by the physical environment, the major challenge for coastal planners in North Carolina is the lack of viable methods for dealing with the hazards that are presently faced. Traditional planning has generally focused on mitigation, aimed at preventing or lessening the impacts of hazards, which tend to be temporary, expensive, and unsustainable. Furthermore, attempts to stabilize dynamic systems and mitigate physical vulnerability along the coast often exacerbate the problems they are trying to fix and create new human-induced hazards.

Mitigation Strategies

Traditional mitigation in coastal areas generally involves attempts to prevent or lessen the impacts of natural hazards on human establishments. Historical efforts to mitigate beach erosion and prevent inlet migration have included hard stabilization, soft stabilization, and relocation. Hard stabilization involves engineered structures such as seawalls, jetties, breakwaters and groins (Pilkey et al., 1989). Although these structures temporarily prevent flooding and erosion, they disrupt normal landward migration by blocking the movement of sand towards the interior of the island and into the estuary. Hard structures also disrupt longshore currents and inlet migration by trapping sand up-drift of the structure, resulting in water that is devoid of sediment which will erode down-drift beaches much faster than under natural conditions (Pilkey et al., 1998). A likely outcome of this approach is a highly engineered shoreline with no beach (Beatley et al., 2002). Although there has been some pressure to change this, North Carolina currently prohibits hard stabilization along its open ocean shoreline (Pilkey et al., 1989). However, these structures are still present along the inlets and inner estuaries. In addition, approximately 6% of the open ocean shoreline contains hard stabilization structures built prior to when they were outlawed (Pilkey et al., 1998).

Many North Carolina beachfront communities have turned to soft stabilization projects such as sandbags, artificial dunes, and beach nourishment. Sandbags and artificial dunes can have the same negative impacts as hard stabilization structures because they prevent the landward migration of sand through overwash. In addition, they are only effective for a limited amount of time. Beach nourishment, which involves dredging sand from nearby inlets or offshore locations and pumping it onto an eroding beach, has been the option of choice along many east coast beaches, including North Carolina. However, these projects are very expensive and generally only last a few months to a few years (Beatley et al., 2002). In addition, since sand is typically added to the upper portion of the beach, the new sand will generally erode at a faster rate than the natural beach due to the increased slope of the nourished beach (Pilkey et al., 1998). One strong hurricane or coastal storm may completely remove a replenished beach. Also, because the sand used to replenish the beach is often taken from nearby inlet channels, erosion is increased as the channels migrate faster. Although a temporary fix, beach nourishment is not a viable long-term solution.

Adaptive Strategies

As indicated by losses from recent coastal disasters, it is clear that traditional mitigation and resistance alone are not enough to protect communities from disasters. Concerns about climate change have emphasized the need to develop flexible and adaptive coastal protection measures as rising sea level amplifies the impacts of future hazard events (Ewing et al., 2010). Adaptive strategies involve taking actions to protect human establishments while allowing natural changes to continue to occur normally, and thus are very important for building and maintaining resilient communities. Adaptive measures for coastal areas can generally be classified as retreat, accommodation or protection (Ewing et al., 2010).

Every disaster provides numerous reasons to avoid development in high hazard areas, or to redevelop near the coast in ways that will reduce the consequences of subsequent events. These include 1) building more resistant structures to withstand anticipated storm forces, 2) relocating structures and infrastructure out of the most vulnerable areas, 3) providing better monitoring and warning systems so people can evacuate to safer areas, and 4) providing better education so that people in high-risk areas are fully aware of the risks they face (Ewing et al., 2010). Adaptive planning solutions for human-built structures include relocation, elevation, setting them back farther (greater physical distance from the ocean), or simply letting them be overtaken by the ocean. Relocating coastal structures is perhaps the best way to preserve beaches and property (Pilkey et al., 1989). This has been known for some time, but relocation is rarely undertaken for political, economic, and social reasons. Relocation is expensive, difficult, very labor intensive and inconvenient for the property owners, and often infeasible due to lack of resources. It also must be repeated periodically as the beach continues to erode. As an alternative, in keeping with the regulations of the National Flood Insurance Program (NFIP), many coastal communities now require homes to be elevated above a base flood elevation (BFE) related to anticipated storm surge heights and wave velocities. Another adaptive strategy is to require further setbacks from the water. This allows the beach to erode or migrate for a considerable time before causing any serious threats to property. It is a North Carolina state law that all oceanfront communities include an ocean erodible setback of 30 x the annual erosion rate from the first line of stable vegetation for small structures and 60 x the annual erosion rate for large structures (Town of Sunset Beach Planning Board, 2007). When no preventive measures are taken, existing structures are generally overtaken by the water and rebuilt farther back, as is happening in many places along the Outer Banks, such as Nags Head and Kitty Hawk (Pilkey et al., 1998). While these options are far from perfect, as they all have their own associated drawbacks, they are more sustainable than traditional beach stabilization because they do not alter the natural evolution and migration of the beach.

Distributing Risks Through Insurance

A different type of management strategy employed in highly vulnerable areas is to distribute costs and risks primarily through insurance. The NFIP provides federally subsidized flood insurance to property owners in flood-prone communities (Beatley et al., 2002). Developed as part of the NFIP, the Community Rating System (CRS) was designed to encourage communities to implement building codes and floodplain regulations that exceed minimum NFIP requirements so that homeowners can get reduced insurance rates (Kunreuther and White, 1994). All three study communities in this analysis participate in the CRS program. In addition, states often provide insurance for high-risk properties at below market rates through insurance pools that “offer subsidized coverage to high-risk properties and rely on assessments imposed on all insurance contracts written in the state as the main means of covering the losses incurred during a major hurricane” (Sutter, 2007, 1).

In 1969, North Carolina developed the Beach Plan, which established an association that functions as an insurance company and makes insurance available to those who are not able to buy it through standard insurance markets. The association is independent of any single company, but all insurance companies present in North Carolina must participate in funding the plan and sharing losses and profits. The Beach Plan thus functions as a safety net, allowing almost anybody with property along the coast to purchase insurance, assuming they meet required building standards. It has been amended and modified on numerous occasions since its initial inception (North Carolina Insurance Underwriting Association, 2009).

Federal or state subsidized insurance has advantages and drawbacks. More people purchasing insurance means that homes will be built to specified standards, which may include better building materials, hurricane proofing, and elevated homes. However, subsidized insurance rates lead to inefficient growth in coastal regions by encouraging development and creating an environment in which more people put themselves at risk due to a false sense of security. Insurance pools also complicate hurricane damage mitigation and can lead to cross subsidization of insurance in which poorer property owners end up subsidizing wealthier property owners (Sutter, 2007).

Resilience, Sustainability, and Coastal Planning

Resilience can be viewed as being subsumed under the umbrella concept of sustainability (or sustainable development). The most widely accepted general definition of sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987, 54). The concept of sustainability addresses both needs and the limitations by society, technology, or the environment to meet those needs. As resource and financial limitations of resistance-only approaches are being realized, sustainability is now a consideration in many disaster risk management efforts (Ewing et al., 2010). A major moral principle of sustainable development is intergenerational equity, ensuring that present and future human needs will continue to be satisfied within the limits of the natural environment and in a manner that can cope with the certainty of change (Handmer and Dovers, 2009). Thus, planning for this change requires the ability to cope with and adapt to hazards, and the creation of decision-making and management approaches with the ability to operate in the face of uncertainty (i.e. resilience) (Handmer and Dovers, 2009).

Resilience can be defined in terms of the ability of any system, natural or human, to cope with, respond to, and recover from pervasive risk and uncertainty. Resilience requires recognition of dynamic interdependency in managing both natural environments and human societies, especially when the concern is with interactions between human and natural systems (Handmer and Dovers, 2009). As opposed to typical management approaches, which emphasize resistance in trying to maintain stability, resilience stresses the creation of flexibility and adaptability of the system. This shift in perspective would not require a precise ability to predict the future, but rather a qualitative ability to create systems that can absorb and accommodate a multitude of uncertain future events and scenarios (Ewing et al., 2010).

In general, resilient communities should be able to adapt to changing conditions without losing function, recover from random events in unexpected ways, rely upon local and regional resources to recover from hazard events, and learn from prior experience to reduce future vulnerability and risk. In the face of coastal disasters, resilient communities should exhibit the following outcomes measures for the built environment: 1) the ability to facilitate the survival of its inhabitants, 2) the ability of people to remain in the community or return quickly after an event, 3) infrastructure remaining functional or quickly repaired after an event, and 4) the maintenance or enhancement of community amenity values such as ecosystems and recreational areas. It is to be expected that the communities with the best planning will be able meet these criteria decades into the future. For coastal communities, resilience should result from a combination of good land use planning, non-disruptive engineering and resistance, redundancy of critical systems, and enhancement of natural buffers (Ewing et al., 2010).

As previously mentioned, resilience and sustainability are closely linked. In fact, Handmer and Dovers (2009) identify different kinds and levels of resilience in human institutional arrangements in the face of uncertainty and change as being one of the most serious obstacles towards achieving a sustainable society. Sustainable and resilient communities should be able to endure extreme geophysical events and recover rapidly from disasters. Thus, it is important that resilience be considered as a guiding principle for effective and sustainable hazard planning in order to lessen the impacts of hazard events and to aid in the recovery process. It is important that this comprehensive planning considers 1) non-disruptive mitigation strategies to reduce risk, 2) post-disaster plans to promote short and long-term recovery, and 3) structural and cognitive factors which influence planning effectiveness. Tobin (1999) suggests that in order to be resilient, communities' plans must include lowered levels of risk to all inhabitants through reduced exposure, reduced levels of vulnerability, a high level of support from responsible agencies and policymakers, incorporation of partnerships and cooperation at different government levels, and strengthened networks for independent and interdependent segments of society. In addition, planning for resilience must be continuous, implemented at the appropriate scale, and requires a complete understanding of the interactions between different components of the system (Tobin, 1999).

Past experience has shown that current hazard response and mitigation measures are ineffective and only perpetuate the disaster damage cycle rather than addressing its root causes (Tobin, 1999). When we manage for stability, we are attempting to maintain communities that exist in an artificial environment and cannot be sustained in the face of environmental hazards and variability. On the other hand, hazards planning attempts to work with the natural environment to produce resilient and sustainable communities. According to Tobin (1999), while some efforts to minimize the effects of disasters are essential, "living with hazards" is the only realistic option. In general, truly resilient and sustainable communities are not feasible in the current socio-political-economic environment. Thus, communities must develop comprehensive and continuous planning strategies which include all potential hazards and their associated effects, including socio-economic and political impacts (Tobin, 1999). Hazard mitigation plans, in addition to land use plans, can serve a critical function in encouraging intergovernmental coordination, enhancing local plan compliance with broader state goals, and building resilience within communities to resist and recover rapidly from the impacts of disasters (Berke et al., 2010).

Setting the Scene: Coastal Planning in North Carolina

All coastal counties in North Carolina must adhere to the Coastal Area Management Act (CAMA), one of the most comprehensive state laws in the country with regard to coastal management. Local land use planning under CAMA is administered by the Coastal Resources Commission (CRC) and is required for the entire coastal region with the main purpose of balancing economic goals and environmental concerns. Although all coastal counties must prepare CAMA land use plans, the CRC is prohibited from requiring municipalities to implement them outside specific areas of environmental concern (Norton, 2005). However, many communities have chosen to implement their own CAMA land use plans because they provide good guidelines for planners. As of the mid-1990s, all 20 coastal counties and 72 municipalities had or were preparing CAMA land use plans (Norton, 2005).

Norton (2005) conducted an analysis of planning effectiveness in the mid-1990s for 36 counties and municipalities in North Carolina, including 10 beachfront communities. The objectives of this research were to determine how well local plans (county and community) addressed growth management and to what extent they struck a balance between economic development and environmental protection. Plans were considered to be high quality if they demonstrated a strong factual basis, provided clearly articulated goals, included a land suitability analysis that distinctly identified natural and built environment opportunities and constraints on development, facilitated meaningful ongoing public participation, and incorporated ongoing monitoring and implementation responsibilities, among other factors (Norton, 2005). Norton was particularly concerned with local elected officials' commitment to planning, overall plan quality, and plan use/implementation, the latter two being most pertinent to this research.

Norton's (2005) findings suggest that as of the mid-1990s, local planning in North Carolina had failed to offer meaningful policy guidance for local land use decision making, focusing primarily on economic development while only minimally addressing environmental protection. While procedurally strong in addressing a broad range of issues they were required to cover, they were substantively weak, providing minimal significant growth management strategies. According to Norton (2005), North Carolina recently amended its local planning mandate under CAMA to refine state/local programs in order to yield more local planning that does a better job of addressing regional concerns, specifically with regard to resource protection. One objective of this analysis is to review the progress of several of these local plans, with more emphasis on hazards planning.

Summary of Literature

The above literature has provided a solid basis for this analysis by characterizing the hazards specific to the North Carolina coast, offering several examples of vulnerability indices and planning approaches that can be applied to this region, and emphasizing the importance of adaptive planning in achieving community resilience. This section is concluded by addressing a previous analysis of planning effectiveness in North Carolina coastal communities, suggesting that these plans are substantively weak and providing justification for further analysis through this study.

CHAPTER 3: RESEARCH METHODS

Study Areas

The complexity of North Carolina's coastal environments and communities provides an ideal setting for this research. The open-ocean shoreline is approximately 325 miles long and consists almost entirely of barrier islands (Riggs et al., 2008). The barrier islands of North Carolina, if left undisturbed, develop a dynamic equilibrium in which they migrate landward due to sea level rise and overwash from strong storms (Hosier and Cleary, 1977). Three major prominences, Cape Hatteras, Cape Lookout and Cape Fear, divide the coast into four separate compartments, resulting in beaches with varying orientations towards the ocean. This is an important indicator of physical vulnerability, as orientation is a determining factor in wave and current intensity and exposure to storms (Riggs et al., 2008). Thus, the beachfront communities along North Carolina's coast vary in terms of their physical vulnerability.

The coast of North Carolina consists of two distinct provinces which vary significantly in terms of their underlying geology and slope. The southern coastal province, which stretches from the South Carolina border north to Cape Lookout, is underlain by rock that is relatively old and has a slope of 3 ft/mi on average (Pilkey et al., 1998). This is a very modest slope by most standards, but much steeper than the northern coastal province, which has an average slope of only 0.2 ft/mi and is underlain by younger rocks and large quantities of unconsolidated sediment (Pilkey et al., 1998). As a result of this underlying geology, the southern province generally consists of short, wide barrier islands separated from the mainland by narrow estuaries which have a high salt content due to the presence of many inlets. In contrast, the northern coastal province (i.e. The Outer Banks) consists of long, narrow barrier islands which are separated from the mainland by wide estuaries which have a lower salt content due to fewer inlets and more source rivers with higher discharges and sediment loads (Pilkey et al., 1998). The northern coastal province of North Carolina is comprised of wave-dominated barrier islands with a low tidal range while the southern coastal province is comprised primarily of mixed-energy barrier islands with a higher tidal range (Brass, 2009).

Considering North Carolina's highly variable geography, three communities (Sunset Beach, Topsail Beach and Kitty Hawk) were chosen as study sites, after visiting roughly a dozen communities along different parts of the North Carolina coast. It was determined that two communities would be insufficient to draw any conclusive results while more than three would be beyond the scope and duration of this research. The three communities were chosen for several reasons: 1) they each represent a different part of the coast with varying orientations, 2) each faces several common hazards, but to varying degrees, and 3) based upon observation from preliminary visits, they all had different planning regulations for addressing these issues. As the ensuing analysis will show, this was very much the case. (See Figure 3.1).

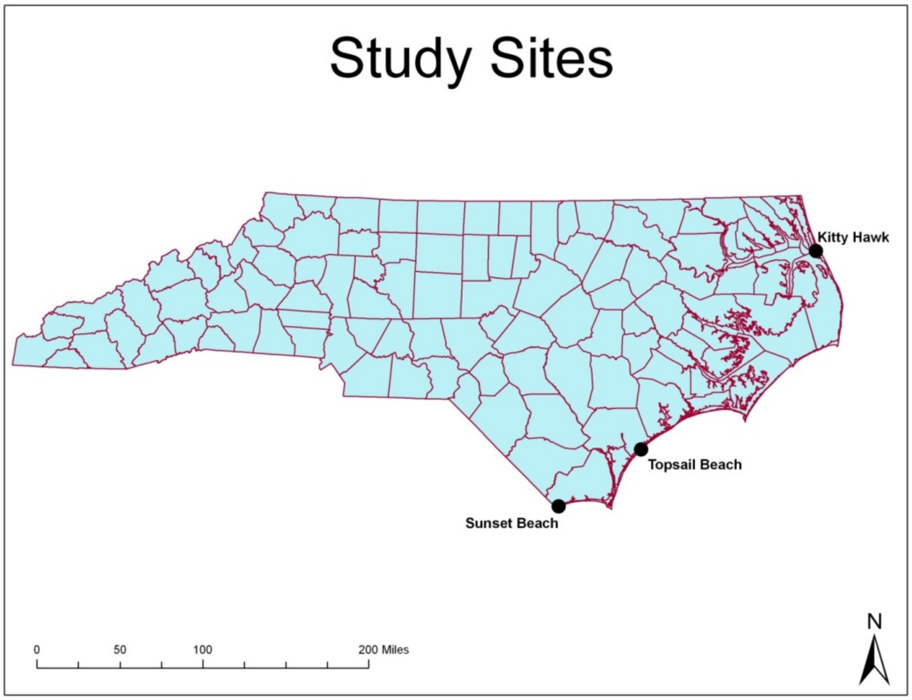

Figure 3.1: Location of study sites on the North Carolina coast

Sunset Beach is the southernmost community on the coast of North Carolina. It is located on the southern coastal province, the Long Bay compartment, and has south-facing beaches. The town is located on both the barrier island and mainland side of the estuary. Approximately 47% of the town is in a high flood hazard zone, including about 60% on the barrier island side (Town of Sunset Beach Planning Board, 2007). As of 2007, the island had a modest long-term erosion rate of 2 ft/yr., although the beach has actually accreted during years with minimal storm activity (Pilkey et al., 1989). However, its southward orientation makes it exceptionally vulnerable to winds from hurricanes tracking northward along the east coast of the United States (Figure 3.2).

Figure 3.2: Photo of Sunset Beach, NC from October, 2009 showing large ocean-erodible setbacks (photo courtesy of Dr. Burrell Montz).

Topsail Beach is located in the southern coastal province on the Onslow Bay compartment and has southeast-facing beaches. Topsail Beach encompasses the southern part of a barrier island (Topsail Island) which also includes the towns of Surf City and North Topsail Beach. The entire community is on the barrier island with no mainland areas. Topsail Island as a whole is extremely prone to erosion because of its flat topography, lack of natural sand dunes, and offshore calcareous rock ridges which significantly limit natural beach replenishment (Ford et al., 2009). The island has relatively dense development (more dense than Sunset Beach), which has disrupted sand transport and caused the island to narrow. In many spots, homes are being encroached upon by the ocean (Figure 3.3).

Figure 3.3: Photo of Topsail Island, NC from October, 2009 showing minimal setbacks from the beach (photo courtesy of Dr. Burrell Montz).

Kitty Hawk is located in the northern coastal province on the Hatteras compartment and has east-northeast facing beaches. It is entirely on the barrier side of the estuaries and is farther from the mainland than the other two communities. Kitty Hawk's orientation makes it comparatively less vulnerable to hurricanes which generally move in from the southwest, but more vulnerable to nor'easters which feature winds blowing directly from the ocean side. Erosion rates are very high, there are no natural dunes, and many homes are being encroached upon by the rising waters (Figure 3.4). Observation has shown that this area was hit very hard by a series of nor'easters during the winter of 2009/10 as evidenced by overwash sand that was present up to several blocks inland in March, 2010. Many homes have had sand bulldozed against them on the ocean side to provide temporary protection.

Figure 3.4: Photo taken in March, 2010 of homes being threatened by erosion from recent storms in Kitty Hawk, NC.

Overview of Approach

The most resilient communities should be able to effectively address the four outcomes measures from Chapter 2 through adaptive planning approaches that reduce vulnerability. Thus, the research methods used in this analysis must 1) determine and compare the vulnerabilities of each community to both acute and chronic hazards, 2) compare how each community plans for common coastal hazards, and 3) determine and compare the overall resilience of each community. The best way to measure these variables is through the development of a resilience index which combines some measure of vulnerability with a critical analysis of planning effectiveness in each community. As Figure 3.5 shows, six variables were evaluated to produce a vulnerability index for each community, which were then combined with plan coding scores to produce an overall measure of environmental resilience. This process is discussed in greater detail later on in this section.

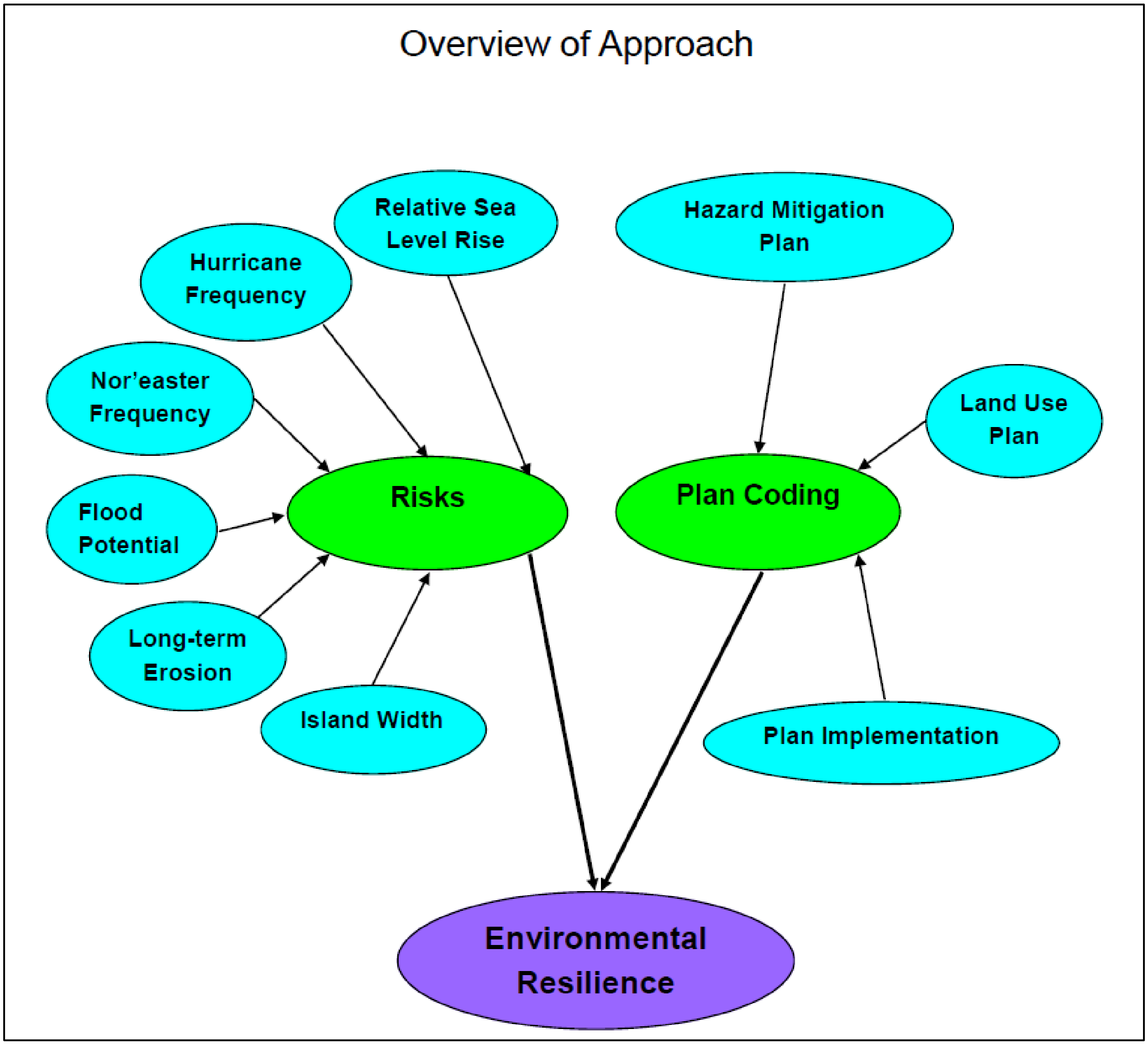

Figure 3.5: Overview of Approach

Data Collection

Physical vulnerability data for this analysis include the following hazards: 1) short-term and long-term erosion rates, 2) relative sea level rise rates, 3) historical hurricane and major hurricane strikes, 4) historical nor'easter strikes, 5) flood zones and storm surge inundation zones, and 6) island/community width. Short and long-term erosion rate data were gathered from the North Carolina Division of Coastal Management (NC DCM) website (2011). Short-term rates are from 2004 and long-term rates are a 50-year average calculated in 1998. Relative sea level rise rates were gathered from the North Carolina Sea level Rise Assessment Report (North Carolina Coastal Resources Commission, 2010) and Thieler and Hammar-Klose (1999). There are no sea level rise data for the specific communities in this analysis, so the values have been interpolated between locations with known sea level rise rates and significant periods of record. The locations of historical hurricane and major hurricane strikes were gathered from the National Oceanic and Atmospheric Adminstration's (NOAA) Historical Hurricane Tracks website (2011). Historical nor'easter tracks were gathered from the National Aeronautics and Space Administration's (NASA) Atlas of Extratropical Storm Tracks (2011). Flood zones and storm surge inundation zones were obtained from the North Carolina Floodplain Mapping Information System (2011), community CAMA land use plans, and community and county websites. Data relating to island/community widths were obtained from NC DCM, NC OneMap, and community land use plans. Data on planning were acquired from community land use plans and personal correspondence with planners from the communities being analyzed.

Study Design

Part I: Physical Vulnerability Index

For the purposes of this research, a resilience index was devised that takes into account both vulnerability and planning approaches for each community. The first part of the resilience index determines the vulnerability of each community to a series of environmental hazards. The purpose of a vulnerability index is to simplify a number of complex and interacting variables to a form that is more easily understood and can be used as a management tool (McLaughlin and Cooper, 2010).

According to McLaughlin and Cooper (2010), it is more effective to use an index with only a few variables as opposed to many, since several variables may be correlated in some fashion. The coastal hazards determined to be most significant for North Carolina were 1) erosion, 2) relative sea level rise, 3) hurricane frequency/intensity, 4) nor'easter frequency/intensity, and 5) flooding. The first two variables are chronic hazards, while variables 3 through 5 are acute hazards. An additional variable, island/community width, is included as part of the index since more land area at a greater distance from the water should provide greater protection from hazards. In a fashion similar to Thieler and Hammar-Klose (1999) and McLaughlin and Cooper (2010), each variable was then ranked on a scale from 1-5, 1 being extremely low vulnerability and 5 being extremely high vulnerability. The ranking of variables is somewhat subjective and the criteria for ranking them must be clearly defined (McLaughlin and Cooper, 2010). Thus, each ranking (in 0.5 point increments) represents a score for which several conditions must all be met. For example, the erosion vulnerability score includes the following conditions: 1) average erosion rate for the community, and 2) percent of the community eroding at different rates. In order to receive a score of 1 (extremely low vulnerability), the entire community must be accreting or not eroding at all. A score of 2 (low vulnerability) means that the following conditions must be met: 1) the average erosion rate must be ≤0 ft/yr., 2) <10% of the community can be eroding at 2.01-5.00ft/yr., and 3) no part of the community can be eroding >5.00ft/yr. If all of those conditions are not met, the community can only receive a score of 2.5 or higher. The specific conditions for each of the other hazards are defined in Appendix A.

Both long-term and short-term erosion rates were gathered for this analysis. Short-term erosion rates are from 2004 while long-term rates reflect approximately 50-year averages ending in 1998. The long-term and short term values have the potential to be significantly different. Short-term values are generally available as the erosion rates from a given year. If the short-term value was derived during a year with minimal storm activity, it is likely that many beach locations will have accreted. This was the case for the majority of Sunset Beach and Topsail Beach. Long-term rates, on the other hand, are taken as an average over 50 years, and hence can compensate for major events. Thus, years with minimal storm activity when the beach accreted slightly are averaged with years with significant storm activity when major erosion took place. In addition, NC DCM (2011) implements a regulatory minimum of 2 ft/yr even if the beach is eroding at a lower rate. Thus, according to the CAMA setback minimum of 30 x the annual erosion rate, 60 feet is the minimum setback for all structures along the open ocean shoreline. This analysis uses the NC DCM long-term minimum of 2 ft/yr, even if the actual average is less. The alternative would have been to use the short-term rates from 2004. However, as previously mentioned the short-term rates may reflect inactive years and give the false assumption that erosion is not an issue if the beaches accreted. As a result, the decision was made that it was better to overestimate the erosion rates and be over-prepared than to underestimate the erosion rates and be under-prepared.

Short-term erosion data were mapped for the entire North Carolina coastline using ArcGIS, and then queried for each of the three communities (Figures 3.6a, 3.7a and 3.8a). Long-term rates were obtained using 1998 setback maps from NC DCM (Figures 3.6b, 3.7b and 3.8b). For Sunset Beach, the 2004 erosion rate map shows the majority of the beach to be accreting, some areas up to 31 feet (Figure 3.6a). However, the NC DCM setback maps use the minimum long-term erosion rate of 2 ft/yr. for the entire community (Figure 3.6b). Similarly, the 2004 erosion rate map for Topsail Beach shows that the majority of the community accreted 0-5 feet (Figure 3.7a), although the setback maps are once again based on a long-term average of 2 ft/yr. net erosion. For Kitty Hawk, the 2004 rate and long-term rate are similar, with the 2004 map showing most of the community to be eroding either 0-2 ft/yr. or 2-5 ft/yr (Figure 3.8a). The NC DCM setback maps for Kitty Hawk show long-term erosion rates of 2-4 ft/yr (Figure 3.8b). Summary statistics were run for each community to determine 1) the maximum and minimum erosion rates, 2) the average erosion rate, and 3) the percentages of beach within each community eroding at different rates. Erosion vulnerability was then ranked on a scale from 1-5 according to a combination of these statistics (refer to Appendix A for all variables measured and explanation of scoring).

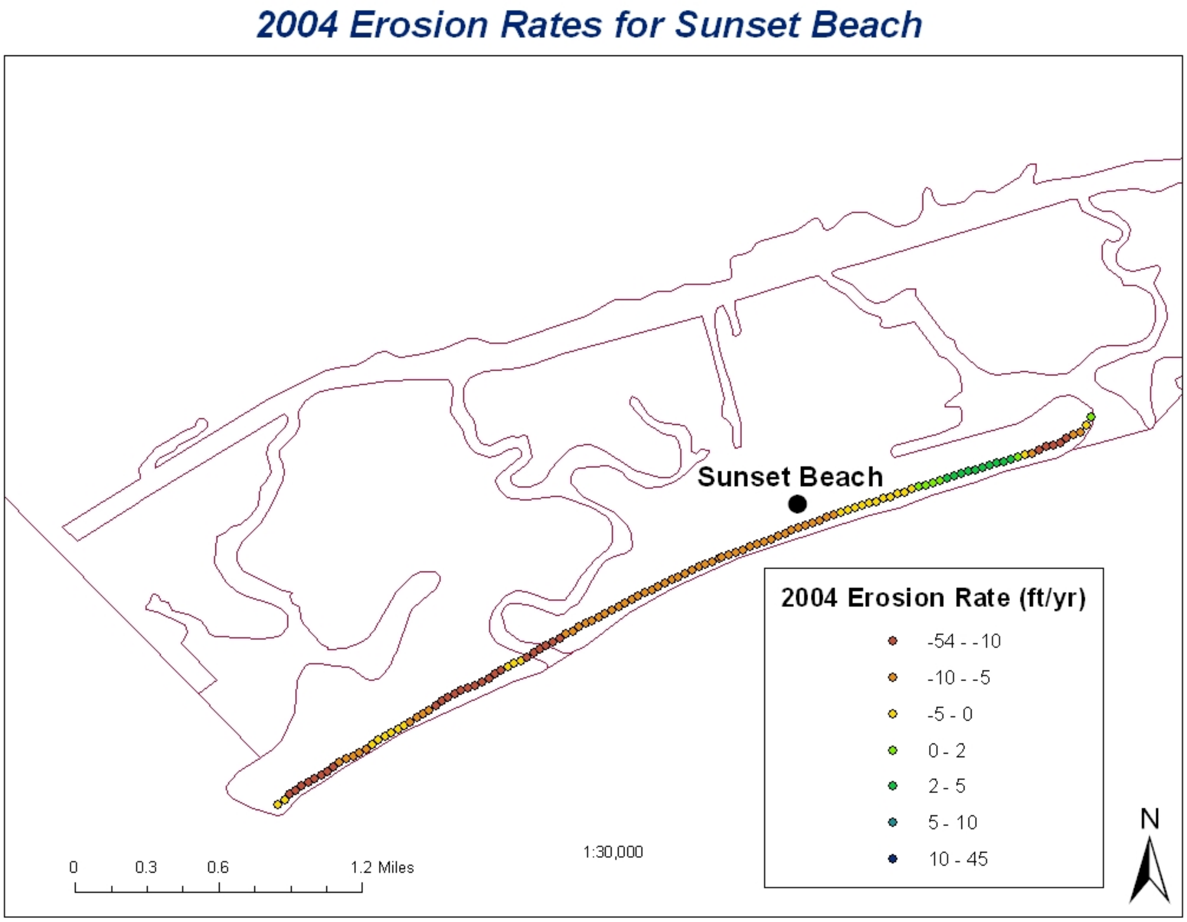

Figure 3.6a: 2004 erosion rates for Sunset Beach. (Note: negative numbers=net accretion) (NC DCM, 2011).

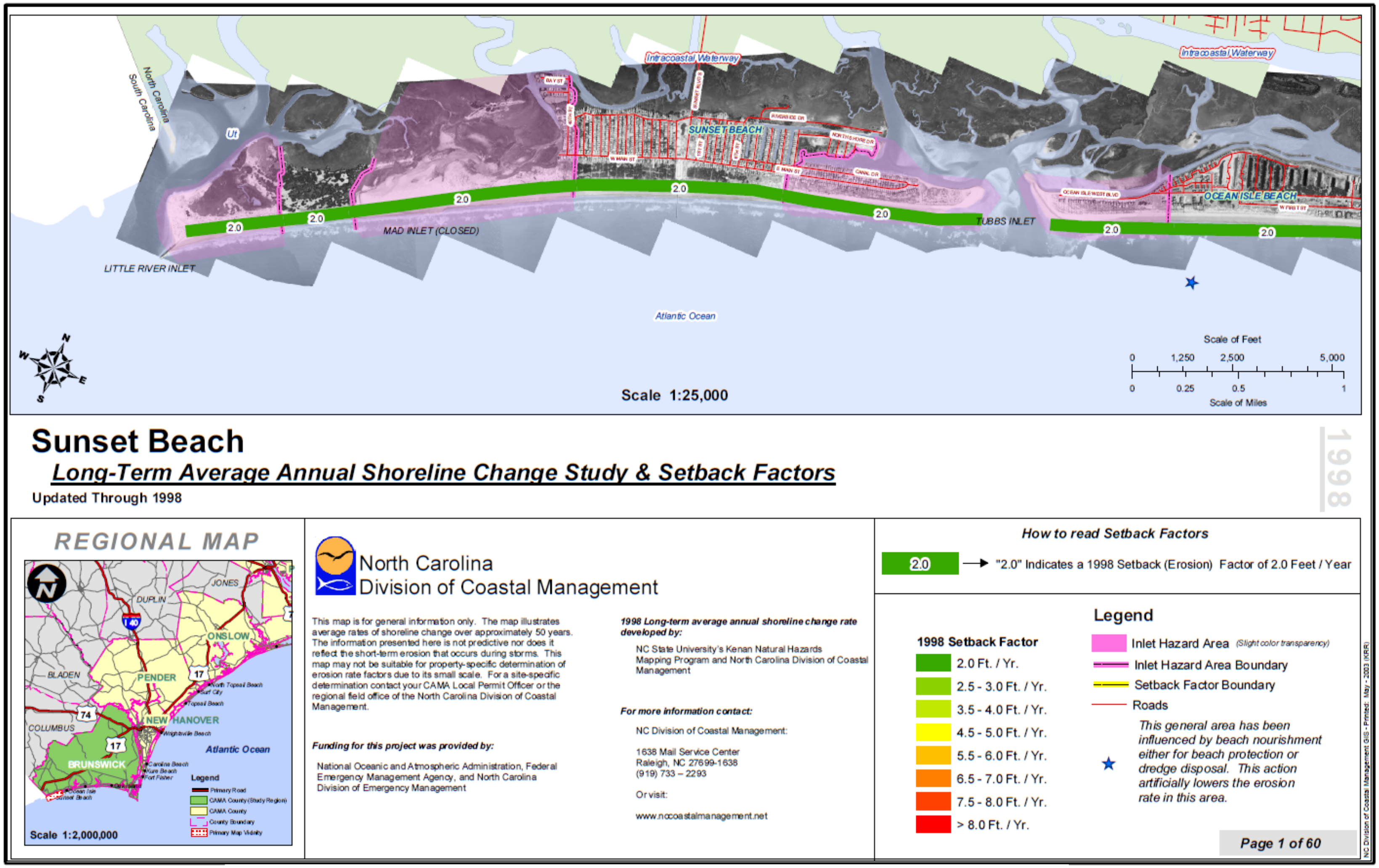

Figure 3.6b: Long-term erosion rates for Sunset Beach (NC DCM, 2011).

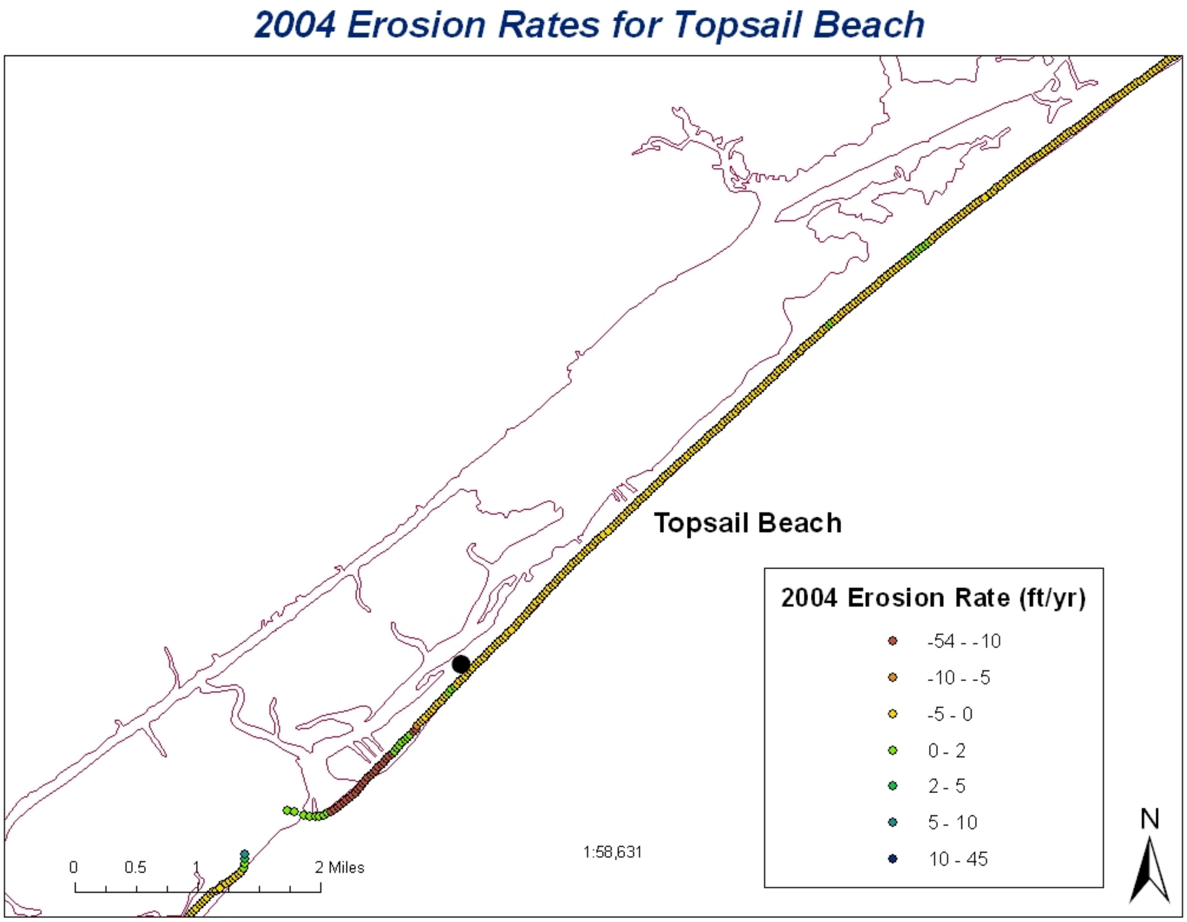

Figure 3.7a: 2004 erosion rates for Topsail Beach. (Note: negative numbers=net accretion) (NC DCM, 2011).

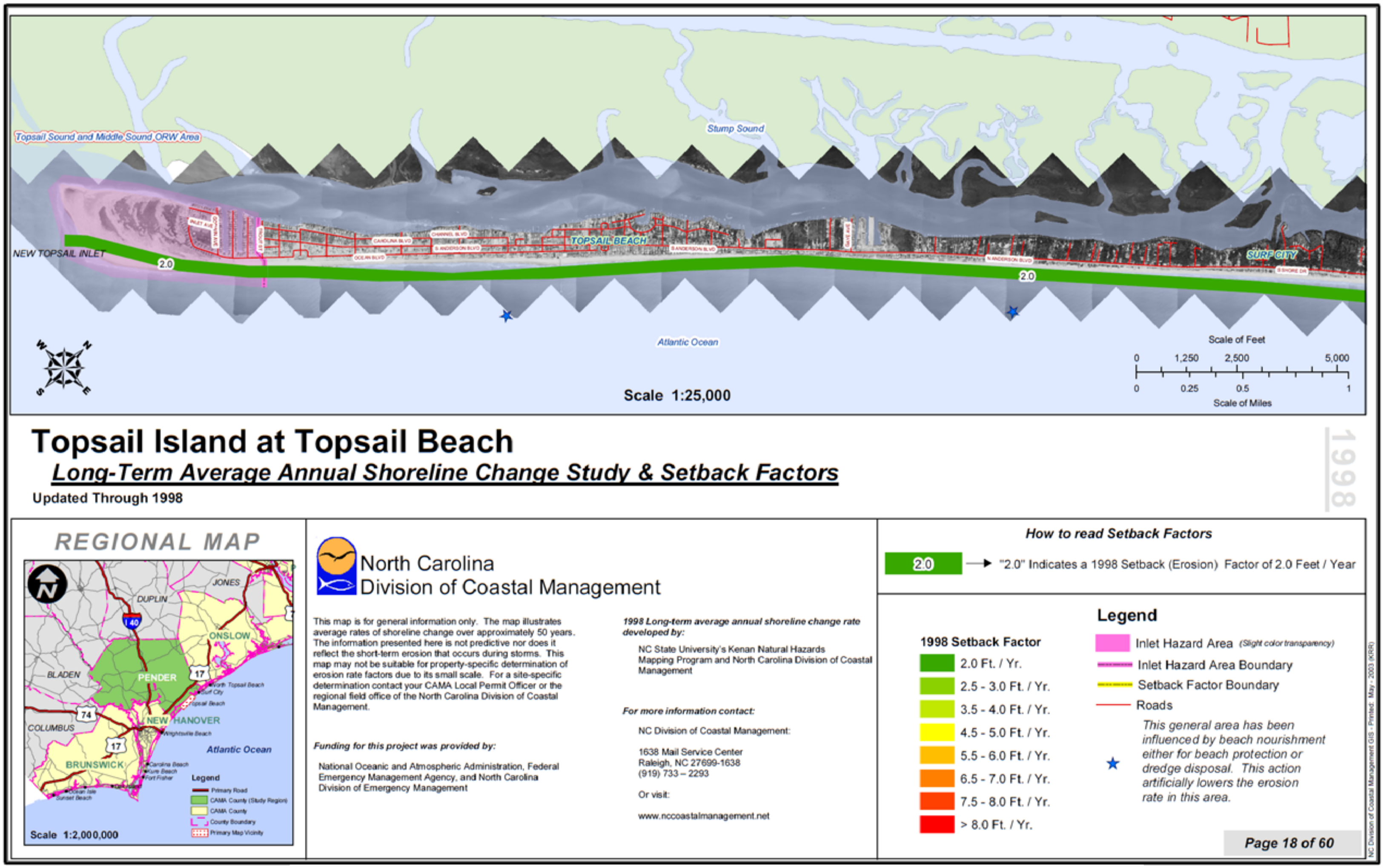

Figure 3.7b: Long-term erosion rates for Topsail Beach (NC DCM, 2011).

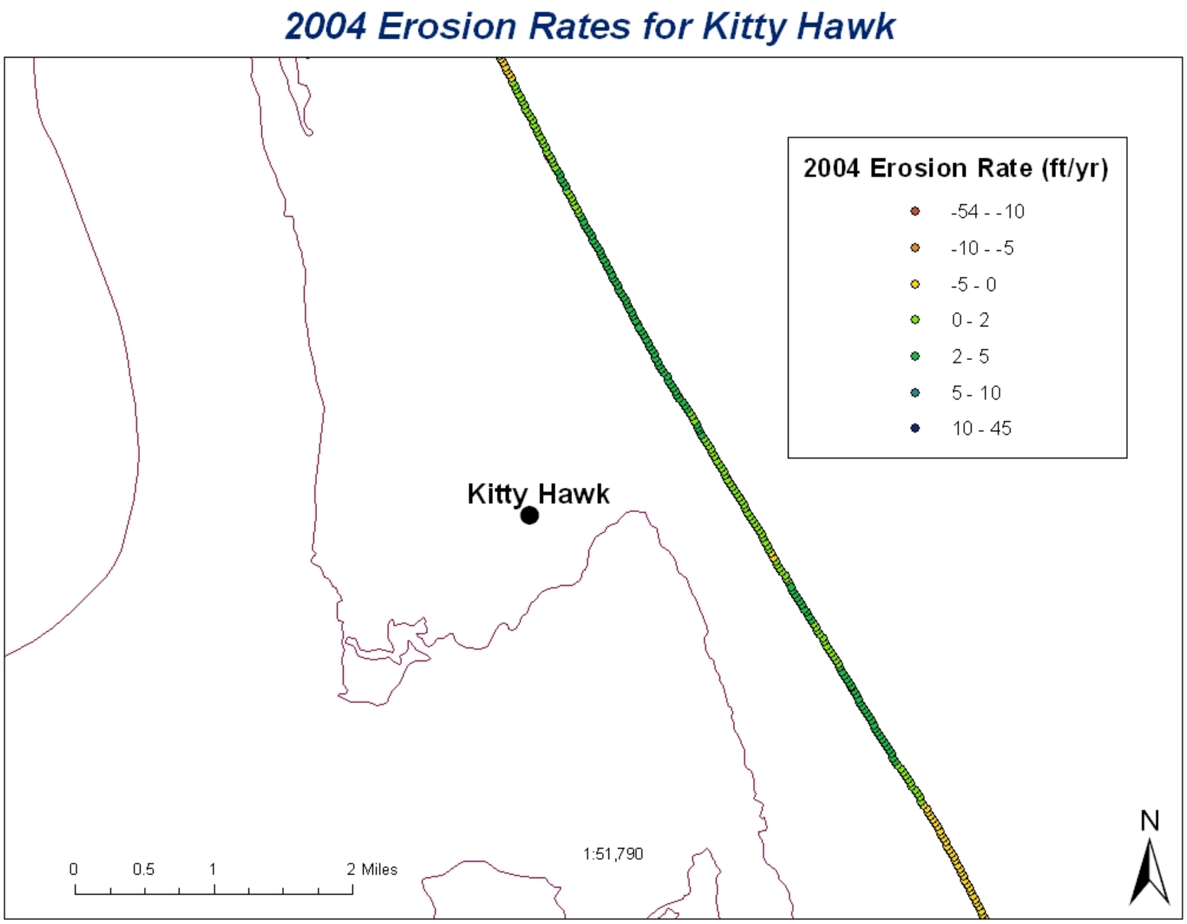

Figure 3.8a: 2004 erosion rates for Kitty Hawk. (Note: negative numbers=net accretion) (NC DCM, 2011).

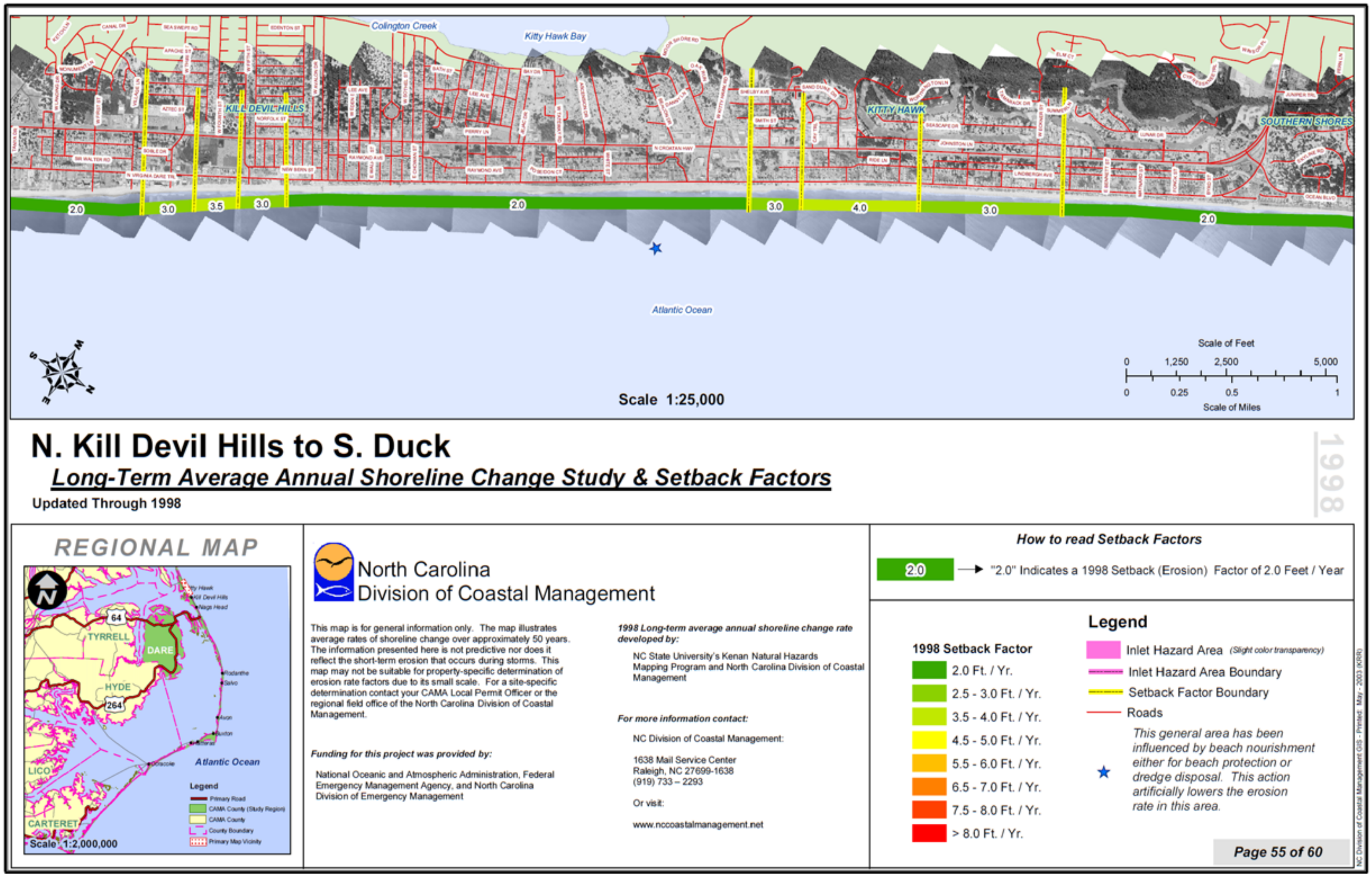

Figure 3.8b: Long-term erosion rates for Kitty Hawk (NC DCM, 2011).

Sea level rise data were obtained from the North Carolina Sea level Rise Assessment Report (North Carolina Coastal Resources Commission, 2010) for various communities along the North Carolina coast. Initial values were given in mm/yr. and converted to ft/yr. Since no sea level rise data exist for the three study communities, values were interpolated between the closest two communities (one north, one south) for which data were available. The difference was then calculated as a percentage of the distance between the study community and the two communities with data. For example, if the community to the north is 20 miles away from the study community with an average annual sea level rise of 0.004 ft/yr. and the community to the south is 10 miles away from the study community with an average annual sea level rise of 0.001 ft/yr., the study community would be interpolated to 0.002 ft/yr. If several communities nearby had available data which seemed inconsistent (for example, if two communities 10 miles away from each other had relative sea level rise rates that differed substantially), the value for the community with a longer period of record was used. Kitty Hawk was interpolated between Duck and Cape Hatteras and Topsail Beach was interpolated between Beaufort and Wilmington. Sunset Beach was trickier since data were not available from any community to the south (in South Carolina). Thus, data were used from the closest community to the north (Southport) and then compared with the sea level rise vulnerability map from Thieler and Hammar-Klose (1999), which showed low vulnerability around the Southport area and moderate vulnerability around the Sunset Beach area, in the same range as Topsail Beach (see Appendix A).

Historical hurricane strikes were gathered from NOAA by taking all of the hurricanes (between 1850 and 2010) in which the center came within 20, 50 and 100 miles of each study community, followed by all of the major hurricanes (categories 3, 4 and 5) in which the center came within 20, 50 and 100 miles of each study community (see Figure 3.9 for example). Each category (six in total) was recalculated as the percent chance of occurrence in a given year by taking the number of strikes and dividing by the number of years of record. The results for the six categories were then added together to produce an average percent chance, which is a derived value, not an actual probability. Average percent chances were then ranked on a 1-5 scale, with a score of 1 corresponding to an average percent chance of 0-2 (extremely low vulnerability) and a score of 5 corresponding to an average percent chance of >14 (extremely high vulnerability) (See Appendix A for a complete description of the scoring rubric).

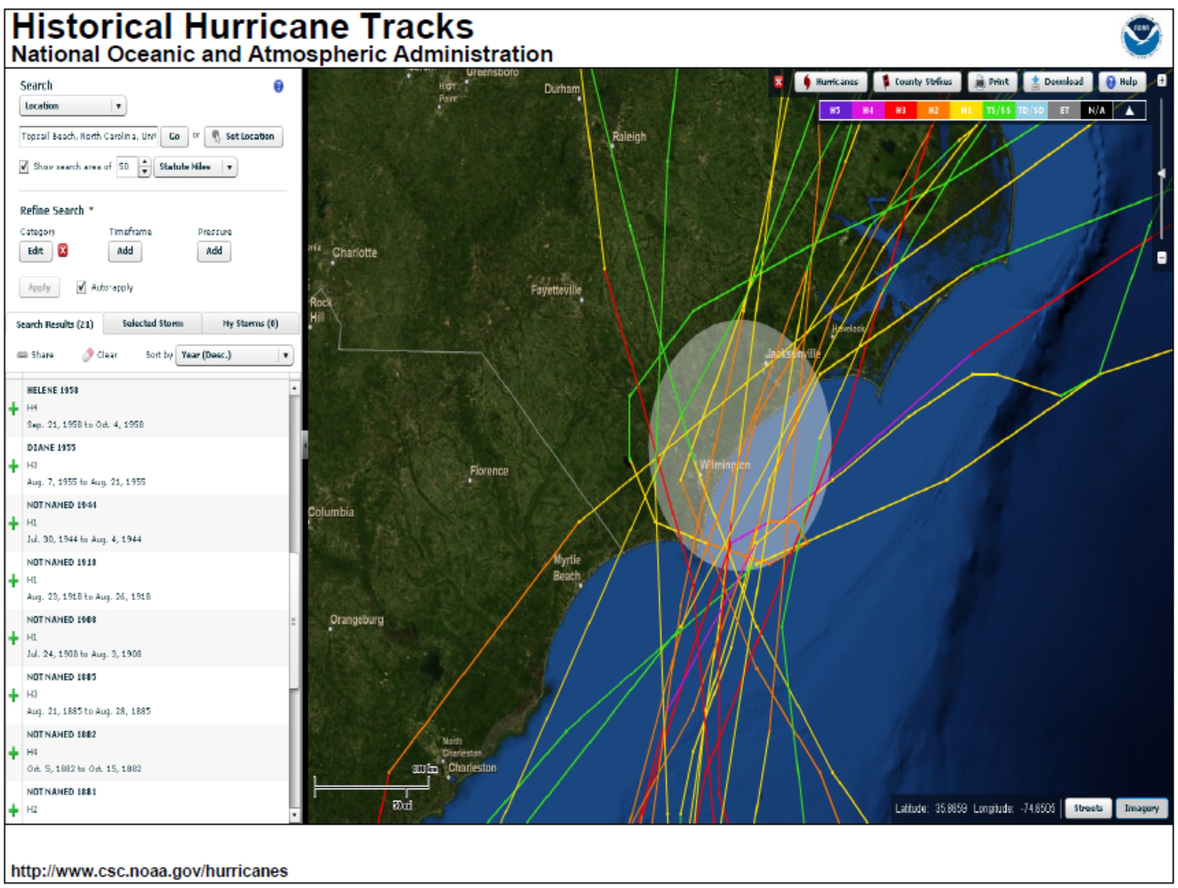

Figure 3.9: All hurricanes to make landfall within 50 statute miles of Topsail Beach since 1850 (http://www.csc.noaa.gov/hurricanes).

Historical nor'easter strikes were evaluated in a similar fashion to hurricanes by taking all of the nor'easters in which the center came within 20, 50 and 100 miles of each study community, although the period of record was not as long (1961-1998). Since in most cases (specifically storms to come within 50 and 100 miles) there were several storms in one year, each category (three in total) was recalculated as a frequency of storms/yr. The three frequencies were then averaged to produce an average frequency, which is a derived value, not an actual frequency. Average frequencies were then ranked on a 1-5 scale, with a score of 1 corresponding to an average frequency of 0-0.2 (extremely low vulnerability) and a score of 5 corresponding to an average frequency of >1.6 (extremely high vulnerability). For a complete description of the scoring rubric, refer to Appendix A.

Flood probability was determined by taking the percentage of each community in the Special Flood Hazard Area (SFHA) and the percentage of each community in the high velocity zone (VE). Also considered here was whether or not the community includes mainland areas, which are less likely to be in the SFHA, specifically in the VE zone. Sunset Beach is the only one of the three communities with mainland areas. An additional consideration was the percentage of each community that would be inundated by storm surge from hurricanes of different magnitudes. Flood potential was then ranked on a 1-5 scale which takes all of these variables into account. For example, a score of 1 (extremely low vulnerability) means that the following conditions must be met: 1) <5% of the community is in the VE zone, 2) <10% of the community is in the SFHA, 3) <5% of the community is inundated by category 1 or 2 storm surge, 4) <10% of the community is inundated by category 3 storm surge, and 5) <15% of the community is inundated by category 4 or 5 storm surge. A score of 5 (extremely high vulnerability) means that >80% of community is in the VE zone, or >90% of community is in the SFHA, or >80% of the community is inundated by a category 1 or 2 storm. Different intervals could have been chosen, but those used here are seen to clearly and distinctly represent differences in vulnerability. For a complete description of the scoring rubric, refer to Appendix A.

Maximum and minimum island widths for each community were determined by using the measurement tool in ArcMap to measure the distance between the ocean and the sound at the islands' widest and narrowest locations. Also considered here are whether or not the community includes mainland areas and the percentage of the community covered by wetlands. A community with mainland areas receives a higher score because there is more land area farther away from the erosive forces of the ocean. Similarly, communities with more wetlands receive higher scores because wetlands act as storm and erosion buffers. Another important geographic variable, elevation, was not considered here as this factors into the designation of flood zones, which were considered in the previous section. Island/community width was then ranked on a 1-5 scale which takes all of these factors into account. For example, a score of 1 (extremely low vulnerability) means that minimum island width is >1 mi and the community is composed of >20% wetlands and a score of 2 (low vulnerability) means that minimum island width is >0.5 mi if there are no mainland areas or the minimum island width is >0.25 mi if there are mainland areas, maximum island width is >0.5 mi, and >20% of the community is composed of wetlands. Regardless of whether any other conditions are met, a community will receive a score of 5 (extremely high vulnerability) if maximum island width is <0.1 mi. For a complete description of the scoring rubric, refer to Appendix A.

Building upon previous studies, McLaughlin and Cooper (2010) state that a vulnerability index based upon the sum of variables is less sensitive than one based on the products. Using a similar method, the six values (erosion, sea level rise, hurricanes, nor'easters, flooding and island/community width) were summed and then averaged to produce a total vulnerability score for each community. Vulnerability scores were calculated using both the long-term and short-term erosion rates. Surprisingly, the final scores were not significantly different, only varying somewhat for Topsail Beach. Ultimately, the scores calculated with the short-term rates were discarded because it is the long-term trends that are of greater interest for this analysis.

Part II: Plan Coding

The second part of the resilience index involved the coding of each community's land use plan and hazard mitigation plan. The purpose of this was to determine what approaches are being employed to address various hazards. In addition, meetings were held with planners from each community to determine the extent to which these approaches are being implemented.

Plan coding in North Carolina has been conducted extensively by Berke and colleagues at the University of North Carolina at Chapel Hill. According to Berke et al., (2009), internal plan quality principles are related to the content of the plan and include 1) issue identification and vision, 2) fact base, 3) goals, 4) policies/actions, and 5) implementation, monitoring and evaluation. Criteria used to evaluate plans were coded on either a 0 to 1 binary scale or a 0 to 2 ordinal scale. For both scales, a score of 0 indicated that the criterion was not included in the plan. On the binary scale, a score of 1 indicated that the criterion was present in the plan, while on the ordinal scale a score of 1 indicated that the criterion was briefly mentioned, but not detailed in the plan and a score of 2 indicated that the criterion was addressed with a clear and detailed description (Berke et al., 2009).

With a minimal understanding of the plan coding process, it was determined necessary to meet with a professional. A meeting was held with a doctoral student of Dr. Berke in September, 2010 to learn more about the criteria used in coding plans, for which he provided an extensive list (Ward Lyles, personal communication, 09/10/2010). An important distinction to make is that while Berke and colleagues are evaluating overall plan quality, what is being evaluated here is the extent to which the plans address hazards and vulnerability. Thus it was deemed necessary to use a subset of their criteria for the purposes of this research. Choosing an appropriate and manageable subset was a difficult task. The initial subset used was quite large and was gradually refined to a more manageable subset, which was tested during a pilot analysis of the town of Atlantic Beach, NC (see Appendix B). The pilot analysis helped to further refine the subset in order to proceed with the study communities.

The final subset used for the plan coding incorporates a combination of criteria used by Berke et al., (2010) as well as several others which are specific to this research. Since plans contain qualitative data, one of the most significant challenges was avoiding subjectivity when converting plan components into quantitative scores. Although a certain level of subjectivity at this stage was unavoidable, it was determined that the most effective way to avoid a significant amount of subjectivity was to devise a very specific scoring method that was consistent for all criteria. However, as is the case whenever an analysis such as this is conducted, there were certain criteria that fit the rubric better than others. To compensate for this, any scores which did not closely fit the scoring rubric were coded with a superscript which corresponded to an explanation underneath as to why that category received that particular score (see Appendix C).

The purpose of the plan coding was to determine 1) how effectively each community has identified acute hazards, 2) how effectively each community has identified chronic hazards 3) how prepared and capable each community is currently to withstand various hazards, and 4) what strategies each community has devised for dealing with different hazards in the future. Thus, the final plan coding instrument included four overall categories: 1) acute hazard identification, 2) chronic hazard identification, 3) capability assessment, and 4) goals/actions. Each major category consisted of several subcategories, which in turn were composed of individual criteria. For example, the acute hazards category includes the following subcategories: 1) floods, 2) hurricanes, and 3) nor'easters. Each of those subcategories is evaluated according to whether or not the following criteria are included: 1) the likelihood of the hazard occurring, 2) the locations and boundaries of particularly hazardous areas, 3) the magnitude and severity of the hazard in that location, 4) specific information explaining the characteristics of the particular hazard, and 5) information about previous hazard events (Table 3.1). Each individual criterion was scored on a scale of 0-4. The scoring rubrics varied slightly according to each category, but were generally reflective of 1) whether or not the topic was mentioned or detailed in the plan (Berke et al., 2009), and 2) whether the strategies employed were for mitigation/resistance or for adaptation/flexibility (only the first applied to hazard identification). As previously stated, actions that are more adaptive in nature are considered here to be more sustainable and contribute to greater community resilience, and are thus scored higher. The scores for each criterion were then summed into a subcategory total and the subcategory scores were summed into a total for the category. Since the plan coding tables are too large to contain within the body of this document, Table 3.1 provides just a section of the plan coding instrument for Kitty Hawk. Refer to Appendix C for the complete plan coding tables and scoring rubrics.

Kitty Hawk								
Category	HMP Unstandardized	HMP Standardized	LUP Unstandardized	LUP Standardized	Implementation Unstandardized	Implementation standardized	Total Unstandardized	Total Standardized
Hazard Identification (Acute)	**51.5/60**	**4.29**	**14/60**	**1.17**	**NA**	**NA**	**32.75/60**	**2.73**
Floods	18.5/20	NA	4/20	NA	NA	NA	11.5/20	NA
Describes likelihood of floods	4	NA	2	NA	NA	NA	3	NA
Describes location and boundaries of hazardous areas	3[A]	NA	0	NA	NA	NA	1.5	NA
Describes magnitude and severity of floods	4	NA	0	NA	NA	NA	2	NA
Describes separate characteristics of coastal flood hazards	4	NA	2	NA	NA	NA	3	NA
Includes information on past flood events	4	NA	0	NA	NA	NA	2	NA
Hurricanes/Coastal Storms	18.5/20	NA	8/20	NA	NA	NA	13.25/20	NA
Describes likelihood of storms	4	NA	2	NA	NA	NA	3	NA
Describes location and boundaries of hazardous areas	2.5[B]	NA	2	NA	NA	NA	2.25	NA
Describes magnitude and severity of storms	4	NA	0	NA	NA	NA	2	NA
Describes separate characteristics of storms	4	NA	2	NA	NA	NA	3	NA
Includes information on previous storms	4	NA	2	NA	NA	NA	3	NA
Nor'easters/Coastal Storms	14/20	NA	2/20	NA	NA	NA	8/20	NA
Describes likelihood of storms	2	NA	2	NA	NA	NA	2	NA
Describes location and boundaries of hazardous areas	0	NA	0	NA	NA	NA	0	NA
Describes magnitude and severity of storms	4	NA	0	NA	NA	NA	2	NA
Describes separate characteristics of storms	4	NA	0	NA	NA	NA	2	NA
Includes information on previous storms	4	NA	0	NA	NA	NA	2	NA

Table 3.1: Section of plan coding instrument for Kitty Hawk dealing with acute hazard identification.

Total scores were then standardized so that each major category was scored on the same scale, regardless of how many subcategories and criteria were listed underneath. The hazard identification (both acute and chronic) and the capability assessment categories were standardized out of a total of 5 points. The goals/actions category was weighted higher and standardized out of a total of 10 points because this is viewed to be the most important part of the plan, reflective of the town's goals, objectives, and implementation strategies aimed at addressing the aforementioned hazards. Thus, the total planning scores are out of a possible 25 points (5 for acute hazards, 5 for chronic hazards, 5 for capability assessment and 10 for goals/actions). Since CAMA stipulates that plans are to be written every 5 years, points were deducted from the final scores if either of the plans were >5 years old, 1 point for the hazard mitigation plan and 2 points for the land use plan. The land use plan has been weighted higher than the hazard mitigation plan for both overall points and deductions because 1) one of the aforementioned research questions examines how differences in physical vulnerability are reflected specifically in land use planning, and 2) good land use planning is mentioned in the literature as being a prerequisite for resilience in coastal communities. Both Kitty Hawk and Topsail Beach had land use plans which were written >5 years ago.

The final plan coding instrument evaluated each community's hazard mitigation plan, land use plan, and plan implementation (via personal correspondence with planners and observation). The Disaster Mitigation Act of 2000 requires all state and local (county) governments to produce hazard mitigation plans in order to be eligible for funding (Berke et al., 2009). Although all counties are required to develop hazard mitigation plans, it is not required of all communities, which may choose to be included within a county multijurisdictional plan. Of the three communities, only Sunset Beach had its own hazard mitigation plan. Kitty Hawk was included within the Dare County multijurisdictional hazard mitigation plan, although there was a section pertaining specifically to Kitty Hawk. Topsail Beach was included under the Pender County multijurisdictional hazard mitigation plan. Since the Pender County hazard mitigation plan did not have a section specifically pertaining to Topsail Beach, one point was deducted from each criterion in the capability assessment and goals/actions categories. Since the hazards impacting the community are included in the hazards impacting the county, points were not deducted from the hazard identification category under the hazard mitigation plan section.

For the first three categories in the plan coding instrument (both types of hazard identification and capability assessment), the hazard mitigation plan and land use plan were weighted equally and the scores were averaged. The land use plan was weighted more than the hazard mitigation plan for goals/actions for the reasons previously mentioned. Under this category, if the hazard mitigation score was higher than the land use score, the two were averaged. If the land use score was higher than the hazard mitigation score, only the land use score was used in calculating the final score. The implementation score is reflective of the actions which have been implemented since the adoption of the land use and hazard mitigation plans. Thus, implementation is only relevant to the goals/actions category (refer to Appendix C).

Part III: Resilience Index

The resilience of each community was determined by combining the total planning scores with the total vulnerability scores. Resilience and good planning should have a positive linear relationship and while it is recognized that vulnerability and resilience are not necessarily opposites, higher vulnerability generally reflects lower resilience. Thus, resilience was calculated using the planning scores in their original form and the maximum-observed vulnerability scores. The maximum-observed vulnerability scores equal 5-the calculated vulnerability score, since 5 is the maximum score possible. After subtracting the vulnerability score from 5, scores were only out of 4 (since the minimum vulnerability score was 1). This value was multiplied by the planning score (maximum of 25) in order to ensure that both parts of the index were weighted equally and to allow for better recognition of differences, producing a total score out of 100. However, since the vulnerability of each community was significant, scores were consistently low even if the planning scores were high. To minimize this effect, the square root of each score was taken to produce final scores on a 0-10 scale. The formula for resilience is as follows:

$$\text{Resilience}=\sqrt{\text{planning score} \times (5\text{-vulnerability score})}.$$

One of the aforementioned research questions asks whether or not it is possible to build a high level of resilience in these communities with good planning, or if their natural vulnerability is simply too great to overcome. In other words, what is being measured is referred to as "resilience potential". To address this question, a resilience potential score was calculated for each community to determine whether or not a high level of resilience is achievable based upon the current state of vulnerability. This was calculated by taking the maximum planning score possible (i.e. holding planning constant for each community) and multiplying by 5-the vulnerability score.

$$\text{Resilience Potential}=\sqrt{25 \times (5\text{-vulnerability score})}.$$

Methods Summary

This process evaluates different indicators of vulnerability and employs several techniques for coding community plans in order to produce two separate numerical scores. This type of analysis makes it possible to produce a quantitative measure of resilience with the intention of serving a practical function for planners in coastal communities.

CHAPTER 4: RESULTS

The results for each community are presented below with summaries of the vulnerability analyses, followed by the plan coding evaluations and assessments of overall resilience. This section is concluded with a comparison of the three communities in each area of investigation and a discussion of overall trends as established through this research.

Sunset Beach

Vulnerability Assessment

The results for the Sunset Beach vulnerability assessment are shown in Table 4.1. According to the NC DCM setback map based on long-term erosion rates, all of Sunset Beach is considered to be experiencing a long-term erosion rate of 2 ft/yr. (refer back to Figure 3.6b). According to the data from the 2004 map, which was mapped using ArcGIS, the majority of Sunset Beach was actually accreting, some areas quite substantially (refer back to Figure 3.6a). As previously mentioned, this may be due to a lack of significant storm events during this year and is not necessarily indicative of the long-term trend. After calculating both the long-term and short-term vulnerability, Sunset Beach received a score of 2.5 (or moderate vulnerability), meaning that the average erosion rate is ≤2 ft/yr., <25% of community is eroding 2.01 - 5 ft/yr., and no part of the community is eroding >5 ft/yr. (see Appendix A).

Hazard	Sunset Beach
Erosion (long-term)	2.5
Sea level Rise	3.5
Hurricanes	3
Nor'easters	3.5
Flooding	4
Width	2.5
Total	19
Cumulative Average	**3.17**
Vulnerability	**Moderate**

Table 4.1: Results of vulnerability assessment for Sunset Beach.
1.00-1.49=extremely low vulnerability
1.50-2.49=low vulnerability
2.50-3.49=moderate vulnerability
3.50-4.49=high vulnerability
4.50-5=extremely high vulnerability

Calculating sea level rise for Sunset Beach was somewhat more challenging. The closest community in North Carolina with a significant record of sea level rise data was Southport, which has been experiencing an average rate of 0.0067 ft/yr. (North Carolina Coastal Resources Commission, 2010). Since Sunset Beach is the southernmost community in North Carolina, there were no data from any points south. According to the USGS map (refer back to Figure 2.1), sea level rise vulnerability increases from what they classified as “low” around Southport, to “moderate” around Sunset Beach. This puts Sunset Beach in the same category as Topsail Beach, according to the map. Since Topsail Beach was interpolated to have a relative sea level rise rate of 0.0079 ft/yr., the same value was used for Sunset Beach, slightly higher than that of Southport and consistent with the USGS map. This gave Sunset Beach a sea level rise vulnerability score of 3.5 (or high vulnerability), meaning that sea level is rising 0.0067-0.0082 ft/yr (see Appendix A).

Since 1850, Sunset Beach has experienced 39 hurricane and 7 major hurricane strikes within a 100 mile radius, 18 hurricane and 4 major hurricane strikes within a 50 mile radius, and 6 hurricane and 1 major hurricane strikes within a 20 mile radius (NOAA, 2011). This means that in a given year during this period, Sunset Beach can expect a 24.375% chance of a hurricane strike and 4.375% chance of a major hurricane strike within 100 miles, an 11.25% chance of a hurricane strike and a 2.5% chance of a major hurricane strike within 50 miles, and a 3.75% chance of a hurricane strike and 0.625% chance of a major hurricane strike within 20 miles. Averaging these yields an average percent chance of 7.813. This number does not have any units because it is not an actual value, but rather simply an average used for ranking and scaling. This yielded a hurricane vulnerability score of 3 (or moderate vulnerability), representing an average percent chance of 6-8 (see Appendix A).

Between 1961 and 1998, Sunset Beach experienced 68 nor'easters with storm centers within a 100 mile radius, 38 nor'easters with storm centers within a 50 mile radius, and 15 nor'easters with storm centers within a 20 mile radius (NASA, 2011). Thus, an average year during this time period will see 1.789 nor'easters within 100 miles, 1.000 nor'easters within 50 miles, and 0.395 nor'easters within 20 miles. Averaging these six frequencies yielded an average frequency of 1.061, resulting in a nor'easter vulnerability score of 3.5 (or high vulnerability), which represents an average frequency of 1.0-1.2 (see Appendix A).

According to the 2006/2007 CAMA Land Use Plan, 55% of the community is within the SFHA with 47% of the community in the VE zone. Since Sunset Beach is both an island and a mainland community, the island area within the SFHA was also taken into consideration. Almost all, or 99% of the island of Sunset Beach, is in the SFHA and 60% is within the VE zone.

According to the CAMA Land Use Plan, 55% of the community would be inundated by storm surge from a category 1 or 2 hurricane, 65% by a category 3 hurricane, and 85% by a category 4 or 5 hurricane. This yielded a flooding vulnerability score of 4 (or high vulnerability), meaning that <60% of the community and <90% of the island is in the VE zone, <70% of the community is in the VE or AE zones, <70% of the community would be inundated by a category 1 or 2 storm, and <85% of the community would be inundated by a category 3 storm (See Appendix A).

Using the measuring tool in ArcGIS, it was determined that the island of Sunset Beach is 1.03 miles across at its widest point, and 0.18 miles across at its narrowest point. According to the 2007 Sunset Beach CAMA Land Use Plan, 29% of the community is covered by wetlands. Since the community contains incorporated mainland areas within its jurisdiction, this was also taken into consideration. This yielded a vulnerability score based on island width of 2.5 (or moderate vulnerability), meaning a minimum island width of >0.25 mi with no mainland areas or a minimum island width of >0.1mi with mainland areas, a maximum island width of >0.5 mi, and >15% wetlands (See Appendix A).

Taking the average of the scores from each of the six variables, the overall vulnerability score of Sunset Beach was calculated to be 3.17, in the moderate category (2.50-3.49) (Table 4.1).

Plan Coding

The results of the plan coding for Sunset Beach are shown in Table 4.2 for each of the four major categories along with a total score. The 2011 Hazard Mitigation Plan was generally sufficient at identifying acute hazards, receiving scores of 18/20 for the floods subcategory, 20/20 for the hurricanes subcategory, and 12/20 for the nor'easters subcategory. This yielded a total acute hazard score of 50/60, and a standardized score of 4.17/5. The hazard mitigation plan was generally poor in its identification of chronic hazards with the exception of coastal erosion. Sea level rise and climate change were not mentioned. Subcategory scores were 16/20 for coastal erosion, 0/20 for sea level rise, and 0/4 for climate change (other than sea level rise). This yielded a total chronic hazards score of 16/44, and a standardized score of 1.82/5. The capability assessment was only somewhat inclusive of the criteria included in the plan coding instrument, receiving subcategory scores of 4/12 for acquisition and elevation and 16/32 for development regulations. This yielded a total capability assessment score of 20/44, and a standardized score of 2.27/5. The hazard mitigation plan was rather mediocre at addressing its goals and objectives, although much of what was not included in the hazard mitigation plan was included in the land use plan, thus nullifying many of the hazard mitigation scores in the overall planning score[1]. The hazard mitigation plan received a score of 0/4 for the land suitability analysis subcategory, 4/4 for the development compatibility assessment subcategory, 2.5/4 for the land use trends subcategory, 3/12 for the acquisition and elevation subcategory, and 22/32 for the development regulations subcategory. This yielded a total goals/actions score of 31.5/56, and a standardized score of 5.63/10. Adding up the four category scores yielded a total hazard mitigation score of 117.5/204 and a standardized score of 13.89/25. For a summary of the plan coding results for each major category, refer to Table 4.2. For the full plan coding table, refer to Appendix C.

[1] The hazard mitigation score is not averaged in for this section if the land use plan score is higher than the hazard mitigation score

Category	HMP Unstan	HMP Stan	LUP Unstan	LUP Stan	Imp Unstan	Imp stan	Total Unstan	Total Stan
Hazard Identification (Acute)	**50/60**	**4.17**	**18/60**	**1.50**	**NA**	**NA**	**34/60**	**2.83**
Hazard Identification (Chronic)	**16/44**	**1.82**	**16/44**	**1.82**	**NA**	**NA**	**16/44**	**1.82**
Capability Assessment	**20/44**	**2.27**	**24/44**	**2.73**	**NA**	**NA**	**22/44**	**2.50**
Goals/Actions	**31.5/56**	**5.63**	**45.5/56**	**8.13**	**43/44**	**9.77**	**49.5/56**	**8.84**
Overall Score	**117.5/204**	**13.89**	**103.5/204**	**14.18**	**43/44**	**24.43**	**121.5/204**	**15.99**
Overall Score With Deduction (If Applicable)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Table 4.2: Results of plan coding for Sunset Beach
HMP=hazard mitigation plan
LUP=land use plan
Imp=implementation
Unstan=unstandardized
Stan=standardized

The 2006/2007 CAMA Land Use Plan did a poor job identifying both acute and chronic hazards (see Table 4.2). For acute hazard identification, the floods subcategory received a score of 12/20, the hurricanes subcategory received a score of 6/20, and nor'easters were not even mentioned, receiving a score of 0/20. This yielded a total acute hazard identification score of 18/60, and a standardized score of 1.5/5. For chronic hazard identification, coastal erosion once again scored the highest of the three subcategories, receiving a score of 12/20, as opposed to 4/20 for sea level rise and 0/4 for climate change. This yielded a total chronic hazards score of 16/44, and a standardized score of 1.82/5. The land use plan scored slightly better than the hazard mitigation plan for the capability assessment, with a score of 4/12 for acquisition/elevation and 20/32 for development regulations. This yielded a total capability assessment score of 24/44, and a standardized score of 2.73/5. The CAMA Land Use Plan scored very high for the goals/actions category. Subcategory scores were 4/4 for land suitability analysis, 4/4 for compatibility assessment, 2.5/4 for land use trends, 7/12 for acquisition/elevation, and 28/32 for development regulations. This yielded a total goals/actions score of 45.5/56, and a standardized score of 8.13/10. Adding together the four category scores yielded a total land use plan score of 103.5/204, and a standardized score of 14.18/25 (See Appendix C for further details).

The implementation evaluation only applies to the acquisition/elevation and development regulations subcategories of the goals/actions category. In order to assess the implementation progress of these plans, a meeting was scheduled with the Sunset Beach Town Planner. Due to personal reasons, the Town Planner became unavailable, so meetings were scheduled with the Sunset Beach Consulting Planner of Holland Consulting Planning and two Sunset Beach Building Inspectors. The Consulting Planner noted that the 2007 land use plan was recently adopted, and the town will most likely sit with it until the next one is required by CAMA. The town does not encourage further development, but is not against it as long as it fits in with existing development. The town has restricted development density by allowing for minimal multifamily usage as well as setting aside roughly 2,000 acres consisting primarily of wetlands (about 30% of the land area within Sunset Beach) as conservation areas. The Consulting Planner stated that very little erosion control is needed since the beach has remained wide and none of the homes are currently threatened. The primary dune is very healthy and there is a dune protection ordinance in place about which the town is very serious. Sunset Beach is also very proactive when it comes to protection of natural vegetation buffers and will do "whatever it takes" to protect their dunes and wetlands. According to the Consulting Planner, the town will address relocation on an as-needed basis, although none has been needed in recent years. However, the option to elevate is still more commonplace. Sunset Beach consistently updates its floodplain development ordinance so that it remains in line with NFIP standards and requires elevation certificates for every property within the flood hazard area (this was discussed in greater detail with the Building Inspectors). Sunset Beach engages in property acquisition and has acquired and demolished at least one property on the mainland within the last year. There are no specific zoning ordinances in place dealing specifically with open space preservation, although there are some open space provisions for residential development (Landin Holland, personal communication, 05/01/2011).

The meeting with the two Sunset Beach Building Inspectors was scheduled primarily to get a sense of the building standards within the community. According to the Building Inspectors, Sunset Beach complies with the CAMA setback regulations with an additional local requirement that "no property be built beyond 125 feet ocean-ward of the property line abutting Main Street" (Randy Walters, personal communication, 05/02/2011). Only one gated community at the east end of the island is not subject to this local ordinance, but is still subject to CAMA regulations (Randy Walters, personal communication, 05/02/2011). Sunset Beach also imposes a 1-foot freeboard for elevating homes above BFE and has a CRS rating of 8, which is the highest score possible and indicates that the town has been effective at implementing this standard (Sandy Wood, personal communication, 05/02/2011). Sunset Beach is in compliance with the North Carolina State Building Code with an additional stipulation that all structures on the island be of pile construction (Randy Walters, personal communication, 05/02/2011).

After analysis of this meeting, Sunset Beach received implementation scores of 12/12 for the acquisition/elevation subcategory and 31/32 for the development regulations subcategory.

This yielded a total implementation score of 43/44 and a standardized score of 24.43/25 (refer back to Table 4.2).

Composite analysis of planning in Sunset Beach yielded standardized scores of 2.83/5 for acute hazard identification, 1.82/5 for chronic hazard identification, 2.50/5 for capability assessment and 8.84/10 for goals actions. This led to a total planning score of 15.99/25 for Sunset Beach (refer back to Table 4.2).

Resilience

With a total vulnerability score of 3.17 and a total planning score of 15.99, the resilience score was calculated using the formula mentioned previously (Resilience score=√planning score*(5-vulnerability score)). This yielded a resilience score of 5.41/10 for Sunset Beach. Next, a resilience potential score was calculated assuming a perfect planning score of 25, yielding a resilience score of 6.76/10. Thus, Sunset Beach can increase their overall resilience if it improves upon its plans (see Table 4.3).

Community	**Sunset Beach**
Vulnerability Score	3.17
5-Vulnerability Score	1.83
Planning Score	15.99
Planning Score x (5-Vulnerability Score)	29.2617
Resilience Score	**5.41**
Resilience Potential Score	**6.76**

Table 4.3: Resilience scores for Sunset Beach.
*Resilience Score=√Planning Score x (5-Vulnerability Score)
*Resilience Score is out of 10

Topsail Beach

Vulnerability Analysis

The results of the vulnerability analysis for Topsail Beach are shown in Table 4.4. According to the NC DCM setback map based on long-term erosion rates, all of Topsail Beach is considered to be experiencing a long-term erosion rate of 2 ft/yr. (see Figure 3.7b). According to the data from 2004, which was mapped using ArcGIS, the majority of Topsail Beach was accreting around 2 ft/yr. (see Figure 3.7a), but this may again be indicative of an inactive year rather than the long-term trend. Topsail Beach in turn received a score of 1.5 (or low vulnerability) using the short-term rate and a score of 2.5 (or moderate vulnerability) using the long-term rate. Since the goal of this research is to examine the long-term trends, only the long-term erosion vulnerability score of 2.5 was used in the final analysis. This means that the average erosion rate is ≤2 ft/yr., <25% of community is eroding 2.01 - 5 ft/yr., and no part of the community is eroding >5 ft/yr. (see Appendix A).

Hazard	**Topsail Beach**
Erosion (long-term)	2.5
Sea level Rise	3.5
Hurricanes	3.5
Nor'easters	3.5
Flooding	5
Width	4
Total	22
Cumulative Average	**3.67**
Vulnerability	**High**

Table 4.4: Results of vulnerability assessment for Topsail Beach.
1.00-1.49=extremely low vulnerability
1.50-2.49=low vulnerability
2.50-3.49=moderate vulnerability
3.50-4.49=high vulnerability
4.50-5=extremely high vulnerability

Sea level rise rates for Topsail Beach were interpolated between Beaufort and Wilmington. Between 1973 and 2002, Beaufort experienced a sea level rise of 0.0105 ft/yr. and between 1935 and 2002, Wilmington experienced a sea level rise of 0.0070 ft/yr. Since Topsail Beach is geographically closer to Wilmington, the relative sea level rise rate for Topsail Beach was interpolated to be 0.0079 ft/yr. This gave Topsail Beach a sea level rise vulnerability score of 3.5 (or high vulnerability), meaning that sea level is rising 0.0067-0.0082 ft/yr. (see Appendix A).

Since 1850, Topsail Beach has experienced 46 hurricane and 10 major hurricane strikes within a 100 mile radius, 21 hurricane and 5 major hurricane strikes within a 50 mile radius, and 6 hurricane and 0 major hurricane strikes within a 20 mile radius (NOAA, 2011). This means that in a given year during this period, Topsail Beach has a 28.75% chance of a hurricane strike and a 6.25% chance of a major hurricane strike within 100 miles, a 13.125% chance of a hurricane strike and a 3.125% chance of a major hurricane strike within 50 miles, and a 3.75% chance of a hurricane strike and 0.0%[2] chance of a major hurricane strike within 20 miles. Averaging these six values yields an average percent chance of 9.167, producing a hurricane vulnerability score of 3.5 (or high vulnerability), representing an average percent chance of 8-10 (see Appendix A).

Between 1961 and 1998, Topsail Beach experienced 77 nor'easters with storm centers within a 100 mile radius, 35 nor'easters with storm centers within a 50 mile radius, and 14 nor'easters with storm centers within a 20 mile radius (NASA, 2011). Thus, an average year during this time period will see 2.0263 nor'easters within 100 miles, 0.921 nor'easters within 50

[2] This is according to the historical record. However, the probability of a major hurricane strike within 20 miles of Topsail Beach is not really 0%.

miles, and 0.368 nor'easters within 20 miles. Averaging these six frequencies yielded an average frequency of 1.105, producing a nor'easter vulnerability score of 3.5 (or high frequency), representing an average frequency of 1.0-1.2 (see Appendix A).

According to the 2005 Topsail Beach CAMA Land Use Plan, 98% of the community is within the SFHA, with 91% of the community in the VE zone. Topsail Beach is an island-only community. According to the CAMA Land Use Plan, 71% of the community would be inundated by storm surge from a category 1 or 2 hurricane, 73% by a category 3 hurricane, and 74% by a category 4 or 5 hurricane. This yielded a flooding vulnerability score of 5 (or extremely high vulnerability), meaning that >80% of the community is in the VE zone, or >90% of the community is in the VE or AE zone, or >80% of the community would be inundated by category 1 or 2 storm surge (See Appendix A).

Using the measuring tool in ArcGIS, it was determined that the town of Topsail Beach is 0.33 miles across at its widest point, and 0.09 miles across at its narrowest point. According to the Topsail Beach CAMA Land Use Plan, 45% of the community is covered by wetlands. Since Topsail Beach is an island-only community with no incorporated mainland areas (unlike its neighbor Surf City to the north), this was also taken into consideration. This yielded a vulnerability score based on island width of 4 (or high vulnerability), meaning a maximum island width of >0.25 mi, and >10% of the community consists of wetlands (See Appendix A).

Taking the average of the scores from each of the six variables, the overall vulnerability score of Topsail Beach was calculated to be 3.67, in the high category (3.50-4.49) (See Appendix A).

Plan Coding

The results of the plan coding for Topsail Beach are shown in Table 4.5 for each of the four major categories along with a total score. The most recent hazard mitigation plan for Topsail Beach is from 2010 and is a Pender County multijurisdictional plan including several communities other than Topsail Beach. Since the hazards impacting Topsail Beach are basically the same as the hazards impacting all of Pender County, the hazard identification categories were scored normally. In addition, the plan did include hazard maps specifically for Topsail Beach in the hazard identification and vulnerability assessment section. However, the plan only discussed county mitigation and adaptation practices in the capability assessment and goals/objectives section with nothing specific to Topsail Beach. Thus, 1 point was deducted from each criterion in this section (e.g. a criterion that would have received a score of 4 would now receive a score of 3). For a summary of the plan coding results for each major category, refer to Table 4.5. For the full plan coding table, refer to Appendix C.

The 2010 Pender County Multijurisdictional Hazard Mitigation Plan was generally effective at identifying acute hazards, receiving scores of 18/20 for the floods subcategory, 20/20 for the hurricanes subcategory, and 8/20 for the nor'easters subcategory. This yielded a total acute hazards score of 46/60, and a standardized score of 3.83/5. The hazard mitigation plan was generally ineffective in its identification of chronic hazards with the exception of coastal erosion. Sea level rise and climate change were not mentioned. Subcategory scores were 16/20 for coastal erosion, 0/20 for sea level rise, and 0/4 for climate change (other than sea level rise). This yielded a total chronic hazards score of 16/44, and a standardized score of 1.82/5.

Category	HMP Unstan	HMP Stan	LUP Unstan	LUP Stan	Imp Unstan	Imp Stan	Total Unstan	Total Stan
Hazard Identification (Acute)	**46/60**	**3.83**	**38/60**	**3.17**	**NA**	**NA**	**42/60**	**3.50**
Hazard Identification (Chronic)	**16/44**	**1.82**	**18/44**	**2.05**	**NA**	**NA**	**17/44**	**1.93**
Capability Assessment	**12/44**	**1.36**	**28.5/44**	**3.24**	**NA**	**NA**	**20.25/44**	**2.30**
Goals/Actions	**17/56**	**3.04**	**38.5/56**	**6.88**	**27/44**	**6.14**	**38.33/56**	**6.84**
Overall Score	**91/204**	**10.05**	**123/204**	**15.34**	**27/44**	**15.35**	**117.58/204**	**14.57**
Overall Score With Deduction (If Applicable)	**NA**	**NA**	**NA**	**13.34**	**NA**	**NA**	**NA**	**12.57**

Table 4.5: Results of plan coding for Topsail Beach
HMP=hazard mitigation plan
LUP=land use plan
Imp=implementation
Unstan=unstandardized
Stan=standardized

The capability assessment was only somewhat inclusive of the criteria included in the plan coding instrument, receiving subcategory scores of 2.5/12 for acquisition and elevation and 9.5/32 for development regulations (these scores included the deductions previously mentioned). This yielded a total capability assessment score of 12/44, and a standardized score of 1.36/5. The goals/actions section was also generally weak, although much of what was not included in the hazard mitigation plan was included in the land use plan, thus nullifying many of the hazard mitigation scores in the overall planning score. The hazard mitigation plan received a score of 0/4 for the land suitability analysis subcategory, 0/4 for the development compatibility assessment subcategory, 0/4 for the land use trends subcategory, 5/12 for the acquisition and elevation subcategory, and 12/32 for the development regulations subcategory. This yielded a total goals/actions score of 17/56, and a standardized score of 3.04/10. Adding up the four category scores produced a total hazard mitigation score of 91/204 and a standardized score of 10.05/25 (see Appendix C for further details).

The 2005 CAMA Land Use Plan was generally effective at addressing acute hazards with the exception of nor'easters, which were not mentioned at all. The floods subcategory received a score of 18/20, the hurricanes subcategory received a score of 20/20, and the nor'easters subcategory received a score of 0/20. This yielded a total acute hazard identification score of 38/60, and a standardized score of 3.17/5. For chronic hazard identification, coastal erosion once again scored the highest of the three subcategories, receiving a score of 16/20, as opposed to 2/20 for sea level rise and 0/4 for climate change, leading to a total chronic hazards score of 18/44, and a standardized score of 2.05/5. The land use plan scored significantly higher than the hazard mitigation plan for the capability assessment, with a score of 3/12 for acquisition and elevation and 25.5/32 for development regulations. This yielded a total capability assessment score of 28.5/44, and a standardized score of 3.24/5. For goals/actions, subcategory scores were 4/4 for land suitability analysis, 4/4 for compatibility assessment, 2.5/4 for land use trends, 6/12 for acquisition/elevation, and 22/32 for development regulations. This yielded a total goals/actions score of 38.5/56, and a standardized score of 6.88/10. Adding together the four category scores produced a total land use plan score of 123/204, and a standardized score of 15.34/25. However, since the land use plan was written >5 years ago and the town has not yet adopted a new land use plan, 2 points were deducted from the overall score resulting in a final land use plan score of 13.34 (See Appendix C for further details).

The implementation evaluation was conducted via personal correspondence with the Topsail Beach Town Manager and only applies to the acquisition/elevation and development regulations subcategories of the goals/actions category. Topsail Beach does not currently have a planner on staff, although the town manager is certified in planning. The Town Manager noted that the land use plan is likely to be amended in the 2011/2012 fiscal year, which was established as a priority in January, 2011. However, it is not expected to be started until May or June of 2011. According to the Town Manager, the town is 85% built out at this point. Thus, the town is discouraging development in most areas except for the small "downtown" area where slightly more retail and business development is being encouraged. There are currently very few areas zoned for business and the town intends to keep it that way. There are also height limitations (generally 35 ft.-38 ft.), although high intensity residential development (some 3000 square ft. lots) is allowed. According to the Town Manager, Topsail Beach continues to adhere to the CAMA ocean-erodible setback standards. At this point, the Town Manager would estimate that approximately 20-25 homes are within the ocean-erodible setback zone and could not be rebuilt if lost. Topsail Beach also strictly adheres to the North Carolina State Building Code and CRS elevation requirements. All new development projects require an initial construction certificate, 21-day progress certificates and finished floor certificates. The town also implements a 1-ft freeboard above BFE. The Town Manager stated that Topsail Beach does not undertake structure relocation or property acquisition. At the time of the meeting, Topsail Beach was about to complete its first ever major beach nourishment project (scheduled for completion 4/20/2011). The town has added 900,000 cubic yards of sand and widened the beach by 300 ft. at low tide and 75 ft. at high tide along the entire 5.1-mile stretch of beach encompassed within the Topsail Beach town limits. The town is also in favor of State Senate Bill 110, which would allow the construction of up to two hardened structures in every North Carolina beachfront jurisdiction.

According to the Town Manager, very little is currently being done to preserve natural vegetation buffers or open space areas due to the fact that there is very little land still available (Tim Holloman, personal communication, 04/08/2011).

After analysis of this meeting, Topsail Beach received implementation scores of 4/12 for the acquisition/elevation subcategory and 23/32 for the development regulations subcategory. This yielded a total implementation score of 27/44 and a standardized score of 15.35/25 (see Appendix C).

Composite analysis of planning in Topsail Beach produced standardized scores of 3.50/5 for acute hazard identification, 1.93/5 for chronic hazard identification, 2.30/5 for capability assessment and 6.84/10 for goals actions. One again, 2 points were deducted from the overall score since the most recent plan is >5 years old. This yielded a total planning score of 12.57/25 for Topsail Beach (see Appendix C).

Resilience

With a total vulnerability score of 3.67 and a total planning score of 12.57, the resilience score was calculated using the formula mentioned previously (Resilience score=√planning score*(5-vulnerability score)). This yielded a resilience score of 4.09/10 for Topsail Beach. Next, a resilience potential score was calculated assuming a perfect planning score of 25, yielding a resilience score of 5.77/10. Thus, Topsail Beach can significantly improve their overall resilience with more effective planning strategies (see Table 4.6).

Community	Topsail Beach
Vulnerability Score	3.67
5-Vulnerability Score	1.33
Planning Score	12.57
Planning Score x (5-Vulnerability Score)	16.7181
Resilience Score	**4.09**
Resilience Potential Score	**5.77**

Table 4.6: Resilience scores for Topsail Beach.
*Resilience Score=√Planning Score x (5-Vulnerability Score)
*Resilience Score is out of 10

Kitty Hawk

Vulnerability Assessment

The results of the vulnerability analysis for Kitty Hawk are shown in Table 4.7. According to the NC DCM setback map based on long-term erosion rates, all of Kitty Hawk is considered to be experiencing long-term erosion rates on the order of 2-4 ft/yr. (see Figure 3.8b), with an average of approximately 2.7 ft/yr. This was not very different than the 2004 erosion rates, which ranged from 0.3-4.4 ft/yr. (see Figure 3.8a). Kitty Hawk in turn received a score of 3.5 (or high vulnerability) using both the short-term and the long-term erosion rates. This means that the average erosion rate is ≤5 ft/yr. and <10% of community is eroding >5 ft/yr (see Appendix A).

Hazard	Kitty Hawk
Erosion (long-term)	3.5
Sea level Rise	5
Hurricanes	3.5
Nor'easters	4.5
Flooding	4.5
Width	1.5
Total	22.5
Cumulative Average	**3.75**
Vulnerability	**High**

Table 4.7: Results of vulnerability assessment for Kitty Hawk.
1.00-1.49=extremely low vulnerability
1.50-2.49=low vulnerability
2.50-3.49=moderate vulnerability
3.50-4.49=high vulnerability
4.50-5=extremely high vulnerability

Sea level rise rates for Kitty Hawk were interpolated between Duck and Cape Hatteras. Between 1978 and 2002, Duck has experienced a sea level rise of 0.0140 ft/yr. and Cape Hatteras has experienced a sea level rise of 0.0113 ft/yr. Since Kitty Hawk is geographically closer to Duck, the relative sea level rise rate for Kitty Hawk was interpolated to be 0.0137 ft/yr. This gave Kitty Hawk a sea level rise vulnerability score of 5 (or extremely high vulnerability), meaning that sea level is rising >0.0115 ft/yr (see Appendix A).

Since 1850, Kitty Hawk has experienced 42 hurricane and 7 major hurricane strikes within a 100 mile radius, 19 hurricane and 2 major hurricane strikes within a 50 mile radius, and 11 hurricane and 1 major hurricane strikes within a 20 mile radius (NOAA, 2011). This means that in a given year during this period, Kitty Hawk has a 26.25% chance of a hurricane strike and 4.375% chance of a major hurricane strike within 100 miles, an 11.875% chance of a hurricane strike and a 1.25% chance of a major hurricane strike within 50 miles, and a 6.875% chance of a hurricane strike and 0.625% chance of a major hurricane strike within 20 miles. Averaging these six values yields an average percent chance of 8.542. This resulted in a hurricane vulnerability score of 3.5 (or high vulnerability), representing an average percent chance of 8-10 (see Appendix A).

Between 1961 and 1998, Kitty Hawk experienced 102 nor'easters with storm centers within a 100 mile radius, 52 nor'easters with storm centers within a 50 mile radius, and 20 nor'easters with storm centers within a 20 mile radius (NASA, 2011). Thus, an average year during this time period will see 2.684 nor'easters within 100 miles, 1.368 nor'easters within 50 miles, and 0.526 nor'easters within 20 miles. Averaging these six frequencies yielded an average frequency of 1.526. This produced a nor'easter vulnerability score of 4.5 (or extremely high frequency), representing an average frequency of 1.4-1.6 (see Appendix A).

According to the North Carolina Floodplain Mapping Information System (NCFMIS, 2011) and the town website, 85% of Kitty Hawk is within the SFHA and <10% of the community in the VE zone. Kitty Hawk is a "barrier-only"[3] community and, according to the Dare County website, approximately 40% of the community would be inundated by storm surge from a category 1 or 2 storm. There were no data regarding what percentage of the community would be inundated by storm surge from a major hurricane. This yielded a flooding vulnerability score of 4.5 (or extremely high vulnerability), meaning that <80% of community is in the VE zone, <90% of community is in the VE or AE zones, and <80% of the community would be inundated by a category 1 or 2 storm (See Appendix A).

Using the measuring tool in ArcGIS, it was determined that the Town of Kitty Hawk is 2.95 miles across at its widest point, and 0.65 miles across at its narrowest point. According to

[3] Kitty Hawk is not on an actual island, but is still on a barrier spit

the NC DCM wetlands maps, >20% of the community is covered by wetlands. Since Kitty Hawk is a “barrier-only” community with no incorporated mainland areas, this was also taken into consideration. This yielded a vulnerability score based on island width of 1.5 (or low vulnerability), meaning a minimum island width of >0.5 mi, a maximum island width of >1 mile, and >20% of the community is covered by wetlands (See Appendix A).

Taking the average of the scores from each of the six variables, the overall vulnerability score of Kitty Hawk was calculated to be 3.75, in the high category (3.50-4.49) (See Table 4.7).

Plan Coding

The results of the plan coding for Kitty Hawk are shown in Table 4.8 for each of the four major categories along with a total score. The most recent hazard mitigation plan for Kitty Hawk is from 2010 and is a Dare County multijurisdictional plan including several communities other than Kitty Hawk. Since the hazards impacting Kitty Hawk are basically the same as the hazards impacting all of Dare County, the hazard identification categories were scored normally. However, the plan did have a section specifically devoted to Kitty Hawk which included a capability assessment and relevant goals and objectives for the future. Thus, no point deductions were given for either of these two sections on the plan coding instrument. For a summary of the plan coding results for each major category, refer to Table 4.8. For the full plan coding table, refer to Appendix C.

The 2010 Dare County Multijurisdictional Hazard Mitigation Plan was generally sufficient at identifying acute hazards, receiving scores of 18.5/20 for the floods subcategory, 18.5/20 for the hurricanes subcategory, and 14/20 for the nor’easters subcategory. This yielded a total acute hazard score of 51.5/60, and a standardized score of 4.29/5. The hazard mitigation plan was generally poor in its identification of chronic hazards with the exception of coastal erosion. Sea level rise and climate change were not mentioned. Subcategory scores were 20/20 for coastal erosion, 0/20 for sea level rise, and 0/4 for climate change (other than sea level rise). This yielded a total chronic hazards score of 20/44, and a standardized score of 2.27/5.

Category	HMP Unstan	HMP Stan	LUP Unstan	LUP Stan	Imp Unstan	Imp Stan	Total Unstan	Total Stan
Hazard Identification (Acute)	**51.5/60**	**4.29**	**14/60**	**1.17**	**NA**	**NA**	**32.75/60**	**2.73**
Hazard Identification (Chronic)	**20/44**	**2.27**	**14/44**	**1.59**	**NA**	**NA**	**17/44**	**1.93**
Capability Assessment	**26/44**	**2.95**	**NA**	**NA**	**NA**	**NA**	**26/44**	**2.95**
Goals/Actions	**7/56**	**1.25**	**43/56**	**7.68**	**40/44**	**9.09**	**47.5/56**	**8.48**
Overall Score	**104.5/204**	**10.76**	**71/160**	**13.05**	**40/44**	**22.72**	**123.25/204**	**16.09**
Overall Score With Deduction (If Applicable)	**NA**	**10.76**	**NA**	**11.05**	**NA**	**NA**	**NA**	**14.09**

Table 4.8: Results of plan coding for Kitty Hawk
HMP=hazard mitigation plan
LUP=land use plan
Imp=implementation
Unstan=unstandardized
Stan=standardized

The capability assessment in the hazard mitigation plan was only somewhat inclusive of the criteria included in the plan coding instrument, receiving subcategory scores 10.5/12 for acquisition and elevation and 15.5/32 for development regulations. This yielded a total capability assessment score of 26/44, and a standardized score of 2.95/5. The goals/actions section was generally ineffective, although much of what was not included in the hazard mitigation plan was included in the land use plan, thus nullifying many of the hazard mitigation scores in the overall planning score. The hazard mitigation plan received a score of 0/4 for the land suitability analysis subcategory, 0/4 for the development compatibility assessment subcategory, 0/4 for the land use trends subcategory, 0/12 for the acquisition and elevation subcategory, and 7/32 for the development regulations subcategory. This yielded a total goals/actions score of 7/56, and a standardized score of 1.25/10. Adding up the four category scores produced a total hazard mitigation score of 104.5/204 and a standardized score of 10.76/25 (see Appendix C for further details).

The 2003/2004 Kitty Hawk CAMA Land Use Plan was generally ineffective at addressing acute hazards. The floods subcategory received a score of 4/20, the hurricanes subcategory received a score of 8/20, and the nor'easters subcategory received a score of 2/20. This yielded a total acute hazard identification score of 14/60, and a standardized score of 1.17/5. At the time that this plan was implemented, the current hazard mitigation plan had not yet been written, but assuming acute hazards were mentioned in similar detail in the former hazard mitigation plan, this may potentially explain the low score. For chronic hazard identification, coastal erosion once again scored the highest of the three subcategories, receiving a score of 12/20, as opposed to 2/20 for sea level rise and 0/4 for climate change. This yielded a total chronic hazards score of 14/44, and a standardized score of 1.59/5. This was the only one of the six plans coded which scored higher for chronic hazards than acute hazards, although both scores were low.

This land use plan did not include a capability assessment. Since a detailed capability assessment was included in the hazard mitigation plan, it was determined unnecessary to deduct points for not including a section that would have been repetitive. Although this section would have been evaluated if it were present, it was determined that averaging in a 0 for this section would have given Kitty Hawk's final score an unnecessarily low bias. Thus, although that section does not exist, the overall score was standardized in a manner consistent with the other two communities. For goals/actions, subcategory scores were 4/4 for land suitability analysis, 4/4 for compatibility assessment, 4/4 for land use trends, 3/12 for acquisition/elevation, and 28/32 for development regulations. This yielded a total goals/actions score of 43/56, and a standardized score of 7.68/10. Adding together the four category scores produced a total land use plan score of 71/160, and a standardized score of 13.05/25. However, since the land use plan was written >5 years ago and the town has not yet adopted a new land use plan, 2 points were deducted from the overall score, resulting in a final land use plan score of 11.05 (See Appendix C for further details).

The implementation evaluation was conducted via personal correspondence with the Kitty Hawk Town Planner and only applies to the acquisition/elevation and development regulations subcategories of the goals/actions category. Kitty Hawk currently has one planner, a building inspector, a zoning technician and a code enforcement officer on staff. According to the Town Planner, the 2003/2004 land use plan was adopted in 2005. Although the land use plan update should have been completed already, DCM has recently appointed a committee to review the CAMA standards and has told Kitty Hawk to hold off on writing another plan for the time being. It is estimated to be at least another two years before an updated plan is completed. Of worthy note is that the 2003/2004 land use plan was written under a different, more conservative town council and thus many of the goals and objectives of this plan are no longer being pursued. For example, one of the goals of the land use plan was to make beach nourishment the primary method of erosion control. However, the current council does not support beach nourishment, and there have been no beach nourishment projects undertaken since the plan was written. Dune stabilization is now the primary method of erosion control. According to the Town Planner, Kitty Hawk is tied for the best CRS score on the Outer Banks and is one of only two Outer Banks communities which have adopted a 1-ft freeboard in addition to the 1-ft above BFE required by CRS (the other two study communities have adopted 1-ft freeboards as well, but neither is on the Outer Banks). In order to limit development density, Kitty Hawk has imposed height limitations, size limitations, and overall density limitations. With only two exceptions, buildings are limited to 35 feet and the majority of the community is low density residential (3 units/acre). According to the Town Planner, Kitty Hawk is almost built to capacity at this point, and he does not foresee increased growth to be a significant issue given the limited amount of land left. Kitty Hawk complies with the CAMA setback regulations and all oceanfront properties are currently within this zone, meaning that the town cannot allow any development or redevelopment to the east of Highway 12. The town acquired about 60 oceanfront lots after the land use plan was completed, but there has been no acquisition in recent years nor is any expected in the future. Kitty Hawk continues to enforce the North Carolina state building code, which recently increased its standards for structures subject to high velocity winds. Kitty Hawk is currently working with the North Carolina Department of Transportation (NCDOT) on a stormwater management plan, but the proposed plan surpasses the town's current budget. The Town Planner is skeptical that this plan will be implemented, at least in the foreseeable future. The Town Planner noted that Kitty Hawk does not undertake structure relocation because the oceanfront lots do not have enough depth. However, the community has a program in place in which it will work with homeowners to identify problems and apply for a grant with Dare County to elevate homes to a higher level. Many homeowners have chosen to do this for the insurance benefits, although the town does not provide direct funding (Joe Heard, personal communication, 03/16/2011).

After analysis of this meeting, Kitty Hawk received implementation scores of 10/12 for the acquisition/elevation subcategory and 30/32 for the development regulations subcategory. This yielded a total implementation score of 40/44 and a standardized score of 22.72/25.

Composite analysis of planning in Kitty Hawk led to standardized scores of 2.73/5 for acute hazard identification, 1.93/5 for chronic hazard identification, 2.95/5 for capability assessment and 8.48/10 for goals actions. Once again, 2 points were deducted from the overall score since the most recent plan is >5 years old. This yielded a total planning score of 14.09/25 for Kitty Hawk (see Appendix C).

Resilience

With a total vulnerability score of 3.67 and a total planning score of 12.57, the resilience score was calculated using the formula mentioned previously (Resilience score=√planning score*(5-vulnerability score)). This yielded a resilience score of 4.20/10 for Kitty Hawk. Next, a resilience potential score was calculated assuming a perfect planning score of 25, yielding a resilience score of 5.59/10. Thus, Kitty Hawk can improve its overall resilience with more effective planning strategies (see Table 4.9).

Community	Kitty Hawk
Vulnerability Score	3.75
5-Vulnerability Score	1.25
Planning Score	14.09
Planning Score x (5-Vulnerability Score)	17.6125
Resilience Score	**4.20**
Resilience Potential Score	**5.59**

Table 4.9: Resilience scores for Kitty Hawk.
*Resilience Score=√Planning Score x (5-Vulnerability Score)
*Resilience Score is out of 10

Community Comparison and Overall Trends

Vulnerability

After assessing vulnerability to each of the six variables and ranking each community, Kitty Hawk was found to be the most vulnerable of the three communities with an overall score of 3.75, followed closely by Topsail Beach with an overall score of 3.67 (Table 4.10). Both Kitty Hawk and Topsail Beach scored in either the high or very high vulnerability category for five of the six variables. Sunset Beach was far and away the least vulnerable of the three communities with an overall score of 3.17, scoring in the high vulnerability category for three of the six variables. Sunset Beach did not score in the very high vulnerability category for any of the six variables.

Of the six variables analyzed, the study communities overall were most vulnerable to flooding, with all three scoring at least in the high vulnerability category (Sunset Beach-4, Topsail Beach-5, Kitty Hawk-4.5). The next most significant hazards were found to be sea level rise (Sunset Beach-3.5, Topsail Beach-3.5, Kitty Hawk-5) and nor'easters (Sunset Beach-3.5, Topsail Beach-3.5, Kitty Hawk-4.5), all of which were at least in the high vulnerability category for all three communities. Both Topsail Beach and Kitty Hawk scored in the high category for hurricanes both with scores of 3.5, while Sunset Beach scored in the moderate category with a score of 3. Of the five hazards analyzed, the study communities were least vulnerable to long-term erosion, with both Sunset Beach and Topsail Beach scoring in the moderate category (scores of 2.5 and 2.5 respectively) and Kitty Hawk scoring in the high category (3.5). Of the six variables analyzed, the communities overall scored lowest for island width, with Kitty Hawk scoring in the low category (1.5) and Sunset Beach scoring in the moderate category (2.5). The one exception here was Topsail Beach, which scored in the high category (4) for island width (see Table 4.1 and Appendix A).

Hazard	**Sunset Beach**	**Topsail Beach**	**Kitty Hawk**	**Total**
Erosion (long-term)	2.5	2.5	3.5	8.5
Sea level Rise	3.5	3.5	5	12
Hurricanes	3	3.5	3.5	10
Nor'easters	3.5	3.5	4.5	11.5
Flooding	4	5	4.5	13.5
Width	2.5	4	1.5	8
Total	19	22	22.5	
Cumulative Average	**3.17**	**3.67**	**3.75**	
Vulnerability	**Moderate**	**High**	**High**	

Table 4.10: Total vulnerability scores for three communities.
1.00-1.49=extremely low vulnerability
1.50-2.49=low vulnerability
2.50-3.49=moderate vulnerability
3.50-4.49=high vulnerability
4.50-5=extremely high vulnerability

Planning

For all three study communities, plans were more effective at addressing acute hazards than chronic hazards (Table 4.11). Topsail Beach scored highest overall for acute hazard identification with a score of 3.50. Sunset Beach and Kitty Hawk scored 2.83 and 2.73, respectively. Both Kitty Hawk and Topsail Beach scored 1.93 for chronic hazard identification and Sunset Beach scored 1.82. The one chronic hazard that the communities did effectively address was long-term erosion, as this is the most easily measureable of the chronic hazards considered in this analysis. However, all three communities gave sea level rise and climate change minimal, if any, consideration. This is not an unexpected result, as humans have an inclination to focus more resources on short-term, recurring disasters than on those for which there is much uncertainty and for which changes are difficult to detect on an observable timescale. In addition, goals outlined by the CRC have avoided these issues, so there is little guidance from the State.

In general, all three communities were only somewhat effective in addressing community capability. Kitty Hawk had the highest capability assessment score with a 2.95, followed by Sunset Beach at 2.50 and Topsail Beach at 2.30. Both Sunset Beach and Kitty Hawk were very effective at addressing and implementing their goals and objectives. In addition, many of the goals and objectives proposed and implemented are at least somewhat adaptive in nature, such as the 1-ft. freeboards. Sunset Beach and Kitty Hawk scored 8.84 and 8.48, respectively for the goals/actions category. Topsail Beach was not quite as effective for this category, scoring 6.84, which, in this scheme, is a good score but still compares poorly with the other two communities.

Both Topsail Beach and Kitty Hawk had fairly low hazard mitigation scores, with scores of 10.05 and 10.76 respectively. This was partially due to the fact that they are both subsumed under their county multijurisdictional plans. Sunset Beach's hazard mitigation plan was significantly better, with a score of 13.89. Sunset Beach also had the best land use plan with a score of 14.18. However, the land use plan for Topsail Beach scored higher than the land use plan for Sunset Beach before the 2-point deduction for being outdated (15.34 before deduction and 13.34 after deduction). Kitty Hawk's land use plan scored the lowest for all three communities both before and after the deduction (13.05 before and 11.05 after), which is due in part to the fact that the town council under which it was written favored structural mitigation over adaptation. Topsail Beach scored significantly lower than both Kitty Hawk and Sunset Beach for implementation with a score of 15.35. Kitty Hawk and Sunset Beach both had excellent implementation scores of 22.72 and 24.43, respectively. Sunset Beach also had the highest overall planning score of 15.99. Kitty Hawk actually had a slightly higher overall score than Sunset Beach before the deduction (16.09 before and 14.09 after). Topsail Beach had the lowest overall planning score both before and after the deduction (14.57 before and 12.57 after). Table 4.11 breaks down the planning scores by each individual plan and major category.

	Sunset Beach	**Topsail Beach**	**Kitty Hawk**
HMP	*13.89/25*	*10.05/25*	*10.76/25*
Acute Hazards	4.17/5	3.83/5	4.29/5
Chronic Hazards	1.82/5	1.82/5	2.27/5
Capability Assessment	2.27/5	1.36/5	2.95/5
Goals/Objectives	5.63/10	3.04/5	1.25/5
LUP	*14.18/25*	*13.34/25*	*11.05/25*
Acute Hazards	1.50/5	3.17/5	1.17/5
Chronic Hazards	1.82/5	2.05/5	1.59/5
Capability Assessment	2.73/5	3.24/5	NA
Goals/Objectives	8.13/10	6.88/10	7.68/10
Implementation	*24.43/25*	*15.34/25*	*22.73/25*
Total	**15.99/25**	**12.57/25**	**14.09/25**

Figure 4.11: Total planning scores for three communities
*All scores are standardized.

Resilience

Since Sunset Beach had both the lowest vulnerability and highest planning scores of the three communities, it was also by far the most resilient with a score of 5.41. Since Sunset Beach was the least vulnerable, it also had the highest resilience potential score of the three communities with a score of 6.76. Topsail Beach was found to be the least resilient of the three communities with a score of 4.09, but only slightly below that of Kitty Hawk with a score of 4.20. It is worth noting that, although the current level of resilience is higher in Kitty Hawk than in Topsail Beach, Topsail Beach has a higher resilience potential (5.77) than Kitty Hawk (5.59) due to the slightly lower vulnerability of Topsail Beach. This implies that Kitty Hawk is currently closer to achieving its resilience potential given its current state of vulnerability than is Topsail Beach (Table 4.12).

Community	Vulnerability Score	5-Vulnerability Score	Planning Score	Planning Score x (5-Vulnerability Score)	Resilience Score	Resilience Potential Score
Kitty Hawk	3.75	1.25	14.09	17.6125	**4.20**	**5.59**
Topsail Beach	3.67	1.33	12.57	16.7181	**4.09**	**5.77**
Sunset Beach	3.17	1.83	15.99	29.2617	**5.41**	**6.76**

Table 4.12: Total resilience scores for three communities.
Resilience Score=√Planning Score(5-Vulnerability Score); *Resilience Score is out of 10

CHAPTER 5: DISCUSSION AND CONCLUSIONS

The analysis presented in this research has 1) measured the vulnerability of three coastal communities to a series of biophysical hazards, 2) evaluated the plan quality of these three communities as they relate to hazards and vulnerability, and 3) measured the resilience of the natural and built environments in each of these three communities. Based upon the analysis presented above, the questions posed at the beginning of this research have effectively been answered.

1) Are differences in physical vulnerability reflected in land use planning?

Not necessarily. For example, Sunset Beach has the lowest vulnerability of the three communities, yet still has the most proactive planning approaches. To get the full picture, vulnerability must be examined separately, as has been done here.

2) How do planning strategies differ amongst three communities along the North Carolina coast?

All coastal communities in North Carolina must adhere to the same regulations as stipulated by CAMA, and in some cases CRS. However, beyond that, communities can be very different in terms of their planning approaches for dealing with hazards, as was seen with the three study communities in this analysis. Some communities follow the minimum regulations, while others choose to employ additional locally mandated ordinances. For example, both Kitty Hawk and Topsail Beach adhere to the minimum CAMA ocean-erodible setback guidelines, while Sunset Beach imposes stricter setback regulations. In addition, some communities tend to plan for resistance to change while others have begun to factor more adaptive measures into their plans.

3) Can these three communities be used to make generalizations about North Carolina's coast as a whole?

Due to differences in planning approaches from community to community, no one community typifies North Carolina's coast as a whole, but rather the three taken together illustrate at least part of the range of planning approaches that can be implemented in this region.

4) Are communities better at planning for acute or chronic hazards?

The three communities analyzed were significantly better at planning for acute hazards than for chronic hazards. This would have most likely been the case for any other community along the North Carolina coast as well. Acute hazards such as flooding and coastal storms are generally known quantities, and past experience with these short-duration, high intensity events, although sometimes catastrophic, has helped these communities better prepare for future events. Although erosion was considered to be a chronic hazard in this analysis, the communities did effectively address it because it is measureable and in many cases, most notably in the town of Kitty Hawk, has become an immediate threat.

With chronic hazards such as sea level rise and climate change, communities know they are happening, but are either reluctant to take action or simply do not know how, due to the significant level of uncertainty involved and a perceived lack of viable solutions. Sea level rise is a very controversial issue in many coastal communities and according to the Sunset Beach Contract Planner, some refuse to even acknowledge it as a hazard at all (Landin Holland, personal communication, 05/01/2011).

5) Which communities (if any) are employing adaptive strategies to deal with natural hazards?

All three communities in this analysis are employing at least some adaptive strategies to varying degrees. For example, all three communities participate in the CRS program, employ a 1-foot freeboard, and have good CRS ratings. However, both Kitty Hawk and Sunset Beach were found to be significantly more proactive in terms of adaptation than Topsail Beach. For example, Topsail Beach is relying on traditional mitigation measures such as beach nourishment and is proposing the construction of a jetty or a groin in the future. The homes in Kitty Hawk, on the other hand, face an even more impending threat from erosion, yet the current town council will not undertake beach nourishment. While the houses along the immediate shoreline are in jeopardy, the most adaptive option in this case may just be to let them be overtaken, which is basically what the town is doing. Sunset Beach does not undertake beach nourishment either, nor does it have any need to because the homes do not face an immediate threat like they do in the other communities. Sunset Beach and Kitty Hawk are also very strict about enforcing their regulations, as evidenced by comments from the planners.

6) Which communities are most resilient and why?

Sunset Beach was found to be the most resilient of the three communities because it faces the lowest physical vulnerability, its plans were the strongest and most up-to-date, and it was most effective at implementing its policies and ordinances. Sunset Beach is also the only one of the three communities which has exceeded the minimum CAMA guidelines for setbacks within the community. As a result, none of the homes in Sunset Beach face an immediate threat from beach erosion like they are facing in the other two study communities.

Kitty Hawk was found to be significantly less resilient than Sunset Beach. This is partially due to Kitty Hawk's higher physical vulnerability. This is also, at least in part, owing to the fact that Kitty Hawk's land use plan is outdated and in many cases not consistent with the current goals and policies of the community. So while Kitty Hawk has been very proactive in implementing adaptive policies, the town would significantly benefit from a new land use plan, rather than having to use one which is outdated and written under a different council which favored more traditional mitigation approaches.

Topsail Beach was found to be the least resilient of the three communities. This is due to a combination of high physical vulnerability, an outdated land use plan, and the implementation of more traditional mitigation policies. It is interesting to note that although Kitty Hawk was found to be slightly more vulnerable than Topsail Beach, it is still more resilient due to more adaptive planning approaches and implementation. Topsail Beach would greatly benefit from an updated land use plan with more adaptive approaches towards hazard mitigation, including some of those being employed in Sunset Beach and Kitty Hawk.

7) Can we build a high level of resilience in these communities with good planning, or is their natural vulnerability simply too great to overcome?

Although resilience will always be limited by physical vulnerability, all of these communities can achieve a higher level of resilience than they have currently with more effective planning practices and more consistency between the content of the plans and the policies that are implemented and enforced. Sunset Beach is currently the most resilient of the three communities and also has the potential to be the most resilient of the three communities with a perfect planning score. Although Kitty Hawk is currently more resilient than Topsail Beach, Topsail Beach has the potential to be more resilient than Kitty Hawk if both communities had perfect planning scores, given the fact that Kitty Hawk is more physically vulnerable than Topsail Beach.

Implications for Vulnerable Coastal Communities

It is not the intention of this research to criticize any community for having “bad” planning approaches. It is also not reasonable to say that certain planning approaches are “right” and that certain planning approaches are “wrong”. It is recognized that hazards planning, particularly in highly vulnerable coastal communities, is an extremely difficult task because there is no one-fix-all solution. Similarly, every potential solution has its own associated drawbacks. Thus, this document should be used solely as a yardstick for measuring progress towards greater environmental resilience, not for policy recommendations. However, by identifying the areas where plans need more emphasis, it is hoped that communities will develop the appropriate policies to decrease vulnerability and increase resilience.

Based upon the results from these three communities, it is evident that coastal communities are doing an effective job at addressing acute hazards. However, chronic hazards such as sea level rise and climate change are given very little consideration in local planning. As previously mentioned, this is a very controversial issue which many communities purposely do not address because there are perceived to be very few viable solutions. This may be due in part to economic and political issues, such as cost or feasibility. In large part, this issue boils down to the desires of the property owners, because they are the ones who ultimately have the most to lose or gain. However, it is important that communities begin thinking about, and coming up with, potential strategies to adapt to sea level rise.

Shortcomings and Limitations

It is worth mention that the above analysis has essentially taken qualitative data and turned them into quantitative scores. Thus, the scores calculated are not meant to be taken as fact, but rather used as a tool to determine overall trends and make comparisons, which this analysis has effectively accomplished. This section does not refer to scores, just overall trends as reflected by the scores.

Like any analysis of this magnitude, the accuracy of this particular resilience index was limited by the data available and the method in which the data were interpreted and processed. There were several value judgments which had to be made for data that were not readily available (such as local relative sea level rise for the communities of interest). In addition, small changes or perturbations (such as beach nourishment when calculating natural erosion rates), have the potential to affect the accuracy of and cause errors within the data, which were not tested for during this analysis. It is suggested that subsequent research involving the environmental resilience of these communities and others include a sensitivity analysis in order to determine whether or not small errors in the data or the processing of the data will significantly skew the overall results. This will ensure a higher level of accuracy with the final product. It is also important to keep in mind that while it is assumed that these communities can be used to represent the entire North Carolina coast, more sample communities would enable more certain generalizations.

Contributions and Directions for Future Research

There is great value in using a structured metric in the development of a diagnostic tool for communities. To this end, this analysis has successfully applied vulnerability assessment and plan coding to the evaluation and comparison of community resilience. Optimally, this resilience index could be most effectively utilized by planners outside of the individual communities at risk, such as at the county or state level, or by consulting planners for a non-biased evaluation. The results would subsequently be passed on to local planners within the communities so they can begin thinking about and ultimately implementing more adaptive planning approaches to decrease vulnerability and increase resilience. The index thus serves a practical function for planners and coastal managers not only in the three study communities, but in other communities along the North Carolina coast, and ultimately in other coastal areas outside the state (although it is likely that the index will have to be altered at least somewhat to reflect the hazards facing different geographic locations).

Although the methodology for this analysis was carefully crafted and refined throughout the entire process, future research on environmental resilience at the community level should continue to refine this metric (for example, by incorporating a sensitivity analysis) to ensure a high level of accuracy amongst the results. In addition to refining the metric for these three communities, subsequent studies should begin to examine other coastal communities so the results could be ultimately combined into a meta-analysis. The geographic area of focus for this meta-analysis could increase over time as the project becomes more in-depth. However, as the project becomes larger, it will be important to not over-generalize and thus to continue to stress the value of analysis at the community level. Thus, one must not lose sight of the ultimate goal of providing knowledge that will help communities more effectively plan for, cope with, and adapt to natural disasters and environmental variability.

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APPENDIX A: VULNERABILITY ASSESSMENT

2004 Erosion Rate (net loss in ft/yr.)

Community	**Sunset Beach**	**Topsail Beach**	**Kitty Hawk**
2004 Erosion Rate (net loss in ft/yr.)			
Max	4	2	4.4
Min	-30.9	-24.4	0.3
Range	34.9	26.4	4.1
Avg.	-6.5	-2.9	2.3
Standard Deviation	6.3	5.5	1.1
% <-10	17.4	15.2	0
% -5 - -10	47.8	0.6	0
% 0 - -5	17.4	73.2	0
% 0 – 2	6.5	11	46.5
% 2 – 5	10.9	0	53.5
% 5 – 10	0	0	0
%>10	0	0	0
Score	**2.5**	**1.5**	**3.5**

1 (Extremely low vulnerability): Erosion rate is ≤0 for entire community
1.5 (low vulnerability): Average erosion rate is ≤0 and no part of community is eroding >2 ft/yr.
2 (low vulnerability): Average erosion rate is ≤0, <10% of community is eroding 2 - 5 ft/yr., and no part of community is eroding >5 ft/yr.
2.5 (moderate vulnerability): Average erosion rate is ≤2 ft/yr., <25% of community is eroding 2 - 5 ft/yr., and no part of community is eroding >5 ft/yr.
3 (moderate vulnerability): Average erosion rate is ≤2 ft/yr., <50% of community is eroding 2 - 5 ft/yr., and no part of community is eroding >5 ft/yr.
3.5 (high vulnerability): Average erosion rate is ≤5 ft/yr. and <10% of community is eroding >5 ft/yr.
4 (high vulnerability): Average erosion rate is ≤5 ft/yr. and <25% of community is eroding >5 ft/yr.
4.5 (extremely high vulnerability): Average erosion rate is ≤10 ft/yr. and <25% of community is eroding >10 ft/yr.
5 (extremely high vulnerability): Average erosion rate is ≥5 ft/yr. or >25% of community is eroding >10ft/yr.
* Data sources: NC DCM (2011), ArcGIS analysis

2004 Erosion Rate with no Inlet Hazard Areas (net loss in ft/yr.)

Community	**Sunset Beach**	**Topsail Beach**	**Kitty Hawk**
2004 Erosion Rate (net loss in ft/yr.)			
Max	4	2	4.4
Min	-9	-17	0.3
Range	13	19	4.1
Avg.	-4.67	-1.09	2.3
Standard Deviation	4.49	1.91	1.1
% <-10	0	1.5	0
% -5 - -10	61.2	0.8	0
% 0 - -5	16.4	90.2	0
% 0 – 2	7.5	7.5	46.5
% 2 – 5	14.9	0	53.5
% 5 – 10	0	0	0
%>10	0	0	0
Score	**2.5**	**1.5**	**3.5**

Note: Erosion rates do not include inlet hazard areas

1 (Extremely low vulnerability): Erosion rate is ≤0 for entire community

1.5 (low vulnerability): Average erosion rate is ≤0 and no part of community is eroding >2 ft./yr.

2 (low vulnerability): Average erosion rate is ≤0, <10% of community is eroding 2 - 5 ft/yr., and no part of community is eroding >5 ft/yr.

2.5 (moderate vulnerability): Average erosion rate is ≤2 ft/yr., <25% of community is eroding 2 - 5 ft/yr., and no part of community is eroding >5 ft/yr.

3 (moderate vulnerability): Average erosion rate is ≤2 ft/yr., <50% of community is eroding 2 - 5 ft/yr., and no part of community is eroding >5 ft/yr.

3.5 (high vulnerability): Average erosion rate is ≤5 ft/yr. and <10% of community is eroding >5 ft/yr.

4 (high vulnerability): Average erosion rate is ≤5 ft/yr. and <25% of community is eroding >5 ft/yr.

4.5 (extremely high vulnerability): Average erosion rate is ≤10 ft/yr. and <25% of community is eroding >10 ft/yr.

5 (extremely high vulnerability): Average erosion rate is ≥5 ft/yr. or >25% of community is eroding >10ft/yr.

* Data sources: NC DCM (2011), ArcGIS analysis

Long-term Rate (net loss in ft/yr.)

Community	**Sunset Beach**	**Topsail Beach**	**Kitty Hawk**
Long-term Rate (net loss in ft/yr.)			
Max	2	2	4
Min	2	2	2
Range	0	0	2
Avg.	2	2	≈2.7
Standard Deviation	0	0	NA
% <-10	0	0	0
% -5.01 - -10	0	0	0
% 0 - -5	0	0	0
% 0.01 – 2	100	100	≈50
% 2.01 – 5	0	0	≈50
% 5.01 – 10	0	0	0
%>10	0	0	0
Score	**2.5**	**2.5**	**3.5**

1 (Extremely low vulnerability): Erosion rate is ≤0 for entire community
1.5 (low vulnerability): Average erosion rate is ≤0 and no part of community is eroding >2 ft/yr.
2 (low vulnerability): Average erosion rate is ≤0, <10% of community is eroding 2 - 5 ft/yr., and no part of community is eroding >5 ft/yr.
2.5 (moderate vulnerability): Average erosion rate is ≤2 ft/yr., <25% of community is eroding 2.01 - 5 ft/yr., and no part of community is eroding >5 ft/yr.
3 (moderate vulnerability): Average erosion rate is ≤2 ft/yr., <50% of community is eroding 2.01 - 5 ft/yr., and no part of community is eroding >5 ft/yr.
3.5 (high vulnerability): Average erosion rate is ≤5 ft/yr. and <10% of community is eroding >5 ft/yr.
4 (high vulnerability): Average erosion rate is ≤5 ft/yr. and <25% of community is eroding >5 ft/yr.
4.5 (extremely high vulnerability): Average erosion rate is ≤10 ft/yr. and <25% of community is eroding >10 ft/yr.
5 (extremely high vulnerability): Average erosion rate is ≥5 ft/yr. or >25% of community is eroding >10ft/yr.
* Data sources: NC DCM (2011)

Relative Sea Level Rise

Community	Relative sea level rise (ft/yr)	Error Range +/- (ft/yr)	Years of record	Score
Duck	0.0140	0.0024	1978-2002	5
Kitty Hawk	0.0137	NA	Interpolated	**5**
Cape Hatteras	0.0113	0.0025	1978-2002	4.5
Beaufort	0.0105	0.0018	1973-2002	4.5
Topsail Beach	0.0079	NA	Interpolated	**3.5**
Wilmington	0.0070	0.0008	1935-2002	3.5
Southport	0.0067	0.0008	1933-1954, 1976-1988	3.5
Sunset Beach	0.0079	NA	Interpolated	**3.5**

1 (extremely low vulnerability): Sea level is lowering or not rising
1.5 (low vulnerability): Sea level is rising 0-0.0016 ft./yr.
2.0 (low vulnerability): Sea level is rising 0.0017-0.0033 ft./yr.
2.5 (moderate vulnerability): Sea level is rising 0.0034-0.0049 ft./yr.
3 (moderate vulnerability): Sea level is rising 0.0050-0.0066 ft./yr.
3.5 (high vulnerability): Sea level is rising 0.0067-0.0082 ft./yr.
4 (high vulnerability): Sea level is rising 0.0083-0.0098 ft./yr.
4.5 (extremely high vulnerability): Sea level is rising 0.0099-0.0115 ft./yr.

5 (extremely high vulnerability): Sea level is rising >0.0115 ft./yr.
*Data Sources: NC CRC (2010), Thieler and Hammar-Klose (1999), ArcGIS analysis

*Values for study communities are interpolated between locations with the longest periods of record due to lack of specific location data, but are consistent when compared to relative sea level rise risk rankings by Thieler and Hammar-Klose (1999)
*Values were initially in mm/yr. and converted to ft./yr.

Hurricanes 1851-2010

Community	**Sunset Beach**	**Topsail Beach**	**Kitty Hawk**
hurricanes <100 miles	39	46	42
% Chance	24.375	28.75	26.25
hurricanes <50 miles	18	21	19
% Chance	11.25	13.125	11.875
hurricanes <20 miles	6	6	11
% Chance	3.75	3.75	6.875
major hurricanes <100 miles	7	10	7
% Chance	4.375	6.25	4.375
major hurricanes <50 miles	4	5	2
% Chance	2.5	3.125	1.25
major hurricanes <20 miles	1	0	1
% Chance	0.625	0	0.625
Average percent chance	7.813	9.167	8.542
Score	**3**	**3.5**	**3.5**

% Chance=# of storms/years of record*100 (there are 160 years of record)
Average percent chance=sum of all % Chance/6
1 (extremely low vulnerability): average percent chance of 0
1.5 (low vulnerability): average percent chance of 0-2
2 (low vulnerability): average percent chance of 2-4
2.5 (moderate vulnerability): average percent chance of 4-6
3 (moderate vulnerability): average percent chance of 6-8
3.5 (high vulnerability): average percent chance of 8-10
4 (high vulnerability): average percent chance of 10-12
4.5 (very high vulnerability): average percent chance of 12-14
5 (very high vulnerability): average percent chance >14
*Data Source: NOAA (2011)

Nor'easters 1961-1998

Community	**Sunset Beach**	**Topsail Beach**	**Kitty Hawk**
nor'easters <100 miles	68	77	102
Storms/yr.	1.789	2.0263	2.684
nor'easters <50 miles	38	35	52
Storms/yr.	1	0.921	1.368
nor'easters <20 miles	15	14	20
Storms/yr.	0.395	0.368	0.526
Average frequency	1.061	1.105	1.526
Score	**3.5**	**3.5**	**4.5**

1 (extremely low frequency): Average frequency <0.2
1.5 (low frequency): Average frequency 0.2-0.4
2 (low frequency): Average frequency 0.4-0.6
2.5 (moderate frequency): Average frequency 0.6-0.8
3 (moderate frequency): Average frequency 0.8-1.0
3.5 (high frequency): Average frequency 1.0-1.2
4 (high frequency): Average frequency 1.2-1.4
4.5 (extremely high frequency): Average frequency 1.4-1.6
5 (extremely high frequency): Average frequency >1.6
Data Source: NASA (2011)

Flooding

Community	Sunset Beach	Topsail Beach	Kitty Hawk
% in VE Zone	47	91	<10
% in VE and AE Zone	55	98	85
% of island in VE Zone (if partially mainland)	60	NA	NA
% of island in VE and AE Zone (if partially mainland)	99	NA	NA
% storm surge inundation in cat 1-2 hurricane	55	71	≈40
% storm surge inundation in cat 3 hurricane	65	73	ND
% storm surge inundation in cat 4-5 hurricane	85	74	ND
Score	**4**	**5**	**4.5**

1 (very low vulnerability): <5% of community is in VE, <10% is in AE and VE, <5% is inundated by cat 1&2 storm surge, <10% is inundated by cat 3 storm surge, <15 is inundated by cat 4&5 storm surge
1.5 (low vulnerability): <10% of community and <20% of island (if mainland) is in VE, <20% of community and <40% of island (if mainland) is in VE and AE, <10% inundated by cat 1&2 storm, <20% inundated by cat 3 storm, <30% inundated by cat 4&5 storm
2 (low vulnerability): <20% of community and <40% of island (if mainland) is in VE, <30% of community and 60% of island (if mainland) is in VE and AE, <25% inundated by cat 1&2 storm, <40% inundated by cat 3 storm, <50% inundated by cat 4&5 storm
2.5 (moderate vulnerability): <30% of community and <60% of island (if mainland) is in VE, <40% of community and 70% of island (if mainland) is in VE and AE, <40% inundated by cat 1&2 storm, <55% inundated by cat 3 storm, <70% inundated by cat 4&5 storm
3 (moderate vulnerability): <40% of community and <70% of island (if mainland) is in VE, <50% of community and 80% of island (if mainland) is in VE and AE, <50% inundated by cat 1&2 storm, <65% inundated by cat 3 storm, <80% inundated by cat 4&5 storm
3.5 (high vulnerability): <50% of community and <80% of island (if mainland) is in VE, <60% of community and 90% of island (if mainland) is in VE and AE, <60% inundated by cat 1&2 storm, <75% inundated by cat 3 storm, <90% inundated by cat 4&5 storm
4 (high vulnerability): <60% of community and <90% of island (if mainland) is in VE, <70% of community is in VE and AE, <70% inundated by cat 1&2 storm, <85% inundated by cat 3 storm
4.5 (extremely high vulnerability): <80% of community is in VE, <90% of community is in VE and AE, <80% inundated by cat 1&2 storm

5 (extremely high vulnerability): >80% of community is in VE, or >90% of community is in VE and AE, or >80% inundated by cat 1&2 storm
*NA=not applicable
*ND=no data
*Data sources: NC Floodplain Mapping Information System (2011), Town of Kitty Hawk Planning Board (2004), Town Sunset Beach Planning Board (2007), Town of Topsail Beach Planning Board (2005), Town of Kitty Hawk (2011), Dare County, NC (2011)
*Some of data for Kitty Hawk is based upon inference from flood/storm surge maps and is not exact, but clear enough to categorize based on above criteria

Island Width

Community	Sunset Beach	Topsail Beach	Kitty Hawk
Max. width (mi)	1.03	0.33	2.95
Min. width (mi)	0.18	0.09	0.65
Incorporated mainland areas	Yes	No	No
Wetlands present	29%	45%	>20%
Score	**2.5**	**4**	**1.5**

1 (extremely low vulnerability): Min. island width is >1 mi and >20% wetlands
1.5 (low vulnerability): Min. island width is >0.5 mi, max. island width is >1 mile, and >20% wetlands
2 (low vulnerability): Min. island width is >0.5 mi with no mainland areas or min. island width is >0.25 mi with mainland areas, max island width is >0.5 mi, and >20% wetlands
2.5 (moderate vulnerability): Min. island width is >0.25 mi with no mainland areas or min. island width is >0.1mi with mainland areas, max. island width is >0.5 mi, and >15% wetlands
3 (moderate vulnerability): Min island width is >0.1 mi with no mainland areas or min. island width is <0.1 mi with mainland areas, max island width is >0.5 mi, and >15% wetlands
3.5 (high vulnerability): Min. island width is >0.1 mi with no mainland areas or min. island width is <0.1 mi with mainland areas, max. island width is >0.25 mi, and >10% wetlands
4 (high vulnerability): Max. island width is >0.25 mi, and >10% wetlands
4.5 (extremely high vulnerability): Max. island width is >0.1 mi
5 (extremely high vulnerability): Max. island width is <0.1 mi
* Data sources: NC DCM (2011), NC OneMap (2011), Town of Kitty Hawk Planning Board (2004), Town Sunset Beach Planning Board (2007), Town of Topsail Beach Planning Board (2005),and ArcGIS analysis

Cumulative with long-term erosion rates

Hazard	**Sunset Beach**	**Topsail Beach**	**Kitty Hawk**	**Total**
Erosion (long-term)	2.5	2.5	3.5	8.5
Sea level Rise	3.5	3.5	5	12
Hurricanes	3	3.5	3.5	10
Nor'easters	3.5	3.5	4.5	11.5
Flooding	4	5	4.5	13.5
Width	2.5	4	1.5	8
Total	19	22	22.5	
Cumulative Average	**3.17**	**3.67**	**3.75**	
Vulnerability	**Moderate**	**High**	**High**	

1.00-1.49=extremely low vulnerability
1.50-2.49=low vulnerability
2.50-3.49=moderate vulnerability
3.50-4.49=high vulnerability
4.50-5=extremely high vulnerability

APPENDIX B: ATLANTIC BEACH PILOT STUDY PLAN CODING INSTRUMENT

Atlantic Beach

Category	Hazard Mitigation Plan	Land Use Plan	Implementation	Total	Points Possible
Hazard Identification (Acute)	**12**	**4**	NA	**12**	**15**
Floods	5	4	NA	5	5
Delineates likelihood of floods	1	1	NA	1	1
Delineates location and boundaries of hazardous areas	1	1	NA	1	1
Delineates magnitude and severity of floods	1	1	NA	1	1
Describes separate characteristics of coastal flood hazards	1	1	NA	1	1
Includes information on past flood events	1	0	NA	1	1
Hurricanes/Coastal Storms	4	0	NA	4	5
Delineates likelihood of storms	0.5	0	NA	0.5	1
Delineates location and boundaries of hazardous areas	1	0	NA	1	1
Delineates magnitude and severity of storms	1	0	NA	1	1
Describes separate characteristics of storms	1	0	NA	1	1
Includes information on previous storms	0.5	0	NA	0.5	1
Nor'easters/Coastal Storms	3	0	NA	3	5
Delineates likelihood of storms	0.5	0	NA	0.5	1
Delineates location and boundaries of hazardous areas	0.5	0	NA	0.5	1
Delineates magnitude and severity of storms	0.5	0	NA	0.5	1
Describes separate characteristics of storms	1	0	NA	1	1
Includes information on previous storms	0.5	0	NA	0.5	1
Hazard Identification (Chronic)	**2.5**	**5**	NA	**4.5**	**11**
Coastal Erosion	2.5	2	NA	3	5
Delineates likelihood of erosion	0.5	1	NA	0.75	1

Delineates location and boundaries of hazardous areas	1	0	NA	1	1
Delineates magnitude and severity of erosion	0.5	1	NA	0.75	1
Describes separate characteristics of coastal erosion	0.5	0	NA	0.5	1
Includes information on past coastal erosion	0	0	NA	0	1
Sea Level Rise	0	3	NA	1.5	5
Delineates likelihood of sea level rise	0	1	NA	0.5	1
Delineates location and boundaries of hazardous areas	0	0	NA	0	1
Delineates magnitude and severity of sea level rise	0	1	NA	0.5	1
Describes separate characteristics of sea level rise	0	0	NA	0	1
Includes information on past sea level rise (if applicable)	0	1	NA	0.5	1
Climate Change (other than sea level rise)	0	0	NA	0	1
Risk/Vulnerability Assessment	**2**	**1.5**	NA	**2**	**2**
Multi-Hazard Risk Assessment	1	0.5	NA	1	1
Land Use Trends	1	1	NA	1	1
Capability Assessment	**0**	**7.5**	NA	**7.5**	**13**
Acquisition and Elevation	0	0.5	NA	0.5	4
Elevation of Structures	0	0	NA	0	1
Relocation	0	0.5	NA	0.5	1
Land Acquisition	0	0	NA	0	1
Structure Acquisition	0	0	NA	0	1
Development Regulations	0	7	NA	7	9
Erosion control	0	1	NA	1	1
Building Standards	0	0	NA	1	1
Density of Land Use	0	0.5	NA	0.5	1
Flood/Stormwater Management	0	1	NA	1	1
Hazards Included in Land Suitability analysis	0	1	NA	1	1
Protection of Natural Mitigation Features	0	0.5	NA	0.5	1
Setbacks of Buffer Zones	0	1	NA	1	1
Subdivision Regulations	0	1	NA	1	1

Zoning	0	1	NA	1	1
Proposed Actions	**5.5**	**8.38**	**9.88**	**9.5**	**13**
Acquisition and Elevation	1	0.5	2	1.33	4
Elevation of Structures	0	0	0.5	0.17	1
Relocation	0	0.5	0.5	0.5	1
Land Acquisition	0.5	0	0.5	0.33	1
Structure Acquisition	0.5	0	0.5	0.33	1
Development Regulations	4.5	7.88	7.88	8.17	9
Erosion control	0	1	0.5	0.75	1
Building Standards	1	0.5	1	0.88	1
Density of Land Use	0.5	1	1	1	1
Flood/Stormwater Management	1	1	1	1	1
Hazards Included in Land Suitability Analysis	0	NA	NA	NA	1
Protect Natural Mitigation Features	0.5	1	1	1	1
Setbacks of Buffer Zones	0	1	0.5	0.75	1
Subdivisions	1	0.5	1	0.88	1
Zoning	0.5	1	1	1	1
Overall Score	**22**	**26.38**	**41.08**	**35.5**	**54**
Standardized Score	**0.41**	**0.49**	**0.76**	**0.66**	**1**

*For all subcategories of Hazard Mitigation Plan and Land Use Plan columns:

0=not present, 0.5=present but not detailed, 1.0=present and detailed, NA =not applicable

*For Implementation:

0=not being implemented, 0.5=being implemented to a partial extent, 1.0=being fully implemented, NA=not applicable

*Scores in italics=sum of subcategories

*Scores in bold=sum of scores in italics

*Overall score=sum of scores in bold

*Standardized Score=overall score/maximum score possible

*If a category (or subcategory) receives a 1.0 for capability assessment NA under proposed actions, it either requires no further mention or is already being implemented to the best extent possible

*If a category (or subcategory) receives a 1.0 for capability assessment and <1.0 for proposed actions, then it was mentioned and detailed in the capability assessment but needed improvement which was not adequately addressed by the proposed actions

*If any subcategory receives an NA, the overall score for that category will be standardized as if that subcategory did not exist

*For Hazard Identification and Risk Assessment

*Total=average of hazard mitigation score and land use score, and implementation if land use score>hazard mitigation score

*Total=hazard mitigation score if hazard mitigation score>land use score

*For Capability Assessment and Proposed Actions

*Total=Average of hazard mitigation score, land use score, and implementation if hazard mitigation score>land use score and implementation score ≠NA

*Total=Average of land use score and implementation score if land use score>hazard mitigation score and implementation score ≠NA
*Total=land use score if land use score>hazard mitigation score and implementation score=NA

APPENDIX C: FINAL PLAN CODING INSTRUMENT

Sunset Beach

Category	HMP Unstan	HMP Stan	LUP Unstan	LUP Stan	Imp Unstan	Imp Stan	Total Unstan	Total Stan
Hazard Identification (Acute)	**50/60**	**4.17**	**18/60**	**1.50**	**NA**	**NA**	**34/60**	**2.83**
Floods	18/20	NA	12/20	NA	NA	NA	15/20	NA
Describes likelihood of floods	4	NA	4	NA	NA	NA	4	NA
Describes location and boundaries of hazardous areas	4	NA	4	NA	NA	NA	4	NA
Describes magnitude and severity of floods	4	NA	4	NA	NA	NA	4	NA
Describes separate characteristics of coastal flood hazards	4	NA	0	NA	NA	NA	2	NA
Includes information on past flood events	2	NA	0	NA	NA	NA	1	NA
Hurricanes/Coastal Storms	20/20	NA	6/20	NA	NA	NA	13/20	NA
Describes likelihood of storms	4	NA	0	NA	NA	NA	2	NA
Describes location and boundaries of hazardous areas	4	NA	4	NA	NA	NA	4	NA
Describes magnitude and severity of storms	4	NA	0	NA	NA	NA	2	NA
Describes separate characteristics of storms	4	NA	2	NA	NA	NA	3	NA
Includes information on previous storms	4	NA	0	NA	NA	NA	2	NA
Nor'easters/Coastal Storms	12/20	NA	0/20	NA	NA	NA	6/20	NA
Describes likelihood of storms	4	NA	0	NA	NA	NA	2	NA
Describes location and boundaries of hazardous areas	4[A]	NA	0	NA	NA	NA	2	NA
Describes magnitude and severity of storms	0	NA	0	NA	NA	NA	0	NA
Describes separate characteristics of storms	4	NA	0	NA	NA	NA	2	NA
Includes information on previous storms	0	NA	0	NA	NA	NA	0	NA
Hazard Identification (Chronic)	**16/44**	**1.82**	**16/44**	**1.82**	**NA**	**NA**	**16/44**	**1.82**
Coastal Erosion	16/20	NA	12/20	NA	NA	NA	14/20	NA
Describes likelihood of erosion	4	NA	4	NA	NA	NA	4	NA
Describes location and boundaries of hazardous areas	4	NA	4	NA	NA	NA	4	NA

Describes magnitude and severity of erosion	4	NA	4	NA	NA	NA	4	NA
Describes separate characteristics of coastal erosion	4	NA	0	NA	NA	NA	2	NA
Includes information on past coastal erosion	0	NA	0	NA	NA	NA	0	NA
Sea Level Rise	0/20	NA	4/20	NA	NA	NA	2/20	NA
Describes likelihood of sea level rise	0	NA	2	NA	NA	NA	1	NA
Describes location and boundaries of hazardous areas	0	NA	2	NA	NA	NA	1	NA
Describes magnitude and severity of sea level rise	0	NA	0	NA	NA	NA	0	NA
Describes separate characteristics of sea level rise	0	NA	0	NA	NA	NA	0	NA
Includes information on past sea level rise (if applicable)	0	NA	0	NA	NA	NA	0	NA
Climate Change (other than sea level rise)	0/4	NA	0/4	NA	NA	NA	0/4	NA
Capability Assessment	**20/44**	**2.27**	**24/44**	**2.73**	**NA**	**NA**	**22/44**	**2.50**
Acquisition and Elevation	4/12	NA	4/12	NA	NA	NA	4/12	NA
Elevation of Structures	0	NA	4[C]	NA	NA	NA	2	NA
Relocation	0	NA	0	NA	NA	NA	0	NA
Property Acquisition	4	NA	0	NA	NA	NA	2	NA
Development Regulations	16/32	NA	20/32	NA	NA	NA	18/32	NA
Erosion control	0	NA	0	NA	NA	NA	0	NA
Building Standards	4	NA	0	NA	NA	NA	2	NA
Density of Land Use	0	NA	4	NA	NA	NA	2	NA
Flood/Stormwater Management	4	NA	4	NA	NA	NA	4	NA
Protection of Natural Mitigation Features	0	NA	4	NA	NA	NA	2	NA
Setbacks of Buffer Zones	4	NA	4[D]	NA	NA	NA	4	NA
Open Space Preservation/Conservation	0	NA	0	NA	NA	NA	0	NA
Zoning	4	NA	4	NA	NA	NA	4	NA
Goals/Actions	**31.5/56**	**5.63**	**45.5/56**	**8.13**	**43/44**	**9.77**	**49.5/56**	**8.84**
Hazards Included in Land Suitability analysis	0/4	NA	4/4	NA	NA	NA	4/4	NA
Multi-hazard development compatibility assessment	4/4	NA	4/4	NA	NA	NA	4/4	NA
Land Use Trends	2.5[B]/4	NA	2.5[B]/4	NA	NA	NA	2.5/4	NA
Acquisition and Elevation	3/12	NA	7/12	NA	12/12	NA	9.5/12	NA
Elevation of Structures	3	NA	4[C]	NA	4[F]	NA	4	NA
Relocation	0	NA	3[E]	NA	4	NA	3.5	NA

Property Acquisition	0	NA	0	NA	4	NA	2	NA
Development Regulations	22/32	NA	28/32	NA	31/32	NA	29.5/32	NA
Erosion control	0	NA	2	NA	4[G]	NA	3	NA
Building Standards	4	NA	4	NA	4[H]	NA	4	NA
Density of Land Use	3	NA	4	NA	4[I]	NA	4	NA
Flood/Stormwater Management	4	NA	4	NA	4[J]	NA	4	NA
Protect Natural Mitigation Features	0	NA	3	NA	4[K]	NA	3.5	NA
Setbacks of Buffer Zones	4	NA	4[C]	NA	4[L]	NA	4	NA
Open Space Preservation/Conservation	3	NA	3	NA	3[M]	NA	3	NA
Zoning	4	NA	4	NA	4	NA	4	NA
Overall Score	**117.5/204**	**13.89**	**103.5/204**	**14.18**	**43/44**	**24.43**	**121.5/204**	**15.99**
Overall Score With Deduction (If Applicable)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

General

HMP=hazard mitigation plan, LUP=land use plan, Imp=implementation, Unstan=unstandardized, Stan=standardized

Hazard mitigation plan is from 2011 and land use plan is from 2007

Scores in italics=sum of criteria below

Scores in bold=sum of scores in italics

Overall score=sum of scores in bold

Standardized scores are only applicable to categories in bold (out of 5 for hazard identification and capability assessment, out of 10 for goals/actions) and overall scores (out of 25)

NA=Not applicable

If any criterion receives an NA, the overall score for that category/subcategory will be standardized as if that subcategory did not exist

If plan does not detail a certain criterion but references another document where it is detailed, it is considered to be mentioned and detailed

Deduct 1 point (out of 25) from final score if HMP is >5 years old, 2 points from final score if LUP is >5 years old, or 3 points from final score if both HMP and LUP are >5 years old

Hazard Identification
*Note that hazard mitigation scores for this category are from Dare County Hazard Mitigation Plan, not Kitty Hawk Hazard Mitigation Plan

Total=average of hazard mitigation score and land use score

For all criteria not in bold or italics (unless otherwise indicated)
0=not mentioned in plan
2=mentioned but not detailed in plan
4=mentioned and detailed in plan

Capability Assessment (unless otherwise indicated)
*Note that the capability assessment is included in the hazard mitigation plan under "capability assessment". In the land use plan the capability assessment is evaluated as Section 7: Review of Current (1997) CAMA Land Use Plan (pp.104-112).

Total= average of hazard mitigation score and land use score

For all criteria not in bold or italics under HMP (unless otherwise indicated)
0=not mentioned in plan
0.5=mentioned but not detailed in plan, insufficient or for stability/resistance, capability is low
1=mentioned and detailed in plan, insufficient or for stability/resistance, capability is low
1.5=mentioned but not detailed in plan, insufficient or for stability/resistance, capability is high
2=mentioned and detailed in plan, insufficient or for stability/resistance, capability is high
2.5=mentioned but not detailed in plan, sufficient or for adaptation/flexibility, capability is low
3=mentioned and detailed in plan, sufficient or for adaptation/flexibility, capability is low
3.5=mentioned but not detailed in plan, sufficient or adaptation/flexibility, capability is high
4=mentioned and detailed in plan, sufficient or for adaptation/flexibility, capability is high

*If above rubric is not applicable to a particular criteria, use same rubric as for goals/actions, unless otherwise indicated by superscript

For all criteria not in bold or italics under LUP, use same rubric as for goals/actions (unless otherwise indicated)

Goals/Actions
*Note that the Goals/Actions category is weighted twice as much as the other categories because this is viewed to be the most important part of the plan, reflective of the town's goals/objectives and implementation strategies aimed at addressing aforementioned hazards

Total=Average of hazard mitigation score, land use score, and implementation if hazard mitigation score>land use score

Total=Average of land use score and implementation score if land use score>hazard mitigation score

Total=Average of hazard mitigation score and land use score if hazard mitigation score>land use score and implementation score=NA

Total=Land use score if land use score>hazard mitigation score and implementation score=NA

For all criteria not in bold or italics (unless otherwise indicated)
0=not mentioned in plan
1=mentioned but not detailed in plan, implemented or proposed actions are insufficient or primarily for stability/resistance
2=mentioned and detailed in plan, implemented or proposed actions are insufficient or primarily for stability/resistance
3=mentioned but not detailed in plan, implemented or proposed actions are sufficient or include adaptation/flexibility
4=mentioned and detailed in plan, implemented or proposed actions are sufficient or include adaptation/flexibility
*If above rubric is not applicable to a particular criteria, use same rubric as for hazard identification, unless otherwise indicated by superscript

Implementation
*Note that the implementation is only applicable to Goals/Actions, and is part of the reason why it is weighted more than the other categories

For all criteria not in bold or italics (unless otherwise indicated)
0=Not being implemented
1=Being partially implemented or still in planning stages, primarily for resistance/stability
2=Being fully implemented, primarily for resistance/stability
3=Being partially implemented or still in planning stages, primarily for adaptation/flexibility
4=Being fully implemented, primarily for adaptation/flexibility

See explanations below

Explanation of individual scores that do not fit above criteria
A: Assuming same hazardous areas as for hurricanes

B: The hazard mitigation plan assumes complete build-out within the town limits in the future but does not give an estimate of how long it will take. The plan estimates an increase of 1,773 housing units and assumes current development regulations will remain constant, but does not say what those regulations are. The land use plan also mentions development of vacant lands and does discuss some of development regulations (Note that if further development is expected, community will never receive a score greater than 2.5, since further development is generally inconsistent with long-term resilience).

C: The town requires a 1-foot freeboard above BFE (LUP p.110)

D: The town of Sunset Beach has seaward development restrictions that exceed the Ocean Erodible AEC requirements in certain areas, which is intended to provide long-term protection for existing properties and reduce the need for public expenditures due to beach erosion (LUP p.32). No identified structures were at threat due to erosion as of 2006/2007 (LUP p.107).

E: The land use plan states that the town supports regular beach nourishment as the primary method of erosion control and property protection. Relocation of threatened structures is the town's next policy of choice in the absence of beach nourishment projects.

F: Sunset Beach conforms to CRS regulations in regards to structure elevation. In addition, the town still requires a 1-ft freeboard above BFE (Sandy Wood, personal communication).

G: Sunset Beach does not currently undertake in beach nourishment, although there have been some small-scale sand pumping projects in the past. There is a jetty on the south end of bird island which is technically in South Carolina which may contribute to the accretion experienced on many parts of the island. Since Sunset Beach does not face the same sort of erosion problems as other parts of the NC coast and all homes are set back a good ways, there are very few erosion control programs in place other than a dune protection ordinance (Landin Holland, personal communication).

H: Sunset Beach is in conformance with the North Carolina state Building Code with an additional ordinance that structures on the island must be of pile construction (Randy Walters, personal communication).

I: Sunset Beach does not encourage further development, but is not opposed to it as long as it fits in with what is already there. To limit density, most areas are zoned for single family homes. Roughly 30% of the community is also zoned as a wetland conservation area and cannot be filled for development (Landin Holland, personal communication).

J: Sunset Beach continues to update its floodplain development ordinance, keeping it in conformance with NFIP standards and requiring elevation certificates for every property within the flood hazard area. Sunset Beach has a CRS rating of 8, which is the highest score possible, indicating that they have been effective at implementing this standard. There is also a stormwater management ordinance in place which is tied in with the county (Landin Holland, personal communication)

K: The primary dune in Sunset Beach is very healthy and there is a dune protection ordinance in place which the town is very serious about. The town is very proactive about the protection of wetlands and other natural vegetation areas and it will do "whatever it takes" to protect them (Landin Holland, personal communication).

L: Sunset Beach is in conformance with the CAMA ocean-erodible setback guidelines. In addition, there is a local ordinance that no property be constructed beyond 125 feet of the property line abutting main street. The local ordinance applies to the entire island with the exception of a gated community at the east end of the island, which is only subject to CAMA regulations (Randy Walters, personal communication).

M: There is no specific open space protection ordinance in place, although there are some provisions in the zoning ordinance for residential development. Steps would be taken to secure land for open space if it were made available, but the town does not have money to just go out and buy land (Landin Holland, personal communication)

Topsail Beach

Category	HMP Unstan	HMP Stan	LUP Unstan	LUP Stan	Imp Unstan	Imp Stan	Total Unstan	Total Stan
Hazard Identification (Acute)	**46/60**	**3.83**	**38/60**	**3.17**	**NA**	**NA**	**42/60**	**3.50**
Floods	18/20	NA	18/20	NA	NA	NA	18/20	NA
Describes likelihood of floods	4	NA	4	NA	NA	NA	4	NA
Describes location and boundaries of hazardous areas	4	NA	4	NA	NA	NA	4	NA
Describes magnitude and severity of floods	4	NA	4	NA	NA	NA	4	NA
Describes separate characteristics of coastal flood hazards	4	NA	4	NA	NA	NA	4	NA
Includes information on past flood events	2	NA	2	NA	NA	NA	2	NA
Hurricanes/Coastal Storms	20/20	NA	20/20	NA	NA	NA	20/20	NA
Describes likelihood of storms	4	NA	4	NA	NA	NA	4	NA
Describes location and boundaries of hazardous areas	4	NA	4	NA	NA	NA	4	NA
Describes magnitude and severity of storms	4	NA	4	NA	NA	NA	4	NA
Describes separate characteristics of storms	4	NA	4	NA	NA	NA	4	NA
Includes information on previous storms	4	NA	4	NA	NA	NA	4	NA
Nor'easters/Coastal Storms	8/20	NA	0/20	NA	NA	NA	4/20	NA
Describes likelihood of storms	2	NA	0	NA	NA	NA	1	NA
Describes location and boundaries of hazardous areas	0	NA	0	NA	NA	NA	0	NA
Describes magnitude and severity of storms	0	NA	0	NA	NA	NA	0	NA
Describes separate characteristics of storms	4	NA	0	NA	NA	NA	2	NA
Includes information on previous storms	2	NA	0	NA	NA	NA	1	NA
Hazard Identification (Chronic)	**16/44**	**1.82**	**18/44**	**2.05**	**NA**	**NA**	**17/44**	**1.93**
Coastal Erosion	16/20	NA	16/20	NA	NA	NA	16/20	NA
Describes likelihood of erosion	4	NA	4	NA	NA	NA	4	NA
Describes location and boundaries of hazardous areas	4	NA	4	NA	NA	NA	4	NA

Describes magnitude and severity of erosion	4	NA	4	NA	NA	NA	4	NA
Describes separate characteristics of coastal erosion	4	NA	2	NA	NA	NA	3	NA
Includes information on past coastal erosion	0	NA	2	NA	NA	NA	1	NA
Sea Level Rise	0/20	NA	2/20	NA	NA	NA	1/20	NA
Describes likelihood of sea level rise	0	NA	2	NA	NA	NA	1	NA
Describes location and boundaries of hazardous areas	0	NA	0	NA	NA	NA	0	NA
Describes magnitude and severity of sea level rise	0	NA	0	NA	NA	NA	0	NA
Describes separate characteristics of sea level rise	0	NA	0	NA	NA	NA	0	NA
Includes information on past sea level rise (if applicable)	0	NA	0	NA	NA	NA	0	NA
Climate Change (other than sea level rise)	0/4	NA	0/4	NA	NA	NA	0/4	NA
Capability Assessment	**12/44**	**1.36**	**28.5/44**	**3.24**	**NA**	**NA**	**20.25/44**	**2.30**
Acquisition and Elevation	2.5/12	NA	3/12	NA	NA	NA	2.75/12	NA
Elevation of Structures	0	NA	0	NA	NA	NA	0	NA
Relocation	0	NA	3	NA	NA	NA	1.5	NA
Property Acquisition	2.5	NA	0	NA	NA	NA	1.25	NA
Development Regulations	9.5/32	NA	25.5/32	NA	NA	NA	17.5/32	NA
Erosion control	0	NA	2[D]	NA	NA	NA	1	NA
Building Standards	3	NA	4[E]	NA	NA	NA	3.5	NA
Density of Land Use	0	NA	4[F]	NA	NA	NA	2	NA
Flood/Stormwater Management	3	NA	4	NA	NA	NA	3.5	NA
Protection of Natural Mitigation Features	0	NA	3[G]	NA	NA	NA	1.5	NA
Setbacks of Buffer Zones	0	NA	2[H]	NA	NA	NA	1	NA
Open Space Preservation/Conservation	0.5[A]	NA	2.5[I]	NA	NA	NA	1.5	NA
Zoning	3	NA	4	NA	NA	NA	3.5	NA
Goals/Actions	**17/56**	**3.04**	**38.5/56**	**6.88**	**27/44**	**6.14**	**38.33/56**	**6.84**
Hazards Included in Land Suitability analysis	0/4	NA	4/4	NA	NA	NA	4/4	NA
Multi-hazard development compatibility assessment	0/4	NA	4/4	NA	NA	NA	4/4	NA
Land Use Trends	0/4	NA	2.5/4[J]	NA	NA	NA	2.5/4	NA

Acquisition and Elevation	5/12	NA	6/12	NA	4/12	NA	5.33/12	NA
Elevation of Structures	3[B]	NA	0	NA	4	NA	2.33	NA
Relocation	2	NA	3	NA	0	NA	1.5	NA
Property Acquisition	0	NA	3	NA	0	NA	1.5	NA
Development Regulations	12/32	NA	22/32	NA	23/32	NA	22.5/32	NA
Erosion control	1[C]	NA	2[D]	NA	2[K]	NA	2	NA
Building Standards	3	NA	4[E]	NA	4	NA	4	NA
Density of Land Use	0	NA	4[F]	NA	4	NA	4	NA
Flood/Stormwater Management	3	NA	4	NA	3[L]	NA	3.5	NA
Protect Natural Mitigation Features	0	NA	3[G]	NA	2[M]	NA	2.5	NA
Setbacks of Buffer Zones	0	NA	1[H]	NA	4	NA	2.5	NA
Open Space Preservation/Conservation	2	NA	0[I]	NA	0	NA	0	NA
Zoning	3	NA	4	NA	4	NA	4	NA
Overall Score	**91/204**	**10.05**	**123/204**	**15.34**	**27/44**	**15.35**	**117.58/204**	**14.57**
Overall Score With Deduction (If Applicable)	**NA**		**NA**	**13.34**	**NA**	**NA**	**NA**	**12.57**

General

HMP=hazard mitigation plan, LUP=land use plan, Imp=implementation, Unstan=unstandardized, Stan=standardized

Hazard mitigation plan is from 2010 and land use plan is from 2005

Scores in italics=sum of criteria below

Scores in bold=sum of scores in italics

Overall score=sum of scores in bold

Standardized scores are only applicable to categories in bold (out of 5 for hazard identification and capability assessment, out of 10 for goals/actions) and overall scores (out of 25)

NA=Not applicable

If any criterion receives an NA, the overall score for that category/subcategory will be standardized as if that subcategory did not exist

If plan does not detail a certain criterion but references another document where it is detailed, it is considered to be mentioned and detailed

Deduct 1 point (out of 25) from final score if HMP is >5 years old, 2 points from final score if LUP is >5 years old, or 3 points from final score if both HMP and LUP are >5 years old

Hazard Identification

*Note that hazard mitigation scores for this category are from Pender County Hazard Mitigation Plan

Total=average of hazard mitigation score and land use score

For all criteria not in bold or italics (unless otherwise indicated)

0=not mentioned in plan
2=mentioned but not detailed in plan
4=mentioned and detailed in plan

Capability Assessment (unless otherwise indicated)

*Note that the capability assessment is included in the hazard mitigation plan under "capability assessment". Since the hazard mitigation plan is for Pender County, but not specifically Topsail Beach, it was deemed necessary to evaluate the land use plan as well. In the land use plan the capability assessment is evaluated as Section 9: Review of Previous (1992) Town of Topsail Beach Land Use Plan (pp.81-88). Subtract 1 point from hazard mitigation scores since there is no community hazard mitigation plan.

Total= average of hazard mitigation score and land use score

For all criteria not in bold or italics under HMP (unless otherwise indicated)

0=not mentioned in plan
0.5=mentioned but not detailed in plan, insufficient or for stability/resistance, capability is low
1=mentioned and detailed in plan, insufficient or for stability/resistance, capability is low
1.5=mentioned but not detailed in plan, insufficient or for stability/resistance, capability is high
2=mentioned and detailed in plan, insufficient or for stability/resistance, capability is high
2.5=mentioned but not detailed in plan, sufficient or for adaptation/flexibility, capability is low
3=mentioned and detailed in plan, sufficient or for adaptation/flexibility, capability is low
3.5=mentioned but not detailed in plan, sufficient or for adaptation/flexibility, capability is high
4=mentioned and detailed in plan, sufficient or for adaptation/flexibility, capability is high

*If above rubric is not applicable to a particular criteria, use same rubric as for goals/actions, unless otherwise indicated by superscript

For all criteria not in bold or italics under LUP, use same rubric as for goals/actions (unless otherwise indicated)

Goals/Actions

*Note that the Goals/Actions category is weighted twice as much as the other categories because this is viewed to be the most important part of the plan, reflective of the town's goals/objectives and implementation strategies aimed at addressing aforementioned hazards. Subtract 1 point from the hazard mitigation scores since there is no community hazard mitigation plan.

Total=Average of hazard mitigation score, land use score, and implementation if hazard mitigation score>land use score

Total=Average of land use score and implementation score if land use score>hazard mitigation score

Total=Average of hazard mitigation score and land use score if hazard mitigation score>land use score and implementation score=NA

Total=Land use score if land use score>hazard mitigation score and implementation score=NA

For all criteria not in bold or italics (unless otherwise indicated)

0=not mentioned in plan
1=mentioned but not detailed in plan, implemented or proposed actions are insufficient or primarily for stability/resistance
2=mentioned and detailed in plan, implemented or proposed actions are insufficient or primarily for stability/resistance
3=mentioned but not detailed in plan, implemented or proposed actions are sufficient or include adaptation/flexibility
4=mentioned and detailed in plan, implemented or proposed actions are sufficient or include adaptation/flexibility

*If above rubric is not applicable to a particular criteria, use same rubric as for hazard identification, unless otherwise indicated by superscript

Implementation

*Note that the implementation is only applicable to Goals/Actions, and is part of the reason why it is weighted more than the other categories

For all criteria not in bold or italics (unless otherwise indicated)

0=Not being implemented
1=Being partially implemented or still in planning stages, primarily for resistance/stability
2=Being fully implemented, primarily for resistance/stability
3=Being partially implemented or still in planning stages, primarily for adaptation/flexibility

4=Being fully implemented, primarily for adaptation/flexibility

See explanations below

<u>Explanation of individual scores that do not fit above criteria</u>
A: The hmp mentions that Topsail Beach does not have a parks and recreation/open space plan

B: The hmp calls for a requirement for "a finished floor elevation certificate for all development within the special flood hazard area (SFHA) within both incorporated and unincorporated portions of the County. All elevation certificates should be submitted on an official FEMA elevation certificate. No certificate of occupancy shall be issued for any development within a defined special flood hazard area without the submittal of the required elevation certificate (new buildings)".

C: One of the objectives of the Pender County hmp is to "reduce flooding and erosion vulnerability through land development initiatives, maintenance, and improvement of storm drainage". However, it does not specify how it will go about erosion control.

D: The plan clearly states that beach nourishment will be adopted as the primary method of erosion control, which is a form of stability/resistance. The plan also mentions on p.81 that the town is not in agreement with CAMA's prohibition of hardened structures along the ocean shoreline and that they are actively pursuing, and will continue to pursue an ACE project involving both beach nourishment and construction of a groin, another form of stability/resistance.

E: The plan states that Topsail Beach is in accordance, and will continue to conform to the NC State Building Code, which requires building standards far in excess of past minimum standards and making construction at Topsail Beach more resistant than it has ever been to storm damage. The standards are not detailed in the plan but can be found in the NC State Building Code.

F: The plan states that the existing residential density for developed land is fairly low, at 6 units/acre (p.84) and that densities for new development shall be consistent with the density of existing land uses as enforced through the town's zoning ordinance (p.86). The plan also states that it is town policy to minimize development and encourage low-moderate intensity uses within natural hazard areas (p.109).

G: The plan mentions dune stabilization, which is a form of stability/resistance, as it impedes the natural evolution and migration of the barrier. However, the plan also mentions that town policy requires, whenever possible the retention and management of natural vegetation in buffer areas along creeks, sounds, and islands (p.96). The plan also mentions that it is town policy to conserve existing maritime forests

H: The plan outlines the ocean erodible setback requirements as set forth by 15A NCAC 7H on p.45/46 and states that these requirements must be met on p.83. However there is no emphasis on ocean erodible setbacks in the plan for the future (goals/actions) section. Therefore it only receives a score of 1 under goals/actions.

I: The plan states that there is currently no land now given over to open space as described by NC CGIA. However, the town believes that this statement paints a false picture of Topsail Beach because its public trust areas, given over to beach front recreation, are some of the most beautiful and recreationally attractive open spaces in the world. However, nothing is stated in the plan for the future (goals/actions) section about setting aside more land for open space preservation.

J: The plan states that Topsail Beach expects residential development to increase over the planning period for this document and that this growth is expected and desired. In general, further development is does not contribute towards building resilience unless it is done very carefully with respect to natural hazards and potential environmental issues. However, the plan also states that Topsail Beach is committed to preserving the natural resources of the Town and that any residential, commercial, or other development activities permitted by the Town of Topsail Beach will be compatible with current regulations, development patterns, AEC requirements, wetlands requirements, soil suitability, and must take measures to mitigate any potential environmental degradation (p.67). Therefore, this category receives a score of 2.5.

K: The town is about to complete a beach nourishment project which has added 900,000 cubic yards of sand along the entire 5.1 mile stretch of beach. The beach has been widened on average 300 feet at low tide and 75 feet at high tide (Tim Holloman, personal communication).

L: The town follows CRS guidelines for flood zone management. There is currently no stormwater management system in place (Tim Holloman, personal communication).

M: The town has a policy for planting vegetation on dunes for stabilization. In the past the town has done dune pushes but came to the conclusion that they are ineffective and remove sand from the beach. There are currently no policies in place to protect natural vegetation buffers, maritime forests or wetlands (Tim Holloman, personal communication).

Kitty Hawk

Category	HMP Unstan	HMP Stan	LUP Unstan	LUP Stan	Imp Unstan	Imp Stan	Total Unstan	Total Stan
Hazard Identification (Acute)	**51.5/60**	**4.29**	**14/60**	**1.17**	**NA**	**NA**	**32.75/60**	**2.73**
Floods	18.5/20	NA	4/20	NA	NA	NA	11.5/20	NA
Describes likelihood of floods	4	NA	2	NA	NA	NA	3	NA
Describes location and boundaries of hazardous areas	3[A]	NA	0	NA	NA	NA	1.5	NA
Describes magnitude and severity of floods	4	NA	0	NA	NA	NA	2	NA
Describes separate characteristics of coastal flood hazards	4	NA	2	NA	NA	NA	3	NA
Includes information on past flood events	4	NA	0	NA	NA	NA	2	NA
Hurricanes/Coastal Storms	18.5/20	NA	8/20	NA	NA	NA	13.25/20	NA
Describes likelihood of storms	4	NA	2	NA	NA	NA	3	NA
Describes location and boundaries of hazardous areas	2.5[B]	NA	2	NA	NA	NA	2.25	NA
Describes magnitude and severity of storms	4	NA	0	NA	NA	NA	2	NA
Describes separate characteristics of storms	4	NA	2	NA	NA	NA	3	NA
Includes information on previous storms	4	NA	2	NA	NA	NA	3	NA
Nor'easters/Coastal Storms	14/20	NA	2/20	NA	NA	NA	8/20	NA
Describes likelihood of storms	2	NA	2	NA	NA	NA	2	NA
Describes location and boundaries of hazardous areas	0	NA	0	NA	NA	NA	0	NA
Describes magnitude and severity of storms	4	NA	0	NA	NA	NA	2	NA
Describes separate characteristics of storms	4	NA	0	NA	NA	NA	2	NA
Includes information on previous storms	4	NA	0	NA	NA	NA	2	NA
Hazard Identification (Chronic)	**20/44**	**2.27**	**14/44**	**1.59**	**NA**	**NA**	**17/44**	**1.93**
Coastal Erosion	20/20	NA	12/20	NA	NA	NA	16/20	NA
Describes likelihood of erosion	4	NA	4	NA	NA	NA	4	NA

Describes location and boundaries of hazardous areas	4	NA	4	NA	NA	NA	4	NA
Describes magnitude and severity of erosion	4	NA	4	NA	NA	NA	4	NA
Describes separate characteristics of coastal erosion	4	NA	0	NA	NA	NA	2	NA
Includes information on past coastal erosion	4	NA	0	NA	NA	NA	2	NA
Sea Level Rise	0/20	NA	2/20	NA	NA	NA	1/20	NA
Describes likelihood of sea level rise	0	NA	2	NA	NA	NA	1	NA
Describes location and boundaries of hazardous areas	0	NA	0	NA	NA	NA	0	NA
Describes magnitude and severity of sea level rise	0	NA	0	NA	NA	NA	0	NA
Describes separate characteristics of sea level rise	0	NA	0	NA	NA	NA	0	NA
Includes information on past sea level rise (if applicable)	0	NA	0	NA	NA	NA	0	NA
Climate Change (other than sea level rise)	0/4	NA	0/4	NA	NA	NA	0/4	NA
Capability Assessment	**26/44**	**2.95**	**NA**	**NA**	**NA**	**NA**	**26/44**	**2.95**
Acquisition and Elevation	10.5/12	NA	NA	NA	NA	NA	10.5/12	NA
Elevation of Structures	3.5	NA	NA	NA	NA	NA	3.5	NA
Relocation	3.5	NA	NA	NA	NA	NA	3.5	NA
Property Acquisition	3.5	NA	NA	NA	NA	NA	3.5	NA
Development Regulations	15.5/32	NA	NA	NA	NA	NA	15.5/32	NA
Erosion control	1.25	NA	NA	NA	NA	NA	1.25	NA
Building Standards	2.75	NA	NA	NA	NA	NA	2.75	NA
Density of Land Use	0	NA	NA	NA	NA	NA	0	NA
Flood/Stormwater Management	3	NA	NA	NA	NA	NA	3	NA
Protection of Natural Mitigation Features	1.5	NA	NA	NA	NA	NA	1.5	NA
Setbacks of Buffer Zones	0	NA	NA	NA	NA	NA	0	NA
Open Space Preservation/Conservation	3.5	NA	NA	NA	NA	NA	3.5	NA
Zoning	3.5	NA	NA	NA	NA	NA	3.5	NA
Goals/Actions	**7/56**	**1.25**	**43/56**	**7.68**	**40/44**	**9.09**	**47.5/56**	**8.48**
Hazards Included in Land Suitability analysis	0/4	NA	4/4	NA	NA	NA	4/4	NA
Multi-hazard development compatibility assessment	0/4	NA	4/4	NA	NA	NA	4/4	NA

Land Use Trends	0/4	NA	4/4	NA	NA	NA	4/4	NA
Acquisition and Elevation	0/12	NA	3/12	NA	10/12	NA	6.5/12	NA
Elevation of Structures	0	NA	0	NA	4[G]	NA	2	NA
Relocation	0	NA	0	NA	2[H]	NA	1	NA
Property Acquisition	0	NA	3	NA	4[I]	NA	3.5	NA
Development Regulations	7/32	NA	28/32	NA	30/32	NA	29/32	NA
Erosion control	1	NA	2.5[E]	NA	3[J]	NA	2.75	NA
Building Standards	1[C]	NA	4	NA	4[K]	NA	4	NA
Density of Land Use	0	NA	4	NA	4[L]	NA	4	NA
Flood/Stormwater Management	3	NA	4	NA	3[M]	NA	3.5	NA
Protect Natural Mitigation Features	1	NA	2.5[F]	NA	4[N]	NA	3.25	NA
Setbacks of Buffer Zones	0	NA	4	NA	4[O]	NA	4	NA
Open Space Preservation/Conservation	1[D]	NA	3	NA	4[P]	NA	3.5	NA
Zoning	0	NA	4	NA	4	NA	4	NA
Overall Score	**104.5/204**	**10.76**	**71/160**	**13.05**	**40/44**	**22.72**	**123.25/204**	**16.09**
Overall Score With Deduction (If Applicable)	**NA**	**10.76**	**NA**	**11.05**	**NA**	**NA**	**NA**	**14.09**

General

HMP=hazard mitigation plan, LUP=land use plan, Imp=implementation, Unstan=unstandardized, Stan=standardized

Hazard mitigation plan is from 2010 and land use plan is from 2003/2004

Scores in italics=sum of criteria below

Scores in bold=sum of scores in italics

Overall score=sum of scores in bold

Standardized scores are only applicable to categories in bold (out of 5 for hazard identification and capability assessment, out of 10 for goals/actions) and overall scores (out of 25)

NA=Not applicable

If any criterion receives an NA, the overall score for that category/subcategory will be standardized as if that subcategory did not exist

If plan does not detail a certain criterion but references another document where it is detailed, it is considered to be mentioned and detailed

Deduct 1 point (out of 25) from final score if HMP is >5 years old, 2 points from final score if LUP is >5 years old, or 3 points from final score if both HMP and LUP are >5 years old

<u>Hazard Identification</u>
*Note that hazard mitigation scores for this category are from Dare County Hazard Mitigation Plan, not Kitty Hawk Hazard Mitigation Plan

Total=average of hazard mitigation score and land use score

<u>For all criteria not in bold or italics (unless otherwise indicated)</u>
0=not mentioned in plan
2=mentioned but not detailed in plan
4=mentioned and detailed in plan

<u>Capability Assessment (unless otherwise indicated)</u>
*Note that the capability assessment is evaluated for the hazard mitigation plan and not for the land use plan. Rather than deduct points from the land use plan, the capability assessment is not evaluated as part of the land use plan because it is not necessary that it be included, provided that it is included in the portion of the Dare County hazard mitigation plan which deals specifically with Kitty Hawk.

Total=hazard mitigation score

<u>For all criteria not in bold or italics (unless otherwise indicated)</u>
0=not mentioned in plan
0.5=mentioned but not detailed in plan, insufficient or for stability/resistance, capability is low
1=mentioned and detailed in plan, insufficient or for stability/resistance, capability is low
1.5=mentioned but not detailed in plan, insufficient or for stability/resistance, capability is high
2=mentioned and detailed in plan, insufficient or for stability/resistance, capability is high
2.5=mentioned but not detailed in plan, sufficient or for adaptation/flexibility, capability is low
3=mentioned and detailed in plan, sufficient or for adaptation/flexibility, capability is low
3.5=mentioned but not detailed in plan, sufficient or adaptation/flexibility, capability is high
4=mentioned and detailed in plan, sufficient or for adaptation/flexibility, capability is high

*If above rubric is not applicable to a particular criteria, use same rubric as for goals/actions, unless otherwise indicated by superscript

<u>Goals/Actions</u>
*Note that the Goals/Actions category is weighted twice as much as the other categories because this is viewed to be the most important part of the plan, reflective of the town's goals/objectives

and implementation strategies aimed at addressing aforementioned hazards

Total=Average of hazard mitigation score, land use score, and implementation if hazard mitigation score>land use score

Total=Average of land use score and implementation score if land use score>hazard mitigation score

Total=Average of hazard mitigation score and land use score if hazard mitigation score>land use score and implementation score=NA

Total=Land use score if land use score>hazard mitigation score and implementation score=NA

For all criteria not in bold or italics (unless otherwise indicated)
0=not mentioned in plan
1=mentioned but not detailed in plan, implemented or proposed actions are insufficient or primarily for stability/resistance
2=mentioned and detailed in plan, implemented or proposed actions are insufficient or primarily for stability/resistance
3=mentioned but not detailed in plan, implemented or proposed actions are sufficient or include adaptation/flexibility
4=mentioned and detailed in plan, implemented or proposed actions are sufficient or include adaptation/flexibility

*If above rubric is not applicable to a particular criteria, use same rubric as for hazard identification, unless otherwise indicated by superscript

Implementation
*Note that the implementation is only applicable to Goals/Actions, and is part of the reason why it is weighted more than the other categories

*Note that a new town council has taken office since the completion of the 2003/2004 land use plan. Thus many of the goals/objectives of those who wrote the land use plan are inconsistent with those involved with implementing them. The current town council is in many regards more conservative than the former town council in terms of further development, beach nourishment and property protection (Kitty Hawk Town Planner) and this is generally reflected by implementation scores that are higher than the land use plan scores due to more adaptive approaches being implemented than those proposed in the land use plan

For all criteria not in bold or italics (unless otherwise indicated)
0=Not being implemented
1=Being partially implemented or still in planning stages, primarily for resistance/stability
2=Being fully implemented, primarily for adaptation/flexibility
3=Being partially implemented or still in planning stages, primarily for resistance/stability

4=Being fully implemented, primarily for adaptation/flexibility

See explanations below

<u>Explanation of individual scores that do not fit above criteria</u>
A: The plan discusses the types of areas that are subject to flooding, gives some discussion of areas subject to flooding in Dare County and provides a map of flood hazard areas, but there is no legend on the map nor is there anything specific to Kitty Hawk.

B: The plan does discuss the locations in Dare County that are susceptible to hurricanes and mentions maps delineating storm surge areas, but does not include those maps or reference them, nor does it include any information specific to Kitty Hawk.

C: The plan mentions providing information to homeowners on hazard-proofing their homes, which is a building standard. However, since it is not listed as a requirement, it only receives a score of 1 as opposed to 3, even though building standards are considered here to be a form of adaptation.

D: The plan mentions educating citizens about the importance of open space and natural resource protection, but does not mention any plans or goals for open space protection. Therefore it receives a score of 1 instead of 3, even though it is considered here to be a form of adaptation.

E: The plan states that beach nourishment along the open-ocean shoreline and bulkheading along the sounds will be the preferred methods of erosion control, which are forms of stability/resistance, but "more environmentally-friendly erosion control measures will be welcomed when conditions are favorable for such use".

F: The plan mentions dune stabilization and protection of natural features. The protection of natural features can be viewed as a form of resilience, but dune stabilization is a form of stability/resistance, as it impedes the natural evolution and migration of the barrier

G: Kitty Hawk is one of only two communities in the Outer Banks to have adopted a 1-foot or greater freeboard above the standard regulations for elevating homes in the flood zone (BFE amsl+1 ft.) (Joe Heard, personal communication).

H: The town does not undertake structure relocation because oceanfront lots do not have enough depth. However, there is a program in place where the town will work with homeowners to identify problems and apply for a grant with Dare County to elevate homes to higher levels. Many homeowners choose to do this for insurance benefits, although the town does not provide any direct funding (Joe Heard, personal communication)

I: All oceanfront homes in Kitty Hawk are within the ocean-erodible setback zone and are thus unbuildable. The town did acquire roughly 60 oceanfront lots shortly after and consistent with the 2003/2004 land use plan, but has not acquired any property in recent years, nor is any more anticipated in the near future (Joe Heard, personal communication).

J: There has been no beach nourishment since the land use plan was written, in part due to the more conservative nature of the current town council than the one under which the land use plan was written. Tax money that was originally meant for beach nourishment went instead towards dune stabilization through sand fencing and the planting of vegetation along all primary oceanfront dunes. No other forms of erosion control have been undertaken by the town (Joe Heard, personal communication).

K: Kitty Hawk enforces the NC State Building Code, which recently upped its standards for structures subject to high velocity winds (includes construction materials such as high impact glass). Kitty Hawk also implements a 1-ft freeboard above the minimum BFE (Joe Heard, personal communication)

L: The town has limited development density to primarily low density residential properties (1 unit/15,000 sq. ft. or <3 units/acre) although there are several multi-family units at <5 units/acre. The town also enforces a 35ft height limit (with 2 exceptions) (Joe Heard, personal communication)

M: The town has a very stringent flood damage protection ordinance and is tied for the best CRS score amongst Outer Banks communities. The town is currently working with NCDOT on a stormwater management plan, but it will take a significant investment from the local government in order to implement, which is beyond the town budget. It is unclear whether it will ever be implemented (at least in the foreseeable future) (Joe Heard, personal communication).

N: As previously stated, the town has spent much tax money on dune protection and stabilization. The town has also set aside large tracts of maritime forests and wetlands for conservation (Joe Heard, personal communication)

O: The town enforces CAMA standards for ocean erodible setbacks (30*annual erosion rate for small structures and 60*annual erosion rate for large structures). All of the current beachfront homes are now within the ocean erodible zone and no further development is permitted to the east of NC highway 12 (Joe Heard, personal communication).

P: The town has set aside large tracts of maritime forests and wetlands, including Kitty Hawk woods for conservation. No development is allowed within these areas (Joe Heard, personal communication).

APPENDIX D: RESILIENCE SCORES

Community	Vulnerability Score	5-Vulnerability Score	Planning Score	Planning Score x (5-Vulnerability Score	Resilience Score	Resilience Potential Score
Kitty Hawk	3.75	1.25	14.09	17.6125	**4.20**	**5.59**
Topsail Beach	3.67	1.33	12.57	16.7181	**4.09**	**5.77**
Sunset Beach	3.17	1.83	15.99	29.2617	**5.41**	**6.76**

*Resilience Score=√Planning Score x (5-Vulnerability Score)

*Resilience Score is out of 10