Abstract

CHARACTERIZING PATTERNS AND DRIVERS OF LAND USE/LAND COVER CHANGE ALONG THE ATLANTIC COAST BARRIER BEACHES: EXAMINING THE ROLES OF DEVELOPMENT PRESSURE, SPATIAL ACCESSIBILITY, AND POLICY

By

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The coastal environment is an ever-changing multifaceted region that continues to evolve from natural processes as well as anthropogenic inputs over time. The purpose of this research is to create a better understanding of the coastal environment of the United States; more specifically the social and physical landscapes of Atlantic coast barrier beaches. In doing so it will move towards a science of U.S. coastal land cover change science. This is important because human land behaviors on the coast have important effects on both natural and cultural resources, terrestrial and marine environments, and regional sense of place. Because of this explicitly coastal-themed research is needed to understand the patterns and drivers of coastal landscape change in ways that integrate the biophysical and social science domains.

This dissertation is comprised of three main parts that examine different aspects of Atlantic barrier beach land change and coastal development. Chapter 3, which is entitled “Landscapes and Land Cover Characterization of the U.S. Atlantic Barrier Coast: A Place-Based Typological Classification, 1990-2000” creates a placed based typology of barrier beach units across the

Atlantic coast. Many of the U.S. Atlantic coast's barrier beaches have undergone a shift in place identity from elite getaway destinations and small fishing communities to tourist-driven, place-based destinations. This dynamic is related to changing demographic and economic characteristics that may also be associated with changing patterns of developed land use. This chapter quantitatively examines spatial patterns of socio-economic and land use/cover characteristics for a comprehensively defined set of coastal barrier places spanning from Long Island, New York to Miami, Florida on the U.S. Atlantic coast. Census data from 1990 and 2000 and satellite derived land use/cover data are used as input to a cluster analysis generating place-based typology. Results reveal that there in fact is a separation among Atlantic Coast barrier beaches into distinct cluster types. This separation is a direct influence of the tourism industry among many of the barrier beach communities where there is large number of the housing units are seasonal units as well as lower development densities and an observed growth in developed land cover during the study period.

Chapter 4, which is entitled "Rates and Drivers of Coastal Development for Atlantic Barrier Beaches" evaluates the hypothesized drivers of developed land cover change on barrier beaches. Barrier beach land use land cover has changed over time as driving forces act to shift natural barrier beach habitat to developed land cover. This is important because the important ecosystem services barrier beaches provide for the coastal region, especially along the Atlantic coast. There is little known about the forces that act upon these barrier beaches that causes developed land cover. After identifying hypothesizes of coastal driving forces of developed land use change, ordinary least squares regression (OLS) is applied. The chapter estimates five regression models that investigate natural, social, spatial, and policy variables, as well as a combination of all variables within a full model. A forward stepwise regression was also run on the full model to identify major influential factors. The results show that the full model highly explains developed land cover change on barrier beaches along the Atlantic coast and that size of a barrier beach unit over all variables is dominant factor for developed land cover change. Along with size the percent of seasonal housing were both found exhibit positive correlation to developed land cover.

Chapter 5 develops a new a theoretical coastal restructuring model of land cover change. A conceptual framework of societal land use/cover change is created to aid in the creation of the historical narratives that can be applied to Atlantic barrier beach communities. The coastal restricting model is then applied to two selected Atlantic barrier beach places to interpret trajectories of development. Historical narratives are paired with quantitative results from prior chapters to guide site selection as well as provide quantitative data about each place. Using the historical narrative the phases of development are determined within the coastal restructuring model. This in turn reveals the how landscape evolves over time from one landscape use to another. The results of the analysis indicate that the coastal restructuring model has the potential to be applied to all barrier beach units as well as to be used as a guiding framework for landscape scholars and coastal planners and managers.

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Andrew T. Bennett

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To my Aunt Jill your life and pursuit of education has inspired and motivated me. For that I will forever remember and continue to inspire all I can.

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Chapter 1: Introduction

The coastal environment is an ever-changing multifaceted region that continues to evolve over time. The purpose of this research is to create a better understanding of the coastal environment of the United States; more specifically the social and physical landscapes of Atlantic coast barrier beaches in an attempt to move towards a science of U.S. coastal land cover change science. To understand resource management issues in the region it is important to understand history of land change that has occurred and to understand the spatial and temporal patterns and processes of land use and cover change. This is important because human land behaviors on the coast have important effects on both natural and cultural resources, terrestrial and marine environments, and regional sense of place. Explicitly coastal-themed research is needed to understand the patterns and drivers of coastal landscape change in ways that integrate the biophysical and social science domains. This research aims to integrate in this manner and will also examine the important role of role of policy as driving force impacting trajectory of land cover change focusing particularly on change from “undeveloped” to “developed” status.

My dissertation is comprised of three main parts that examine different aspects of Atlantic barrier beach land change and coastal development. Each part will form the basis of a dissertation chapter and a stand-alone peer-reviewed manuscript submission. While the dissertation operates in a “three article” mode, the three chapters along with introductory and concluding chapters will also form a coherent whole analysis that represents the first efforts to my knowledge that systematically analyze land cover change for the entire assemblage of Atlantic coast barrier beaches. My three main research goals are:

Goal 1: Identify the population of Atlantic coast barrier beach spatial units and perform a quantitative descriptive analysis resulting in a classification typology of different Atlantic barrier beach types.

Goal 2: For the population of barrier beaches, develop a quantitative statistical model of developed land conversion that incorporates theories, tests hypothesizes and applies methods from the emergent field of land change science.

Goal 3: Using results from prior goals to guide site selection perform a localized, place-based analysis of land change using quantitative and qualitative data, historical and newspaper data, and policy history for two or three selected units in order to construct narratives that account for the spatially and temporally contingent process of barrier beach place creation.

The dissertation is organized as follows: chapter 2 provides an overview of barrier beaches as well as a literature review of land change science and coastal policy that informs and supports research objectives stated at the end of the chapter. Chapters 3, 4, and 5 describe elements of the proposed goals stated above dealing with Goal 1's descriptive analysis, Goal 2's statistical modeling, and Goal 3's place-based analysis.

Chapter 2: Importance and State of U.S. Barrier Beaches

The coast of the United States, like many other countries around the world, has a long history of human development pressure, especially on barrier beaches (Walker 1990). Barrier beaches are elongated bodies of sand bounded on either end by inlets that allow salt and fresh water to flow into and out of the estuary behind the system (Pilkey et al. 1998). These beaches comprise 13-15 percent of the world's coastline and approximately 4,350 km of the U.S. coastline from Maine to Texas (USDOI 1982), it is the *"longest and best evolved chain of barrier beaches in the world"* (Leatherman and Godfrey 1979 p.57). They provide the first line of defense to the mainland and adjacent wetlands, estuaries, inlets and near shore waters from the direct impact of wind waves and streams. Barrier beaches are also dynamic geomorphic features changing constantly by the actions of wind, waves, currents, and tides. Storms, including nor'easters and hurricanes, often impact the U.S. Atlantic Coast, which can cause drastic changes on barrier beaches through erosion, and even creation of inlets. Their low-lying topography makes them vulnerable to storm-surge flooding; many barrier beaches are only a few meters above sea level (Leatherman 1988).

Barrier beaches and surrounding coastal region represents some of the highest anthropogenic development and human populations in the world (Weinstein et al. 2007). These beaches are some of the most valuable in terms of real estate, yet they are one of the most, if not the most, vulnerable ecosystems in the world (U.S. Commission on Ocean Policy 2004; Perez-Maqueo et. al. 2007). The affinity for the coastal setting from beaches to ocean views has drawn multitudes of people to barrier beaches taking vacations and even building homes (Zhang and Leatherman 2011). From 1945 to 1973 barrier beaches urbanized at a rate of 153 percent, which at the time was three to four times faster than the mainland (Dolan et al. 1973). In 1975 urban use in the entire U.S. was three percent while on the 282 barrier beaches urban use was more than four times greater, 14 percent (Stiffin 1981). Zhang and Leatherman (2011) found that according to 2000 census there are roughly 1.4 million people living on barrier beaches with an average population increase for census years 1990 to 2000 of 14 percent. Population densities of barrier beaches compared to coastal states are on average three times greater (Zhang and Leatherman 2011).

2.1 *The Importance of Barrier Beaches*

Barrier beaches provide the first line of defense to the mainland and adjacent wetlands, estuaries, inlets and near shore waters from the direct impact of wind waves and streams. Barrier beaches have been found to be most common in coastal settings that have the a gentle sloping continental shelf bordering a low-relief coastal plain, an abundant supply of sediment, and moderate to low tidal ranges (Glaeser 1978). A prime example of a coastline with these characteristics is found along the U.S. Atlantic coast. Davis (1994) goes on to state that the barrier beaches are sandy beaches developed from a broadened barrier beach that is above high tide and parallel to the shore and extending from the beach it has dunes, vegetated zones and swampy terrains. Schwartz (1971) found that factors such as the sediment source, the sediment type and supply, the rate and direction of relative sea-level changes, the basin shape, the slope of the continental shelf, the direction and strength of currents and waves, and the magnitude of tides all affect barrier beach development. Barrier beaches development can be explained by one of three major theories: offshore bar theory, spit accretion theory and submergence theory (Figure 2-1). Davis et al. (2004) stated that barriers can form by a number of different mechanisms and no single theory can explain the development of all barrier beaches. Offshore barrier theory was originally proposed by De Beaumont (1845) and supported by Johnson (1919) in which he believed waves moving into shallow water churned up sand, which was deposited in the form of a submarine bar when the waves broke and lost much of their energy. As the bars accreted vertically, they gradually built above sea level, forming barrier beaches. Spit accretion theory proposed by Gilbert in 1885 suggests that material for the bar is transported along the shore rather than coming from erosion of the sea floor. Submergence theory McGee (1890) described beach formation by the detachment of mainland beaches during sea-level rise.

Barrier beaches are formed primarily of sand and generally include features such as a sandy beach, dunes (both primary and secondary), maritime forest, wetlands, and a backshore comprised mainly of marsh (Figure 2-2). Lagoons or sounds generally separate the barrier beach from the mainland. Beaches on barrier beaches are the areas where sediment transfer takes place as well as the initial disruption of wave energy. Dunes are vital yet extremely vulnerable component of the barrier beach because primary dunes act as buffers to salt spray. Dune creation and vegetation allows for stabilization of the barrier beach because many species of plant can exist in the mid barrier region along the barrier flats as well as the maritime forest at the back of the barrier beach.

Barrier beaches are very dynamic geomorphic features and change constantly by the actions of wind, waves, currents, and tides. Storms, including nor'easters and hurricanes, often impact the U.S. Atlantic Coast during the winter and summer, causing drastic changes of barrier beaches through erosion and inlet breaching. Barrier beaches have an extremely dynamic nature whereby major changes in geomorphology and hydrology can occur over days, or even hours, in response to extreme episodic storm events (EESEs) such as tropical cyclones, hurricanes, and northeasters (Feagin et al. 2010). Barrier beach width, dune elevation, tidal prism, wave energy, and storm surge energy influence the likelihood of overwash (Leatherman et al. 1977; Claudino-Sales et al. 2008), transport of sediment offshore, and formation of new inlets during storms (Fitzgerald and Van Heteren 1999).

2.2 *Towards a Science of U.S. Coastal Land Change*

The science of U.S. coastal land change is an area that has been explored, but there has yet to be a uniform understanding and exploration of the human and land use change process that occur within this spectrum (Klemas et al. 1993; Ramsey et al. 2001; Corssett et al. 2004; Ellis et al. 2011). These areas range from coastal development (Dolan et al. 1973; Stiffin 1981; Crawford 2007), coastal population (Bartlet et al. 2000; Zhang and Leatherman 2011), coastal hazards (Cutter et al. 2000; Boruff et al. 2005), and coastal land cover (Forman 2009). This research will attempt to take into context the concepts of land change science and move towards an understanding of land change within the coastal U.S. through creation of barrier beach data base as well as a localized place based analysis of landscape change over time.

Land change science (also known as, land systems science or Land Use/Cover Change (LUCC)), is an interdisciplinary field of study, which seeks to comprehend, explain, and project land use and land-cover change (Turner 2002; Turner et al. 2007). Thirty to fifty percent of the land has been transformed by anthropogenic inputs on the surface (Vitousek et al. 1997), cultivation on the land has taken up an area nearly the size of South America (Raven 2002). No land can be considered unspoiled due to the fact that human induced climate change and pollution has impacted all landscapes (Meyer and Turner, 1994). Land change science has emerged as a cornerstone of global environmental change and attempts to understand the human and biophysical factors influencing land cover dynamics defined as the temporal variations in land cover and land use (Rindfuss et al. 2004). Within the context of coastal land change science major milestones reflect not only coastal specific advances in understanding, but overall land change science advances, (Figure 2-3). The most notable milestone for U.S. coastal land Change is the creation of the Coastal Change Analysis Program (C-CAP) in 1992. C-CAP created a nationally standardized database to observe land cover change for the coastal area of the United

States (Thomas and Ferguson 1990; Thomas et al. 1991). The National Land Cover Database was created in 1993 as a multiagency attempt to map land cover for the entire United States as well as monitor land cover change.

2.2.1 Themes and Perspectives of Land Change Science

The key themes for land change science include identifying patterns of land cover change, processes of land use change, human responses to Land use/cover change, integrated global and regional models and development of databases on land surface, biophysical processes, and their socioeconomic and biophysical drivers (IGBP 1999) (Figure 2-4). Land change science modeling has been largely focused on topics such as tropical deforestation (Lambin 1994; Kaimowitz and Angelsen 1998), economic models of land use (Irwin and Geohegan 2001; Plantinga 1999), land change science dynamics (Veldkamp and Lambin 2001; Agarwal, et al. 2002; Verburg et al. 2004), and ecological landscapes (Baker 1989; Turner et. al. 2001).

Land change science modeling requires a mixture of approaches, which include the narrative, the agent based, and the systems approach perspectives (Lambin et.al. 2003). The narrative perspective, essentially a case study, looks for understanding through historical detail and analysis. It tells the land change science story through providing an empirical and interpretative history. Through this narrative history the validity and accuracy of the other visions can be tested as well as projected over time. Narrative is most beneficial when it comes to identifying chance events that considerably impact land-use/cover change, but are overlooked by approaches implementing temporal and spatially insufficient methods. Agent based as well as the systems approach are dependent on explicit model development and empirical testing (Briassoulis 2000). The agent based model of land-use/land-cover change consists of the cellular model representing the landscape and the agent based model representing human interaction and decisions. In the agent based model rules define the relationship between agents and their environment, and rules that determine sequencing of actions in the model (LUCC 2001). The systems perspective, in contrast, finds agents are constrained by the rules that society establishes creating in turn opportunities and constraints on decision making (Ostrom 1990). Systems perspective operates interactively at different spatial and temporal scales with the ability to link local conditions to global processes (Moran et al. 1998).

2.2.2 Driving Forces

In land cover change science there is an understanding that underlying forces are changing the landscape. These forces (i.e. population change, erosion, housing density change) that that cause observed landscape changes, i.e. they influence the trajectories of landscape development are called driving forces (Bürgi et al. 2004). These forces have been described as keystone processes (Marcucci 2000), drivers (Wood and Handley 2001) or causal or causative factors (Geist et al. 2006). Driving forces of landscape change has long history within the discipline of geography (Wirth 1969; Wood and Handley 2001) and has been recognition that land use/cover change is one of the key factors affecting global environmental change (Dale et al. 1993; Meyer and Turner 1994). Driving forces recognize that society and the environment are interconnected in space and time and the cultural landscape reflects changes in these interconnections (Russell 1997). The importance of understating the interconnections of society and nature that make looking at the forces driving landscape change significant (Bürgi and Russell 2001). Many studies highlight the role of policies in driving land-use changes (Lambin et al. 2001), but it is due to a lack of spatially explicit data (*socioeconomic* and *biophysical*) and difficulties in methodology that make linking social and biophysical data difficult to operationalize in ways leading to direct linkages of policy to land change outcomes (Veldkamp and Lambin 2001). Political factors can be expressed spatially as social construct with implied boundaries over territory. They can also be measured in terms of efficiently and spatial area that it can span by observing change over time.

More work examines the roles of population growth (i.e. population increase and migration) on land cover change. I=PAT is an important theoretical development involving population that seeks to explain land use/cover change. I=PAT defines land use/cover change as the product of total population (P); affluence (A); and all other human activities (T), or technology (Holdren and Ehrlich 1974). Over large temporal and spatial resolutions I=PAT explains change, however at lower spatial and temporal scales it overlooks many economic and biophysical factors impacting the landscape (Lambin et al. 2003). Driving forces can best be explained by a combination of factors, which are identified through a greater understanding of existing institutions, economy and culture explicate to the area being analyzed (Agarwal and Yadama 1997; Barbier and Burgess 2001; Lambin et al. 2001). Nagendra et al. (2004) found that through the use of a variety of driving forces interact dynamically to give rise to different scenarios and trajectories of change, based on the environmental, social, political and historical extent. To better understand dynamics and nature of changes in the coupled human-environment system social, economic, and political driver data can be used along with the land cover data to link drivers through exploratory analysis and regression approaches (Marsik et al. 2011). Exploratory and regression analysis methods are selected techniques from a wider set of methods used in the land change science community. These two general method types are reviewed below because they are the proposed methods to accomplish two of my research goals.

2.2.3 Regression Analysis

Regression analysis is used to investigate the association of a dependent variable with one or more independent variables. Regression techniques used in land change science include, but are not limited to linear regression, logistic regression, and multinomial regression. Linear regression is a method that estimates the coefficients of a linear equation, involving one or more independent variables, which best predict the value of the dependent variable. Logistic regression is used in situations where the dependent variable has binary outputs, which there are only two possible values for each digit. The method is useful to predict the probability that a case will be classified into one as opposed to the other of the two categories of the dependent variable. Multinomial regression models are used for the case of a dependent variable with more than two categories (Jobson 1992). This type of regression is similar to logistic regression, but it is more general because the dependent variable is not restricted to two categories.

2.3 ***Federal Coastal Policy (1968 -1982)***

The history of U.S. coastal policy has evolved over time stemming from general policies, such as the National Flood Insurance Program and OBRA to policies specific to the coastal region such as CZMA Barrier Island Bill and the CBRA. U.S. coastal policy can best be understood as a unique process in which competing policy coalitions work together, though not always in agreement to produce a patchwork of policies, plans, programs, and actions that affect the conservation and development of coastal areas and resources (Godschalk 1992). This grouping of policies, plans, programs, and actions are highlighted in Figure 2-5 showing the major policies at the federal level that have directly influenced coastal land use from 1968 through 2005.

2.3.1 National Flood Insurance Program (NFIP)

The National Flood Insurance Act of 1968 (NFIA) was motivated by a long history of property damage and loss of life due to flooding. Following the destruction caused by the Hurricane Betsy flood surge in 1965, the legislation was enacted because of the flood loss sustained in Florida and Louisiana. The legislation created the National Flood Insurance Program (NFIP), which provided government subsidized flood insurance. The NFIP goals are to:

- Provide flood insurance for structures and contents in communities that adopt
- Enforce an ordinance outlining minimal floodplain management standards
- Identify areas of high and low flood hazard
- Establish flood insurance rates for structures inside each flood hazard area

2.3.2 Coastal Zone Management Act (CZMA)

The Coastal Zone Management Act of 1972 (CZMA) was the first high-level coastal bill of its kind to recognize there is a national interest in the effective management, beneficial use, protection, and development of the coastal zone. CZMA was administered by NOAA's Office of Ocean and Coastal Resource Management (OCRM), providing framework for the management of the nation's coastal resources in an attempt to balance economic development with environmental conservation. Participation in CZMA by states is voluntary, but in an effort to encourage their participation, the act provides federal assistance to any coastal state or territory that is willing to develop and implement a coastal management program. Under the CZMA coastal states may protect coastal resources as well as manage coastal development under their coastal management programs. Coastal states with an OCRM approved program have the right to deny or restrict any development that is conflicting with its coastal zone management program.

2.3.3 Barrier Island Bill

The Barrier Island Bill focused on the acquisition of critical resources such as estuarine sanctuaries and undeveloped barrier beaches. Specifically, it sought to unite development of nearshore coastal policy with state fishery management efforts. The bill aimed at creating an effective state-federal and local-federal relationship that would be promoted through coastal zone management programs (Hochberg 1981). The bill would work with the coastal zone management energy impact program, which grants and loans for mitigating the impact of off-energy development. The most important part of the Barrier Island Bill is that it supported the acquisition of undeveloped barrier beaches, which included many high hazard floodplain areas and estuarine sanctuaries. Under the barrier island acquisition bill undeveloped beaches would be overseen by the National Park Service (Hochberg 1981).

2.3.4 Omnibus Budget Reconciliation Act (OBRA)

In an attempt to cut back on government spending Congress passed the Omnibus Budget Reconciliation Act of 1981 (OBRA). OBRA contained a provision, Section 342, "that will halt the availability of flood insurance for new development or major improvement of structures located on designated undeveloped barrier beaches starting on October 1, 1983" (Gordon 1984). The National Flood Insurance Program (NFIP) was identified by Congress as a source of significant federal expenditure. In a report from Congress the monetary liability of the NFIP was second to the Social Security Program in government spending (Kuehn 1981). The OBRA cut spending on vulnerable barrier beaches and concentrated funds towards more appropriate areas.

2.3.5 Coastal Barrier Resources Act of 1982

In 1982, the Coastal Barrier Resources Act (CBRA) was signed into law, establishing a policy that protected coastal barrier in defined geographic locations along with their waterways inlets and wetlands through restricting Federal expenditures, which encourage development of these coastal barriers. An undeveloped coastal barrier, defined by the CBRA, is any landform composed of unconsolidated shifting sand or other sedimentary material which is generally long and narrow and entirely or almost entirely surrounded by water. These barriers are above normal tides and usually have terrestrial vegetation and dunes. These barriers were also fairly undeveloped with a density of less than on building per five acres and devout of infrastructure including roads, water, electricity, and wastewater removal. Another feature of these barriers is that they enclose and in so doing protect other features, such as estuaries, salt marshes, and the mainland from direct wave action from the open ocean. CBRA established the John H. Chafee

Coastal Barrier Resources System (CBRS), comprised of undeveloped coastal barriers along the Atlantic, Gulf, and Great Lakes coasts (Figure 2-6).

In these defined locations no new Federal expenditures or financial assistance are allowed, with the exception of specific exempted projects (mainly dredging for navigational purposes).The overall intention of the act was to reduce the loss of human life, wasteful expenditure of Federal revenues, and damage to natural resources associated with the development of coastal barriers, including fish and wildlife. Under the CBRA, any federal program that may have the effect of encouraging development on coastal barrier beaches is restricted. CBRA attempted to curb/halt development on barrier beaches through banning the sale of NFIP flood insurance for structures built or substantially improved on or after a specified date in the identified locations. Under CBRA if an owner of a building in an identified zone wanted to buy flood insurance, he or she would need a copy of the building permit showing that the building was properly built before the designation date.

After the creation of the CBRA there have been attempts to improve the act through the inclusion of new units and new projects to better manage the John H. Chafee Coastal Barrier Resources System. The first improvement to the CBRA came in 1990 with the Coastal Barrier Improvement Act (CBIA), which expanded the CBRS with new units in Puerto Rico, the U.S. Virgin Beaches, the Great Lakes, and enlarging some previously designated units along the Atlantic and Gulf coasts. CBIA also designated areas established under Federal, state, or local law, or held by a qualified organization, primarily for wildlife refuge, sanctuary, recreational, or natural resource conservation purposes as Otherwise Protected Areas (OPA). The only prohibition within OPA's is they are not eligible for NFIP.

The Coastal Barrier Resources Reauthorization Act of 2000 directed the U.S. Fish and Wildlife Service to complete a Digital Mapping Pilot Project for up to 75 CBRS units. Along with creating digital maps the act also conducted an economic assessment of the effects of CBRA in 2002. It estimated CBRA has saved taxpayers $1.3 billion by restricting Federal spending for roads, wastewater systems, potable water supply, and disaster relief. The Coastal Barrier Resources Reauthorization Act of 2005 directed the U.S. Fish and Wildlife Service to finalize the Digital Mapping Pilot Project. The Act provided a public comment period for the draft maps and preparing a report to Congress that contains the final recommended digital maps. The act also created digital maps for the remainder of the CBRS.

Godschalk (1984) found that the CBRA had slowed the development rate on certain undeveloped barrier beaches. He based his study on the institutional framework that in response to the CBRA actors had directions to respond eventually giving the final impact (Figure 2-6). The three main forms of information gathering methods were used included case studies of two coastal barriers, a mail survey of coastal government officials, developers and conservationists in three states, and finally mail, telephone and personal inquiries among insurance, financial, and related government agencies. In the case studies it was found that there was initial confusion by developers coupled by increased state legislation that heavily impacted the development trajectories of the two case studies. The mail survey as well as telephone and personal inquiries concluded that it was too early to give definitive answers about the impact of CBRA. While some barrier beaches' development slowed as a result of CBRA the study found that ultimately the overall impact of the CBRA would depend largely on the responses of stakeholders in the coastal barrier Beaches as well as future federal actions.

While the CBRA was seen as a success, Jones (1991) found that there were other forces acting upon the system that allowed development to occur. The Government Accountability Office (GAO) (1992) found that CBRA's prohibitions against new federal financial assistance have discouraged development in some CBRS units, and others are not likely to undergo significant development in the near future because of their inaccessibility and/or lack of developable land. Significant development has occurred in some attractive and/or accessible CBRS units since 1982, and extensive new development is planned in these units and other units displaying similar characteristics. Salvesen (2005) found that CBRS units have undergone so much development that they are virtually indistinguishable from adjacent areas that are not part of the system. Yet in other cases, the difference between CBRS and non CBRS units are polar opposites. GAO (2007) stated that the CBRA does not appear to have been a major factor in discouraging development in those CBRS units that have developable land, local government and public support for development, and access to affordable private flood insurance.

2.4 ***State Coastal Management***

Coastal management at the state level is generally overseen by the CZMA. The funding and guidelines for programs within the state coastal zones are largely influenced by getting approval from the OCRM. These guidelines are very basic and leave much interpretation for states to create their own agendas as far as it goes for coastal management (Table 2-1). North Carolina has one of the most progressive programs under its Coastal Area Management Act (CAMA). CAMA requires each of the 20 coastal counties to have a local land-use plan in accordance with guidelines established by the Coastal Resources Commission. In each CAMA land-use plan local policies that address growth issues such as the protection of productive resources, desired types of economic development, natural resource protection and the reduction of storm hazards are addressed. The Florida Coastal Management Program (FCMP) is Florida's equivalent of CAMA. FCMP includes all counties in Florida and consists of a network of 24 Florida Statutes administered by nine state agencies. The goal of the program is to coordinate local, state and federal agency activities using existing laws. Maryland Coastal Zone Management Program (CZMP) is a comprehensive and coordinated program, based on existing laws and authorities, for the protection, preservation, and orderly development of the State's coastal resources. CZMP in Maryland is identified as three miles out in the Atlantic Ocean to the inland boundaries of the 16 counties and Baltimore City that border the Atlantic Ocean, Chesapeake Bay and the Potomac River up to the District of Columbia. These are just a few of the coastal management programs that exist around the United States, but it is evident that these plan all have differences in how they manage and how they carry out their objectives even though they function under the same guidelines of the CZMA.

2.5 *Local Coastal Management*

Coastal policy at the local/county level varies depending on region or even municipality. Local Governments have to follow the guidelines set by federal and state agencies, but they have their own power to further regulate their coastal areas. Through the use of local planning, most likely through zoning regulations, local municipalities can manipulate the trajectory in which their coastal landscape will evolve over time. Many times regions that have low growth within their coastal areas have a stakeholder support from community to preserve/protect its coastal region. State, regional, and national efforts to manage resources are consistently mediated and constrained by the preferences, incentives, attitudes and values of those who are in direct contact with the resources (Wiley et al. 2007). When looking at local coastal policy it is the interest of the local stakeholders that plays a pivotal role in shaping the policies within an area. This is where the strict enforcement of specific policies occurs and it is based on this preference of policy that some are enforced more than others.

2.6 *Objectives*

The overall objective of this research is to characterize the patterns and drivers of land use/cover change on barrier beaches along with examining the role that development, spatial accessibility and policy have in determining land use/cover change. This will ultimately help in the contribution to knowledge of U.S. coastal land change science. The research will also describe and classify barrier beaches into a descriptive typology. In creating the barrier beach typology it will include data ranging from land cover, social attributes, anthropogenic inputs, as well as coastal hazard elements. Along with creating a barrier beach typology the research will seek to assess the relative strengths and drivers of development using statistical regression techniques. Through review of literature specific coastal drivers will be identified and measured to determine the degree to which the chosen factors affect the trajectory of developed land cover on barrier beaches. Finally, the research will seek to understand the influences and forces that cause outliers through detailed case studies of identified units. Through the use of attributed spatial data as well as historic documentation the research will seek to understand changes in barrier beaches at high spatial and temporal scale.

Goal 1: Identify the population of Atlantic coast barrier beach spatial units and perform a quantitative descriptive analysis resulting in a classification typology of different Atlantic barrier beach types.

- Produce a thematic GIS data layer containing the population Atlantic barrier beaches.
- Develop a database characterizing biophysical, socio-economic, and policy attributes of Atlantic barrier beaches
- Perform descriptive and quantitative cluster analysis to produce a typology of Atlantic barrier beaches.

Goal 2: For the population of barrier beaches, develop a quantitative statistical model of developed land conversion that incorporates theories, tests hypothesizes and applies methods from the emergent field of land change science.

- Develop theoretically informed expectations of factors that influence land conversion to developed use status for Atlantic barrier beaches.

- Apply statistical regression analysis to test hypothesizes regarding drivers of coastal land change.

Goal 3: Using results from prior goals to guide selection perform a localized, place-based analysis of land change using quantitative and qualitative data, historical and newspaper data, and policy history for two or three selected beaches in order to construct narratives that account for the spatially and temporally contingent process of barrier beach places.

- Select a set of barrier beaches whose observed land change trajectory is substantially different from that predicted from the quantitative predictive model in order to explore more nuanced, localized, and place-based model of coastal land change.
- Assemble a qualitative database for targeted beaches to include historical documentation, newspaper articles, and policy information.
- Create a theoretically informed, narrative analysis of barrier beach land change.

Table 2-1: State Coastal Management Programs

STATE	PROGRAM NAME	PROGRAM OVERSEER	AREA OF INCLUSION	LAND USE PLAN TYPE
North Carolina	Coastal Area Management Act	NC Department of Environmental Resources	Coastal Counties	County Plan
Florida	Florida Coastal Management Program	FL Department of Environmental Protection	Entire State	State Plan
Maryland	Coastal Zone Management Program	MD Department of Natural Resources	Coastal Counties	State Plan

Figure 2-1: Barrier Beach Creation Theories (Adapted from Wanless 1974)

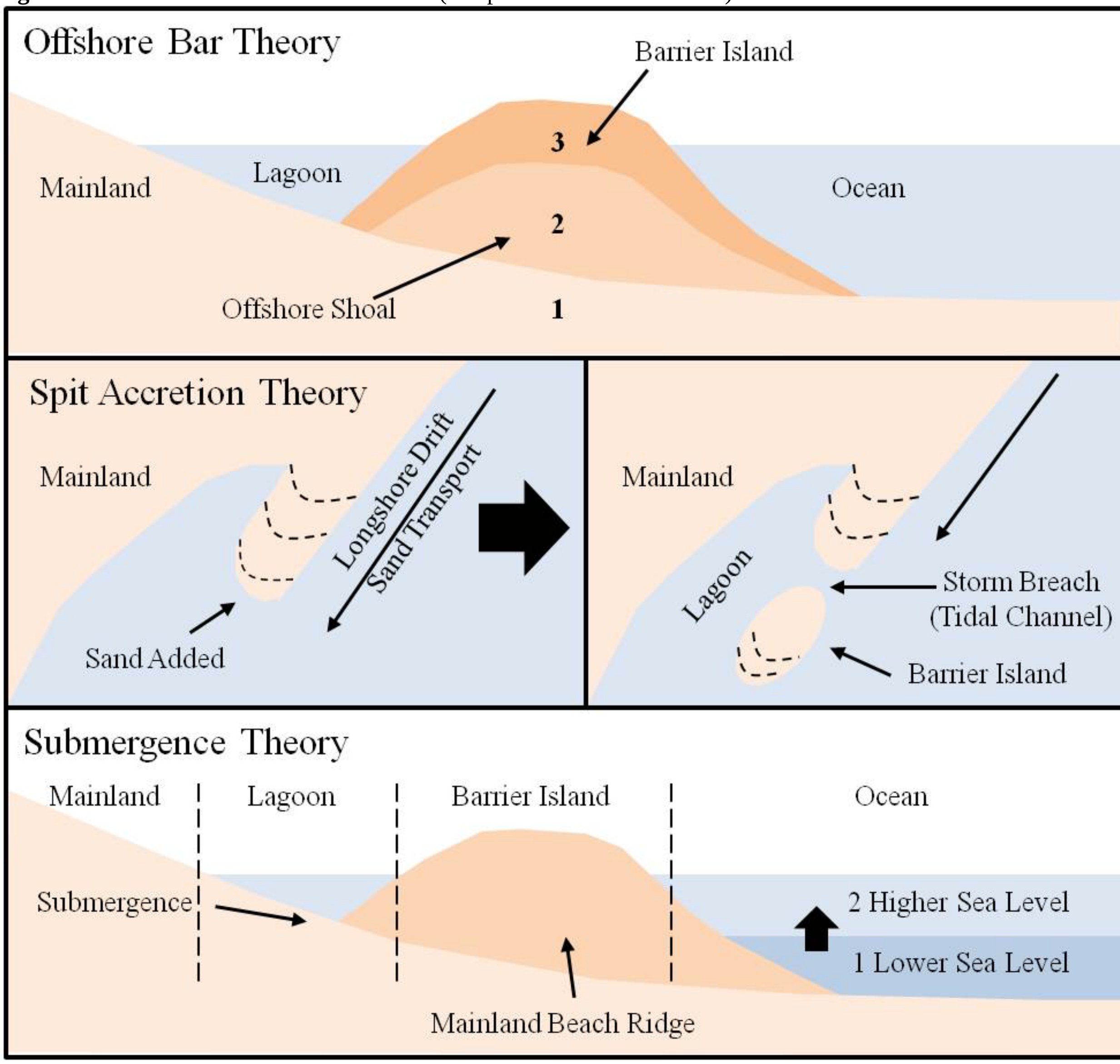


Figure 2-2: Barrier Beach Cross Section

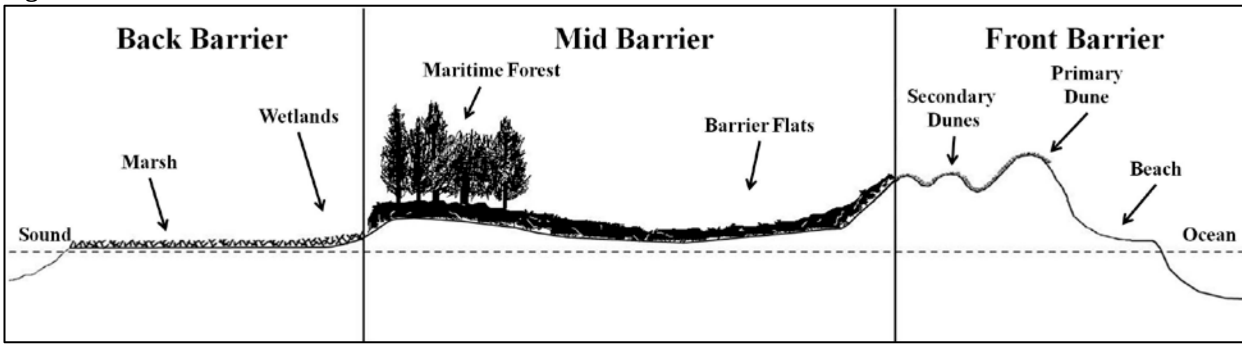


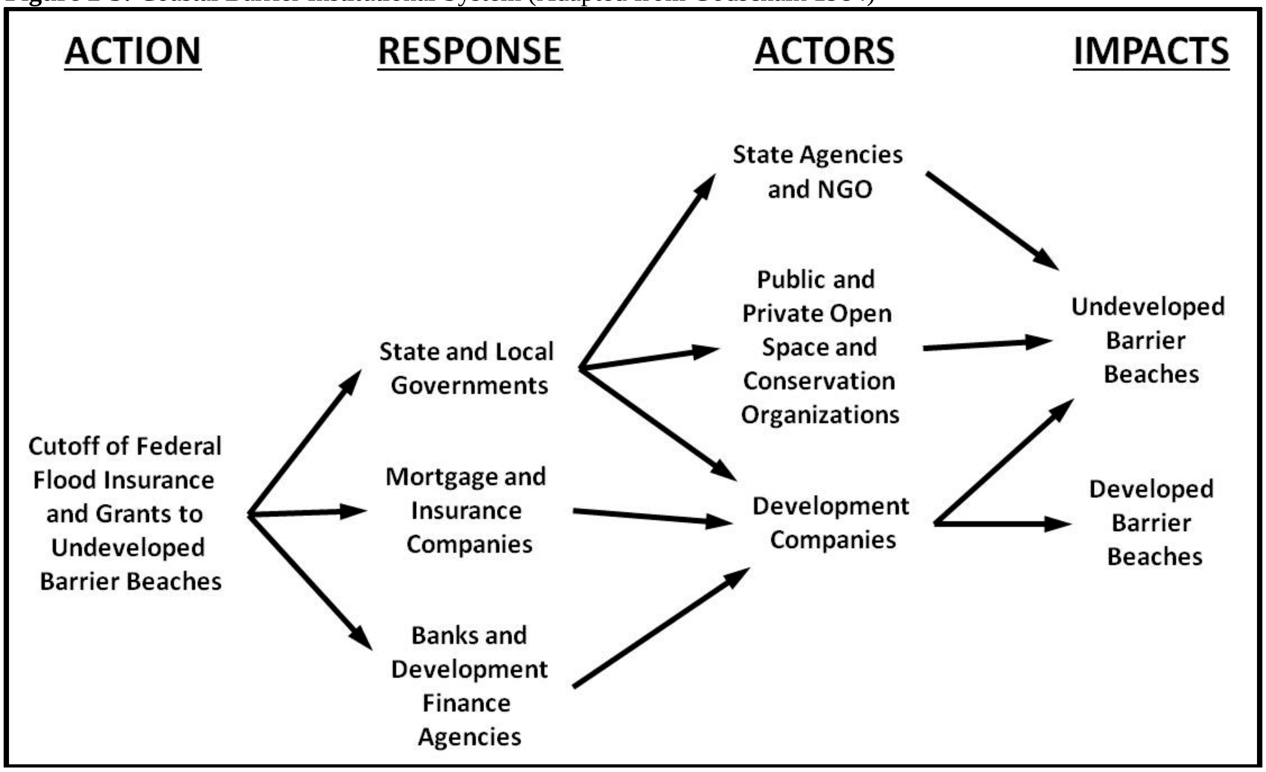
Figure 2-3: Coastal Land Use/Cover Change Milestones

- 1992 • **NOAA creates the Coastal Change Analysis Program (C-CAP)**
- 1993 • **National Land Cover Data Base is formed**
- 1994 • **Launch of IGBP's Land Use and Cover Change Program (LUCC)**
- 1996 • **Launch of NASA's Land Cover/Land-Use Program (LCLUC)**
- 1999 • **Launch of NSF's Biocomplexity Program**
- 2001 • **NRC Identifies "Land Use Dynamics" among eight *Grand Challenges in Environmental Sciences***
- 2004 • **Publication of *Land Change Science,* a Synthesis of prior LCLUC Program Results**
- 2005 • ***USGS Circular 1281 Geography for a Changing World Identifies nine land change science goals***
- 2006 • **Publication of *Land Use Land Cover Change,* a synthesis of prior LUCC program results**
- 2006 • **Launch of the new *Journal of Land Use Science***
- 2006 • **LUCC project closes and is integrated within the IGBP Global land Project**
- 2007 • **Launch of NSF's Dynamics of Coupled Natural and Human Systems Program**

Figure 2-4: Federal Barrier Beach Policy Timeline

- **1968** • **National Flood Insurance Program**
- **1972** • **Coastal Zone Manamgent Program**
- **1980** • **Barrier Island Bill**
- **1981** • **Omnibus Reconciliation Act**
- **1982** • **Coastal Barrier Resources Act**
- **1990** • **Coastal Barrier Resources Improvement Act**
- **2000** • **Coastal Barrier Resources Reauthorization Act I**
- **2005** • **Coastal Barrier Resources Reautherization Act II**

Figure 2-5: Coastal Barrier Institutional System (Adapted from Godschalk 1984)



Chapter 3: Social Landscapes and Land Cover Characterization of the U.S. Atlantic Barrier Coast: A Place-Based Typological Classification, 1990-2000

Effective coastal management requires understandings of focal environments that span the multiple facets of both human and natural systems. A coupled natural-human systems approach is therefore a critical perspective that contemporary coastal managers should strive to incorporate in planning and policy analyses. Natural scientists across multiple disciplines have a robust research record that examines environmental coastal patterns and processes. At the most fundamental level, classification approaches have identified a comprehensive set of different coastal environments based on factors such as geomorphic form, biotic communities, and hydro geochemical environments (Buddenmeier et al. 2008). The Land-Ocean Interactions in the Coastal Zone Project (LOICZ) of the International Geosphere-Biosphere Program has focused on quantifying and classifying the global coastal zone in terms of variation of carbon and nutrient dynamics (Talaue-McManus et al. 2003). The LOICZ effort explicitly attempts to perform assessments that, following coupled natural-human systems paradigm, attempts to link both biophysical and socio-economic data.

Marcucci et al. (2012) have recently described the intersections between professional coastal management and urban and regional planning, articulating the need for an integrative ecological landscape planning framework and the importance of landscape meaning. Both of these lessons point to the significance of coupled natural-human systems and place-based approaches. The coast in its broadest sense is a place, but at finer scales clearly the coast is made up of multiple distinct places each having an array of natural and social characteristics. Adopting a place-based approach provides a context in which problems to be addressed by coastal managers and planners can be identified and expressed, which different ideals can be understood (Potschin and Haines-Young 2012). An exploration and understanding of place, has been acknowledged as one way in linking the connections between people and the environment (Wilson and Bryant 1997; Bryant and Wilson 1998; Lackey 1998; Stringer et al. 2006; and Reed 2008). Albrechts (2006a, 2006b, 2010) states that a ‘‘sociospatial’’ method must be both ‘‘transformative’’ and ‘‘integrative’’, which through integration of people is able to ‘‘shape and frame what a place is and what it might become’’. The anthropogenic inputs onto the coastal landscape make the coast a place of interest and it is at the intersection of both physical characteristics and anthropogenic inputs that coastal typological classification can and should be created. The goal of this current research is to develop and present a place-based classification of barrier beach units along the U.S. Atlantic coastline that incorporates human social dimensions and land cover patterns.

Many examples of typological classification exist spanning the natural and social sciences, but there are few examples for explicitly coastal settings that integrate natural and social science domains targeted towards management end-users. Brenner et al. (2006) provide one example for the Spanish Catalon coast that uses GIS to incorporate human population, economic indicators, and land use with geomorphic, biotic, and hydrological characteristics as input to cluster analysis that yields a set of “homogenous environmental management units”. With the use of GIS, applied geodemographic classification involving cluster analysis techniques applied to spatial data has become a common approach to disentangle the complexities of multi-variate datasets into more parsimonious regional typologies (Debenham et al. 2003; Singleton and Longley 2009).

This place-based approach to classifying coastal regions is best exemplified in Tym and Partners (2011). Coastal typologies of coastal 10,057 community units along the entire coast of

United Kingdom were classified. They measured 42 socioeconomic characteristics of communities and clustered them using a K-Means algorithm. They created ten clusters based on the collected data. They furthered the research through creating four sub clusters were based on the ten created cluster characteristics. The four created groups were classified as coastal retreat, coastal challenges, coastal fringe, and cosmopolitan coast. Coastal retreats represented areas that are sparsely populated areas where small less developed resorts exist. Coastal Challenges are areas which have places shifting industries creating new ones and areas living in poverty. Coastal fringe is areas outside of the larger coastal cities as well as ones who have changed little over time. Cosmopolitan coast are areas that have striving economies either in tourism or industry with highly skilled workforce.

Particularly relevant for this analysis of the Atlantic barrier coast is the body of work investigating regional transformation in the U.S. Rocky Mountain west resulting in what many have termed the "New West". While the New West clearly is not a coastal region, it is suspected that the underlying dynamics share similarities with transformations occurring in at least some parts of the barrier beach coast. The general theme of the emergent New West is the transformation from traditional Old West communities focused on production landscapes associated with extractive farming, ranching and mining to consumption landscapes associated with amenity-oriented in-migration and land use, growth of service sector economies, tourism, and seasonal housing growth (Williams and Patrick 1990; Nash 1993; Rudzitis 1993; Riebsame et al. 1997; Bennett and Mcbeth 1998; Beyers and Nelson 2000; Shumway and Otterstrom 2001; Crawford and Wilson 2005; Winkler et al. 2007).

The U.S. Atlantic barrier coast is of course very different from the Rocky Mountain west in terms of its much longer history of development where many coastal places have a long history of significant and sizable human occupation and disturbance. Despite this significant difference, this typological analysis seeks to characterize these coastal places to yield a heterogeneous set of place types that can be interpreted in a manner similar to homogeneous ecological management units (Brenner et al. 2006). While multiple place types will be present, there likely exist pockets of coastal barrier beach places similar to New West communities where amenity oriented growth and land use and tourism are key factors transforming the coastal landscape.

I also bring an explicitly coastal management theme to my analysis by considering the role of national coastal policy in the context of coastal hazards. The Atlantic barrier coast is vulnerable to damaging effects of coastal storms and shoreline erosion. The federal government has attempted to reduce costly expenditures related to these hazards by creating the Coastal Barrier Resources Act (CBRA) of 1982. CBRA was designed to promote a free market approach to coastal development through the removal of federal flood insurance and federal spending that would induce development by reducing development costs. CBRA impacts have been mixed (Salvesen 2005; Godschalk 1984; GAO 2007 and 1992). Development growth since 1982 within some CBRA units is virtually indistinguishable from adjacent non-CBRA units while others are starkly different (Godschalk 1984). A secondary goal of this analysis is therefore to compare the resulting place-based classification typology with CBRA status to determine if places in resulting place types experience higher rates of growth associated with CBRA status. The expectation is that the influence of CBRA status will act to dampen growth rates.

To summarize objectives: First, I perform a quantitative descriptive analysis of the Atlantic barrier coast region to yield an integrative coastal place typology classification that incorporates both socio-economic and land cover data. Second, I evaluate the patterns and linkages amongst CBRA units and non-CBRA units with respect to the coastal barrier beach typology.

3.1 ***Study Area***

The study area encompasses the Atlantic coast seaboard spanning nine states and 2,000 km from Long Island, New York to Miami Florida (Figure 3-1). Barrier beach units are defined as barrier islands, tombolos, spits, bay barriers, Sea Islands, or ocean proximal land areas directly in contact with the Atlantic Ocean. Coastal landform types present in other parts of the U.S. (i.e. rocky shores, marine terraces, etc.) were excluded in order to focus solely on coastal barrier beach environments. Input data used were temporally organized to quantify estimated patterns of change for the period 1990 to 2000. Ideally the temporal framework would span a longer time period with a more current end date. However, data availability limited the analysis to this period because required census data at the block or block group level for 2010 were not available at the time of analysis. Similarly, the most recent available land cover data temporally consistent with available census data were from 2001. Despite these temporal limitations, using these best available data enables one to characterize fairly recent patterns and dynamics across the entirety of the Atlantic barrier coast. The methodological process describe more fully below included: (1) creating a GIS layer defining barrier beach spatial units (i.e. coastal barrier beach places), (2) characterizing land use/cover change, socio-economic patterns and change and CBRA status, (3) performing cluster analysis to create a place-based coastal barrier beach typology, and (4) comparing results of the classification results with the CBRA policy status.

3.2 ***Barrier Beach Data***

Data used to create a barrier beach place-based database integrated a variety of datasets including administrative boundaries, satellite classified land cover data products, census socioeconomic data, and policy status data. All measures of this data were performed at different processes to calculate the best available calculations for each barrier beach unit. This process attempts to create constancy with calculations. Barrier beaches present a challenge when analyzing areal units due to the mobility of these places to shift and move over time as well as the procedures to analyze the data. When looking at this data the dilemma of the Modifiable Areal Unit Problem (MAUP) noted by Openshaw (1984) must be taken into account. MAUP stresses that the areal units, which are used geographical studies are subjective, changeable, and subject to whoever is doing, or did, the data collection.

3.2.1 Barrier Beach Unit Identification

Barrier beach units are treated as individual "places" and were identified using methods adapted from Zhang and Leatherman (2011) using Bing Maps imagery (Figure 3-2) and GIS spatial data editing. The dates for the Bing Maps varied, ranging from 1993 to 2010 in concert with other GIS data products. Barrier beach landforms were digitized as vector GIS polygons to conform to land/ocean interface boundaries visually evident in the Bing Maps imagery at a constant viewing scale of 1:20,000. This initial boundary layer was then combined with the U.S. Fish and Wildlife Services (USFWS) Coastal Barrier Resources shapefile containing vector polygons identifying the boundaries of formally defined units subject to the CBRA as well as Otherwise Protected Areas (OPA). OPA areas include national wildlife refuges, national parks and seashores, state and county parks, and land owned by private groups for conservation or recreational purposes. Coastal barrier beach land areas not identified as CBRA and OPA were understood to be non-CBRA. This union of geospatial datasets yielded three different barrier beach unit groups: CBRA, non-CBRA, and OPA. Note that this grouping is simply part of the initial data preprocessing and is not part of the analytical clustering process or results.

Spatially large units and those with more complex geomorphologies such as Sea Islands in South Carolina and Georgia were examined at finer resolutions to perform more nuanced spatial data editing. Myrtle Beach initially had a land area much larger than other units which led required separating it into three parts, North Myrtle, Myrtle Beach, and South Myrtle, according to 1990 census tract boundaries. New Jersey's initial Belmar and Asbury Park barrier beach units are cemented to the mainland as opposed to barrier beaches on true barrier islands that are prevalent throughout much of the study area. For these mainland cemented units, only the 1990 census tract land areas adjacent to the ocean were included. A small number of other isolated cases were treated in an identical manner.

In no cases did CBRA or OPA units span state boundaries. Non-CBRA units that crossed state boundaries were split to create two separate non-CBRA units. Some non-CBRA units were not spatially contiguous due to perforation by OPA or CBRA units so that they contained two or more distinct parts. Spatially disconnected parts no more than two miles in distance from one another on the same barrier beach landform were defined into a single common barrier beach unit. Finally, military installations were removed from the study due to their unique characteristics related to national defense.

In total, 188 barrier beach units were identified. Off these units, 49 were CBRA, 58 were OPA, and 81 were non-CBRA (Table 3-1). The barrier beach units are treated as distinct coastal places where a place may be, for example, a settled coastal community not subject to CBRA (i.e. Asbury Park, NJ), a coastal community subject to CBRA (i.e. Currituck Banks, NC) or an OPA protected area (i.e. Cape Hatteras National Seashore).

3.2.2 Land Cover Data

Land cover data were obtained from the Multi-Resolution Land Consortium (MRLC), a group of 11 federal agencies that coordinates and generates geospatial land cover products for the United States (Homer et al. 2007). The National Land Cover Database (NLCD) land cover classification provided by the MRLC is based on Landsat Thematic Mapper satellite imagery (NOAA 1995) and has a pixel resolution of 30 meters. The NLCD uses image processing and classification techniques to provide land use/cover and change information at the Anderson Level II classification scale (Anderson et al. 1976).

The NLCD products were used to quantify for each barrier beach unit (i.e. place) amounts of developed land use and change. Land cover data from 1992 and 2001, the closest available dates to 1990 and 2000 census products, were used. The data were generalized from the more detailed Anderson Level II classification to a Level I classification. Generalization acts to simplify the data by creating singular thematic classes (i.e. developed, forest, wetland, etc.) as opposed to multiple classes per theme (i.e. high, medium or low developed). Generalization also improves classification accuracy. Wickham et al. (2010) found that the users' accuracy of the NCLD 2001 Anderson Level I classification for the developed classification had an accuracy up to 93.1 %.

For each of the barrier beach units GIS processing was used to quantify: (a) total land area, (b) potentially developable land area, (c) 1992 developed land area, (c) land area developed during 1992-2001. Potentially developable land area was calculated by subtracting all water, wetlands, and park land area from total land area (Figure 3-3). The logic is that development would be unlikely to occur for these land cover categories. Note that some pixels in the NLCD products contained small counts of water pixels (i.e. interior ponds, canals, etc.). Importantly, subtracting in this manner allows for a measure of the amount of land available for development as well as actual amounts of development and development change.

3.2.3 Socio-economic Data

Population and economic characteristics for each unit were assembled from 1990 and 2000 census data (Table 3-2). Various GIS overlay and aggregation methods using census blocks and block groups were necessary to derive the variables due to the fact that census units in many cases did not perfectly align the self-generated barrier beach unit boundaries. Count data (i.e. population, housing) were computed by selecting block centroids falling within the boundaries of identified barrier beach units and summing the associated values which were assigned to the appropriate respective units, (Figure 3-4). Population and housing unit density were calculated by dividing these respective counts by the amount of land area available for development. Percents of population by age categories were calculated by dividing these respective counts by total population. To determine median housing value and income, census block group data from 1990 and 2000 were used as higher resolution census block data do not contain these attributes due to confidentiality issues related to data release. Due to the larger size of block groups compare to blocks, the centroid method was not used, and instead the block group data were transformed into a 30 meter raster with each pixel being assigned the value of the block group within which it was located. For example, pixels were assigned median income values for their respective block groups. Zonal statistics were used to calculate the mean of all pixels in a barrier beach unit to yield the final variable. For example, a unit may have pixels located in three different block groups thereby having three different median income values represented by these pixels. Summing all pixel values and dividing by the total count of pixels yields an estimate, in this example, of median income for the barrier beach unit. This method is similar to vector areal interpolation but differs by operating in a raster environment.

Development density was measured by calculating the amount of developed land cover in 1992 and dividing it by the amount of available land in 1992. The step was repeated to generate development density for 2001 data. Population and housing densities in 1990 and 2010 were calculated by taking the total number of population and housing units and dividing by the total available land using 1992 land cover data for 1990 and 2001 land cover data for 2000. Percent of seasonal housing was calculated by taking the total seasonal housing units and dividing that by the total number of housing units. Percent of population over 65 (i.e. retirement age) and between 18 and 64 (i.e. working age) were calculated by dividing the respective population counts by the total population. Median housing value and median income were calculated by taking the created pixel value average for each barrier beach unit for 1990 and 2000. Units that were classified by the US Fish and Wildlife Service's CBRA as Otherwise Protected Areas (OPA) (i.e. national wildlife refuges or other protected status) and those barrier beach units with no population or housing for either 1990 or 2000 were omitted and determined to be protected/undeveloped. This reduced the total number of units used for analysis from 188 to 114. These 114 units represent all coastal barrier beach places that are not in protected status from Long Island, New York to Miami, Florida.

3.3 *Cluster Analysis*

A set of 16 variables were used as input for cluster analysis (Table 3-2). The temporal logic for use of these variables is that it accounts for characteristics at the 1990 start date coupled with change over the 1990-2000 periods. Eight variables represented characteristics at the initial 1990 date while the remaining eight represented change for 1990-2000. The K-Means cluster analysis technique was used to generate the place-based typology. In the clustering process, K-Means separates observations into distinct, relatively homogenous groups having the minimum within-cluster variation and the maximum between-cluster variation K-Means also requires numeric interval or ratio scaled variables with equal scale units (Bacher et al. 2004). The variables included in the typology are based on different scale units (i.e. some are counts and some are percentages). All variables were therefore standardized prior to analysis using SPSS statistical software.

Within K-Means the value of *k*, or the total number of clusters, is not prescribed rather it is chosen by the user. To generate an appropriate value for *k* a hierarchical approach is taken; in this case Wards Linkage is used. It has been found that when combining both hierarchal approaches along with K-Means results better cluster creation (Chen et al. 2005, Li et al. 2007). The first part of process is all variables are placed into a Principle Components Analysis (PCA). The PCA converts the variables into a set of linearly uncorrelated variables otherwise known as principle components (PC). Of the sixteen variables placed into the PCA 7 PCs were created whose cumulative variance of 83.6% (Table 3-3). The PC's variance is what accounts for the variability or how the numbers are spread out within the data.

The loadings based on the rotated component matrix revealed that for the first PCA, which explained roughly 15.5% of the variance density of development, population, and housing in 1990 were the most heavily loaded variables (Table 3-4). While PC2 which accounted for 14% of the variance revealed that median income in 1990 and change as well as median housing value in 1990 had the highest loadings. For PC3 housing and population change were leading loaders with a variance of 12.7%. Working class 1990 and Change were the heaviest loaded variables for PC4 explaining 11.5% of the variance. PC 5 highest loaded variables were seasonal housing

1990 and change with a total variance of 10.9%. Development change and Over 65 1990 and change were highest loaded variables for PC6 with a variance of 10.6%. Finally PC7 highest loaded variable was median housing value change with an 8.4%variance.

The second step in determining *k* is placing the seven generated PCs from the PCA into a Ward's Method. This method is used in succession with K-Means to create aggregate the appropriate number for *k*. This is done through finding the stage where the greatest variance between coefficients exists in the Wards Methods, otherwise referred to as the elbow (Figure 3-5). Then the total number of stages is subtracted by the elbow, which determines the appropriate number of cluster for K-Means analysis (Thorndike 1953). Results revealed six clusters to be optimal as indicated by the number of stages subtracted by the elbow location (114 stages minus elbow at stage 108 = 6).

3.4 ***K-Means Results***

K-Means cluster analysis results yielded 6 clusters containing 2, 2, 6, 21, 37, and 46 barrier beach units respectively. The clusters are plotted on a scatter plot in Figure 3-6 using the PCA output. The PC1 through PC4 were used to chart the different cluster comparison. Small clusters (n=2) were not reported on because they were a third of the smallest cluster making them less meaningful compared to larger clusters. They also were identified as CBRA barrier beach units meaning that a degree of variability was created based on policy interaction that would be hard to explain in clusters. The mean, median, and standard deviation values were calculated to assess the general characteristics of each cluster (Table 3-5). Based on inspection of quantitative cluster results for the original untransformed input variables classification names were assigned to each cluster. Naming classifications admittedly introduces some subjectivity (Vickers and Rees 2007 and Lupton et al. 2011) although resulting clusters are based entirely on quantitative data and methods. Along with interpretation of the qualitative meaning of the quantitative variables, place characteristics were researched through town web pages to aid interpretation and naming of the resulting cluster types.

The four cluster classifications created include beach cottage, established vacation, vacation, and second home communities. The creation of these cluster classifications help validate typology as a management or planning tool (Tym and Partners 2011). It allows the creation of place identity and typology understanding and visualization to the observer. After the four clusters were identified they were placed into one of two generalized categories termed Old Atlantic and New Atlantic (Figure 3-7). Two sub clusters were created inductively through looking at the raw data results for the original created clusters as done in Tym and Partners (2011). The first sub cluster community type created is Old Atlantic communities; these units are described as areas whose characteristics remained largely stable over the study time frame with high population and high permanent housing densities. The second sub cluster community type is New Atlantic communities, which are those units whose characteristics exhibited greater change associated with growth and development over the observed period.

3.5 ***Atlantic Coast Barrier Beach Communities***

3.5.1 Old Atlantic Communities

The results from the K-Means cluster analysis show that Old Atlantic Communities embody highly developed and established communities. During the study period, slow to no growth in population density as well as housing density portray these places as exhausted in terms of new development (i.e. built out) and population. While these places are highly developed and slow growing over the study period, they also exhibit larger working age populations as well as lower median incomes and median housing values. These units range from developed urbanized coasts to highly developed beach cottage communities. These places over the observed period exhibit the characteristics of places slowed by the availability of land as well as the existing population and housing pressures existent at the beginning of the study period.

Beach Cottage communities represent the largest clustering of units (n=46), these units exhibit slow growth in developed density over the observed period. These areas can be seen as barrier beach communities that have slower paced change yet have been developed over a longer period of time then observed in this study. Communities such as Wildwood, NJ and Hatteras, NC are representative of these beach cottage communities. Over the observed period these places have lost a percent of seasonal housing yet have increased in population density as well as housing density. This reflects the idea that this area is a permanent coastal settlement instead of one that is based on seasonal tourist driven amenities. From the beginning of the observed period the changes in these beach cottage communities has been minimal. This is because there are other factors at play that are limiting the changing within these areas from becoming tourist and amenity driven destinations.

Established Vacation communities embody an area that has been highly developed over time. These areas are ones that are not only highly developed, compared to beach cottage communities, but have high population and housing densities as well as high percentages of working age and retired age populations. These areas are representative of the urbanized coast such as north Myrtle Beach, SC and Miami Beach, FL. Over the observed period the home density was nearly equal to the population density. This ratio along with the high development density is consistent with the idea that this is a permanent barrier beach community that is fully developed yet still visited by tourist. The reason why these units are established is due in part to the high overall development of these places. With little room to grow these barrier beach communities are left to either knock down and rebuild or remain the way that they are.

3.5.2 New Atlantic Communities

The coupling of land availability and demand for vacation housing has likely contributed to the resulting set of New Atlantic places. New Atlantic is comprised of two cluster groupings with a total of 43 units. New Atlantic place types represent units with low development and population densities, high increases in percent of seasonal housing and development densities. These increases are reflective of population that is based on tourist influxes and not on permanent residents. When comparing housing density to population density, homes well outnumber any population over the observed periods. Permanent population makeup in these areas is largely made up of working age and retired age populations only less than ten percent of the population under the age of 18.

Vacation communities are one of the two New Atlantic places, which are characterized by high percentage of housing designated as seasonal homes. These areas are driven by tourism and people's affinity for coastal places/getaways like Cape May, NJ and Corolla, NC. These places are driven by the idea of a coastal vacation getaway with plenty of seasonal rental homes. When looking at the comparison between housing density and population density reveals that there are 1.5 homes to every person. From this one can say it is highly focused on seasonal housing. Through combining the working age and retired age populations leaves a small percentage of the population under the age of 18. This small percentage of population under the age of 18 along with housing and population characteristics create the image that these barrier beach units are vacation getaways with a small permanent population most likely retired and local workers.

Second home communities are illustrated by populations that are older with high percentage of homes designated as seasonal. These communities have lower overall incomes as well as housing values compared to vacation communities. Sunset Beach, NC and Jupiter Island, FL are examples of second home communities. While these are classified as units with high older populations these areas are lined with residents who move to and develop homes on the coast. The second home communities on these barrier beaches may not be centered on the notion of tourism, but coastal amenities are the impetus for drawing these populations to the coast and to develop a second home.

3.5.3 CBRA and Non CBRA

When looking at the differences in CBRA and Non-CBRA units in both new and old Atlantic communities a common trend emerges (Table 3-6). Both Old and New Atlantic CBRA units have exhibited the greatest growth over the observed period (1990-2000). While these areas are without any federal assistance in terms of access to national flood insurance and federal funding for infrastructure improvements, people are drawn to these areas to develop. Rate of growth in CBRA units over the observed period shows that change on barrier beach units are somehow directly linked to one another. While these barrier beach units are small in overall land area, compared to Non-CBRA units, they warrant a closer look as to how driving forces and place histories have influence this change.

3.6 ***Nonparametric Results***

Nonparametric results were reported by using two different tests (Table 3-7). These tests were chosen because the data were not normally distributed. The Kruskal Wallis test was used to identify differences between the four created clusters. It is the nonparametric version of a one way-ANOVA and tests the hypothesis that *n* populations have the same continuous distribution based on the medians. All the measures from all samples are placed into a single set. The assembled measures are ranked in order from lowest to highest. The ranks are then returned to the sample to which they belong and substituted for the raw measures. The null hypothesis in this or any situation involving several independent samples of ranked data is that the mean of the ranks of the groups will not significantly differ.

The Mann-Whitney U test was used to determine any differences between New and Old Atlantic groupings and is the nonparametric equivalent of a t-test that is evaluated on whether or not the median of the scores is equal to zero. If the respective test statistics the Kruskal Wallis and Mann-Whitney U have p-values $p<.05$ then one interprets that there is a significant differences between the cluster means. A difference in clusters means indicates there is a separation between the created clusters which in turn creates a level of validity in the cluster results.

3.6.1 Kruskal-Wallis Test (Four Clusters)

Testing the four identified clusters the results showed that there were significant differences between some of the 16 explored variables. The test revealed that all 1990 variables had at least one pair of clusters that were significantly difference from each other. For development density in 1990 established vacation had differences between both vacation and beach cottage communities. Population density and housing density significant differences were found between established beach communities and all other identified clusters. For percent of seasonal housing it was found that beach cottage had differences between vacation and established vacation. Age over 65 and working class differences existed between vacation and second home clusters. Median income cluster differences were found between second home and both vacation and established vacation clusters. While media housing value ha differences between second home cluster and beach cottage and vacation clusters.

For the 1990-2000 change variables, only seasonal housing percent and median income change were statistically significant. Result shows the differences in initial 1990 characteristics and that percent of seasonal housing change and change in median income were the major changing factors that are existent along the four groups. Percent seasonal housing change differences between beach cottage and vacation clusters were found. While looking at median income change second home clusters expressed differences between beach cottage and vacation clusters as well as vacation and established vacation clusters were found significant. This indicates that these two change variables are what drives and ultimately creates the deviations between the created clusters. This makes them important factors in creating the typology for these barrier beach places.

3.6.2 Mann-Whitney U Test (Two Clusters)

These factors, more than those found with the Kruskal-Wallis test, exemplify change for the more generalized in Old and New Atlantic communities. Testing New and Old Atlantic groupings, the results showed that development density, population density, housing density, percent of seasonal housing percent, percent over 65, and percent working age for 1990 were significantly different between the two groups. This varies from the results found in Krustkal-Wallis test in median income and median housing values were not found significantly different. For change variables, results showed that development density, seasonal housing percent and over 65 were change factors that were significantly different. Percent of seasonal housing change was the only change variable that was statistically significant in both tests. This suggests that percent of seasonal housing is the major component that separates these groupings on coastal barrier beaches.

3.7 *Discussion*

Results from the research suggest that there is a typology of places characterized by land use development and socio-economic patterns for 1990-2000 along the Atlantic coast's barrier beaches. Different coastal barrier beach place types have experienced different levels of development and socio-economic change during this period. This change is ultimately causing a shift in the manner in which barrier beaches are developed and populated. The structure of these different communities embodies trajectories of change that have occurred within the observed period. These patterns seem to be consistent with ones seen in parts of the New West region where a landscape of production is turned into a landscape of consumption. For the New Atlantic this representation is best viewed in the vacation community where influxes in housing as well as the percentage of seasonal housing stock in these communities represents a shift in the way barrier beach communities have evolved.

There exists the issue of policy when looking the results. It was found that of the New Atlantic communities CBRS units had the highest rates of development change over time. This leads one to believe that there is more going on in these two categories than can be seen through this analysis. The forces driving new development or redevelopment that exist within the different units could explain the variation in land conversion as well as socioeconomic atmospheres among these different units. CBRS units also represent an opportunity to further understand how policy and policy implication reflect changes along different units. This can be due in part of the availability of land in these areas to be developed or for other reasons unknown. Further research is needed to truly understand the drivers that lead to development on these barrier beach units.

The typology provides a way of clustering barrier beach units with similar socioeconomic and land cover characteristics. It is intended as a tool for coastal planners and researchers to better understand local socio-economic and land cover conditions and inform additional dialogues with local land-based planners and stakeholders. The typology names are intended to aid planners and searchers in using the typology. Like any clustering procedure there are clear limitations. First being the typology name will not directly correlate with those who live in the designated area because the naming convention is a social construct given to a generalized group of statistics. The second being the typology is merely a reflection at a given point and time and does not reflect the future, even though the future can be inferred from this research. Finally consistent data sources and interpretation measures on these areas limit the accuracy in which the data is reported and calculated.

Where this research has its shortcomings is in the consistency and accuracy of data. Ideally coupling historic land cover and socio-economic data from years prior to 1990 would be ideal way to track these trends, but due to the nature of data availability accuracy and consistency becomes a problem when dealing with the scale and scope of this analysis. Along with constancy of land cover and census data is the overall accuracy and scale of land cover data. For barrier beach that represent narrow strips of ever evolving land the size and accuracy at which land cover is generated can have a profound influence on the calculations. With average width of barrier beach only being one mile in width the use of 90m, 60m, and even 30m land cover pixels, which was used in this analysis, are not ideal when measuring barrier beach island land cover. Ideally 5m or less could accurately identify building footprints as well as road networks that exist instead of large areas of developed classification for smaller areas of actually developed surfaces. It is rationalized that if this research were done with finer resolution land cover data that overall development density would decrease but clustering results would remain the same.

This work contributes to the scholarship of land change science through engaging in analysis of land use land cover change beyond the basis of just strictly land cover in ways that attempt to integrate social and biophysical variables in an attempt to couple human and natural systems. This coupling of both the human and natural systems creates an analytical context that aims at explaining current patterns on unique barrier beach communities. This research is only the beginnings of attempts to both analyze as well as understand the land cover change and socio-economic paths that barrier communities undergo. For the first time all barrier beach places on the Atlantic coast have comprehensively classified based on thematic variables. This approach sets a template to organize places allowing for more detailed place-based accounts that investigate in more detail the historical trajectories and the local level policy can be performed. The product created through this research includes, in addition to class results, a data product that can be used to track all these places on in to the future. This will provide coastal policy managers a tool to track change of these places as time moves forward.

Table 3-1: Barrier Beach Identification Classification Breakdown

STATE	CBRA	OPA	NON-CBRA	TOTAL
New York	3	3	7	13
New Jersey	1	6	10	17
Delaware	2	3	3	8
Maryland	0	1	1	2
Virginia	2	7	3	12
North Carolina	9	7	16	32
South Carolina	14	6	16	36
Georgia	5	7	5	17
Florida	13	18	20	51
TOTAL	49	58	81	188

Table 3-2: Barrier Beach Variable Description

Variable		Unit	Definition
1990	Developed Density	Percent	1992 developed land area / available land area 1992
	Population Density	Persons/ha	1990 total population / available land area 1992
	Housing Density	Homes/ha	1990 total housing / available land area 1992
	Seasonal Housing Percent	Percent	1990 seasonal housing / 1990 total housing
	Over 65 Age	Percent	1990 population age 65 or over / 1990 total population
	Working Age	Percent	1990 population age 18-65 / 1990 total population
	Median Income	Dollars	Average of pixels for selected barrier beach unit
	Median Housing Value	Dollars	Average of pixels for selected barrier beach unit
Change from 1990-2000	Developed Density Δ	Percent	(2001 developed land area / available land area 2001) - (1992 Developed land area / available land area 1992)
	Population Density Δ	Persons/ha	(2000 total population / available land area 2001) - (1990 total population / available land area 1992)
	Housing Density Δ	Homes/ha	(2000 housing density / available land area) - (1990 housing density / available land area)
	Seasonal Housing Percent Δ	Percent	(2000 seasonal housing / available land area) - (1990 seasonal housing / available land area)
	Over 65 Age Δ	Percent	(2000 population age 65 or over / 2000 total population) - (1990 population age 65 or over / 1990 total population)
	Working Age Δ	Percent	(2000 population age 18-65 / 2000 total population) - (1990 population age 18-65 / 1990 total population)
	Median Income Δ	Dollars	Average of pixels 2000 - Average of pixels 1990
	Median Housing Value Δ	Dollars	Average of pixels 2000 - Average of pixels 1990

*Pixels are based on a 30m generated raster of block group boundaries

Table 3-3: Principle Components Total Variance Explanation

Component	Initial Eigenvalues		
	Total	Percent of Variance	Cumulative Percent
1	**3.072**	**19.201**	**19.201**
2	**2.582**	**16.140**	**35.341**
3	**2.041**	**12.757**	**48.098**
4	**1.872**	**11.703**	**59.801**
5	**1.529**	**9.556**	**69.357**
6	**1.156**	**7.223**	**76.580**
7	**1.124**	**7.022**	**83.602**
8	.810	5.063	88.665
9	.510	3.190	91.854
10	.392	2.452	94.307
11	.310	1.935	96.242
12	.214	1.340	97.582
13	.168	1.049	98.631
14	.099	.616	99.247
15	.073	.459	99.706
16	.047	.294	100.000

*****Bolded were used in the Analysis

Table 3-4: Principle Components Rotated Component Matrix

Variables	Component						
	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**
Developed Density	**.721**	.273	.079	.150	-.145	.163	-.008
Developed Density Δ	-.243	-.096	.200	.373	.345	**.616**	-.177
Population Density	**.906**	-.007	.036	.023	.176	.025	-.061
Population Density Δ	.140	.052	**.961**	.072	.040	-.028	.049
Housing Density	**.918**	.014	.027	-.016	-.014	.050	-.062
Housing Density Δ	-.012	.080	**.960**	.062	.033	-.096	.103
Seasonal Housing Percent	-.207	-.025	-.031	.113	**-.828**	.026	-.057
Seasonal Housing Percent Δ	-.149	.156	.046	-.126	**.814**	-.120	.020
Over 65	.256	.270	-.014	-.261	-.193	**.767**	.093
Over 65 Δ	-.163	.137	.281	.220	.158	**-.794**	-.044
Working Age	.089	.077	-.004	**.890**	-.020	-.185	.020
Working Age Δ	-.061	-.142	-.173	**-.825**	.364	.040	.019
Median Income	.040	**.941**	.040	.098	.135	-.006	-.081
Medina Income Δ	-.005	**-.608**	.016	.117	.076	.082	.654
Median Housing Value	.159	**.859**	.112	.129	.069	.050	.126
Median Housing Value Δ	-.118	.095	.134	-.053	.034	-.007	**.912**

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Rotation converged in 12 iterations.

Shaded and bolded cells represent highest loaded variables for the particular PC

Table 3-5: Barrier Beach Cluster Change from 1990 to 2000

Variable		Old Atlantic n=67			New Atlantic n=43		
		Beach Cottage n=46	Est. Vacation n=21	Average	Vacation n=37	Second Home n=6	Average
Developed Density	Mean	51.0%	87.0%	64.2%	58.0%	42.0%	55.8%
	Median	60.0%	90.0%	69.4%	61.0%	41.0%	58.2%
	Std Dev	29.0%	13.0%	24.0%	31.0%	28.0%	30.6%
Developed Density Δ	Mean	1.0%	2.0%	1.4%	3.0%	9.0%	3.8%
	Median	0.0%	0.0%	0.0%	2.0%	3.0%	2.1%
	Std Dev	4.0%	3.0%	3.7%	4.0%	14.0%	5.4%
Population Density	Mean	73	690	275	40	130	53
	Median	53	480	187	37	73	42
	Std Dev	73	423	183	33	183	54
Population Density Δ	Mean	17	53	29	10	20	11
	Median	13	33	19	10	7	10
	Std Dev	27	93	48	13	60	20
Housing Density	Mean	130	523	261	67	90	70
	Median	83	380	176	50	77	54
	Std Dev	143	307	194	57	87	61
Housing Density Δ	Mean	13	17	15	23	23	23
	Median	13	10	12	27	13	25
	Std Dev	33	57	41	17	50	22
Seasonal Housing Percent	Mean	52.0%	23.0%	44.2%	35.0%	21.0%	33.0%
	Median	53.0%	22.0%	43.3%	35.0%	18.0%	32.6%
	Std Dev	29.0%	13.0%	24.0%	27.0%	18.0%	25.7%
Seasonal Housing Percent Δ	Mean	-5.0%	2.0%	-2.9%	29.0%	15.0%	27.0%
	Median	-2.0%	1.0%	-1.1%	19.0%	7.0%	17.3%
	Std Dev	24.0%	5.0%	18.0%	33.0%	24.0%	31.7%
Over 65	Mean	21.0%	32.0%	25.2%	29.0%	16.0%	27.2%
	Median	21.0%	24.0%	21.9%	25.0%	13.0%	23.3%
	Std Dev	14.0%	15.0%	14.3%	22.0%	10.0%	20.3%
Over 65 Δ	Mean	3.0%	-1.0%	1.8%	12.0%	3.0%	10.7%
	Median	3.0%	-1.0%	1.7%	6.0%	2.0%	5.4%
	Std Dev	8.0%	6.0%	7.4%	20.0%	10.0%	18.6%
Working Age	Mean	53.0%	56.0%	55.6%	46.0%	66.0%	48.8%
	Median	62.0%	58.0%	60.7%	53.0%	65.0%	54.7%
	Std Dev	25.0%	9.0%	20.0%	26.0%	17.0%	24.7%
Working Age Δ	Mean	5.0%	0.0%	3.5%	7.0%	-4.0%	5.5%
	Median	1.0%	0.0%	0.7%	1.0%	-1.0%	0.7%
	Std Dev	21.0%	6.0%	16.3%	21.0%	19.0%	20.7%
Median Income	Mean	$32,375	$42,539	$36,655	$95,571	$38,060	$87,546
	Median	$32,040	$38,160	$33,958	$77,155	$36,959	$71,546
	Std Dev	$15,426	$11,560	$14,214	$38,573	$11,217	$34,756
Medina Income Δ	Mean	$15,600	$15,215	$15,956	-$30,522	$21,334	-$23,286
	Median	$13,795	$13,281	$13,634	-$21,580	$22,289	-$15,459
	Std Dev	$12,039	$12,992	$12,338	$38,507	$14,632	$35,176
Median Housing Value	Mean	$151,041	$209,433	$174,554	$342,749	$156,590	$316,773
	Median	$132,193	$218,318	$159,187	$321,352	$153,124	$297,878
	Std Dev	$89,710	$84,221	$87,990	$124,707	$59,096	$115,552
Median Housing Value Δ	Mean	$73,390	$84,065	$79,097	$99,749	$112,317	$101,503
	Median	$63,964	$69,659	$65,749	$9,246	$78,400	$18,895
	Std Dev	$75,991	$101,818	$84,086	$199,821	$97,758	$185,580

Table 3-6: Barrier Beach CBRA and Non-CBRA Percent Change 1990-2000

Unit Type	Type	Developed Density	Pop Density	Housing Density	Seasonal Housing Percent	Over 65	Working Age	Median Income	Median Housing Value
CBRA	New Atlantic	33%	164%	254%	27%	11%	-4%	41%	81%
	Old Atlantic	9%	52%	43%	-1%	-9%	23%	92%	88%
Non CBRA	New Atlantic	12%	10%	15%	12%	4%	-4%	25%	54%
	Old Atlantic	2%	8%	3%	-1%	1%	0%	39%	43%

Table 3-7: Barrier Beach Cluster Nonparametric Tests

Variable	Mann-Whitney U (2 Clusters)	Kruskal-Wallis (4 Clusters)	Kruskal-Wallis Individual Cluster Differences
Developed Density	.001*	.000*	Established Vacation and Vacation Established Vacation and Beach Cottage
Developed Density Δ	.043*	.193	-
Population Density	.048*	.000*	Established Vacation and Vacation Established Vacation and Beach Cottage Established Vacation and Second Home
Population Density Δ	.456	.381	-
Housing Density	.000*	.000*	Established Vacation and Vacation Established Vacation and Beach Cottage Established Vacation and Second Home
Housing Density Δ	.316	.639	-
Seasonal Housing Percent	.000*	.000*	Beach Cottage and Vacation Beach Cottage and Established Vacation
Seasonal Housing Percent Δ	.000*	.000*	Beach Cottage and Vacation
Over 65Age	.004*	.000*	Vacation and Second Home
Over 65Age Δ	.104*	.053	-
Working Age	.008*	.007*	Vacation and Second Home
Working Age Δ	.072	.227	-
Median Income	.068	.000*	Vacation and Second Home Established Vacation and Second Home
Median Income Δ	.084	.000*	Vacation and Second Home Beach Cottage and Second Home Established Vacation and Vacation
Median Housing Value	.686	.000*	Beach Cottage and Second Home Vacation and Second Home
Median Housing Value Δ	.057	.073	-

*Differences Between Groups at $p<0.05$

Figure 3-1: Study Area

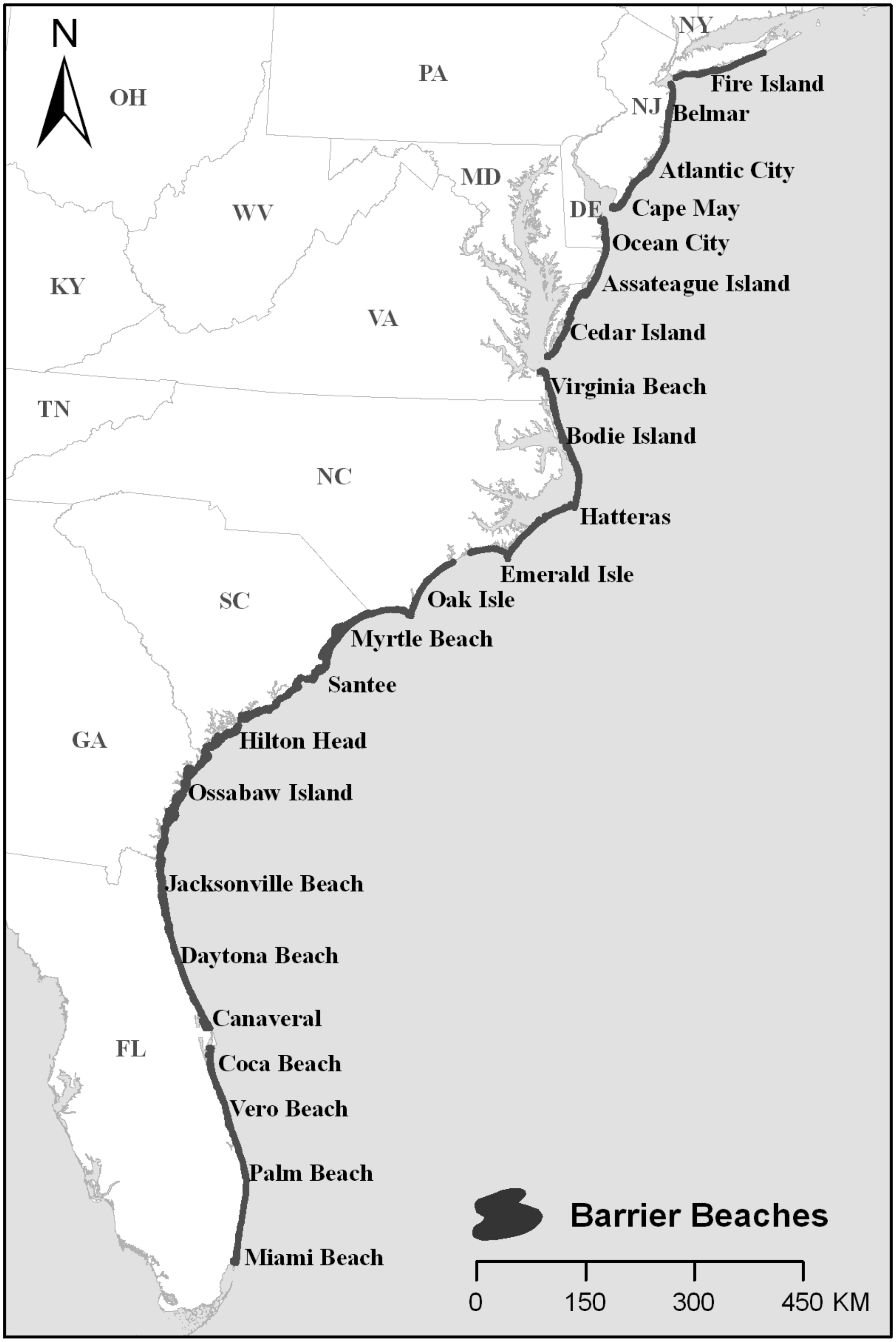


Figure 3-2: Barrier Island Identification Screenshot using Bing Map Extension

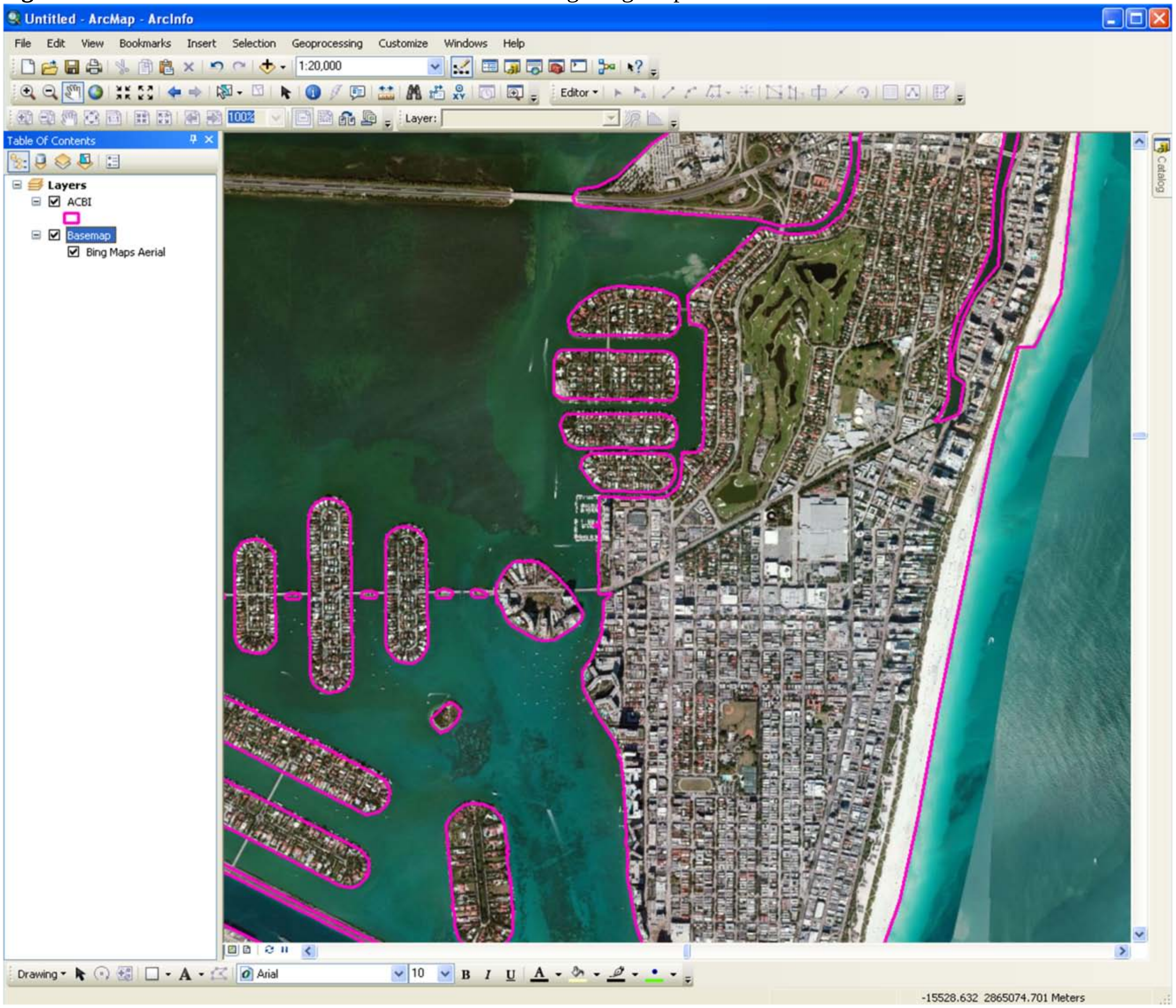


Figure 3-3: National Land Cover Database Land Cover Reclassification

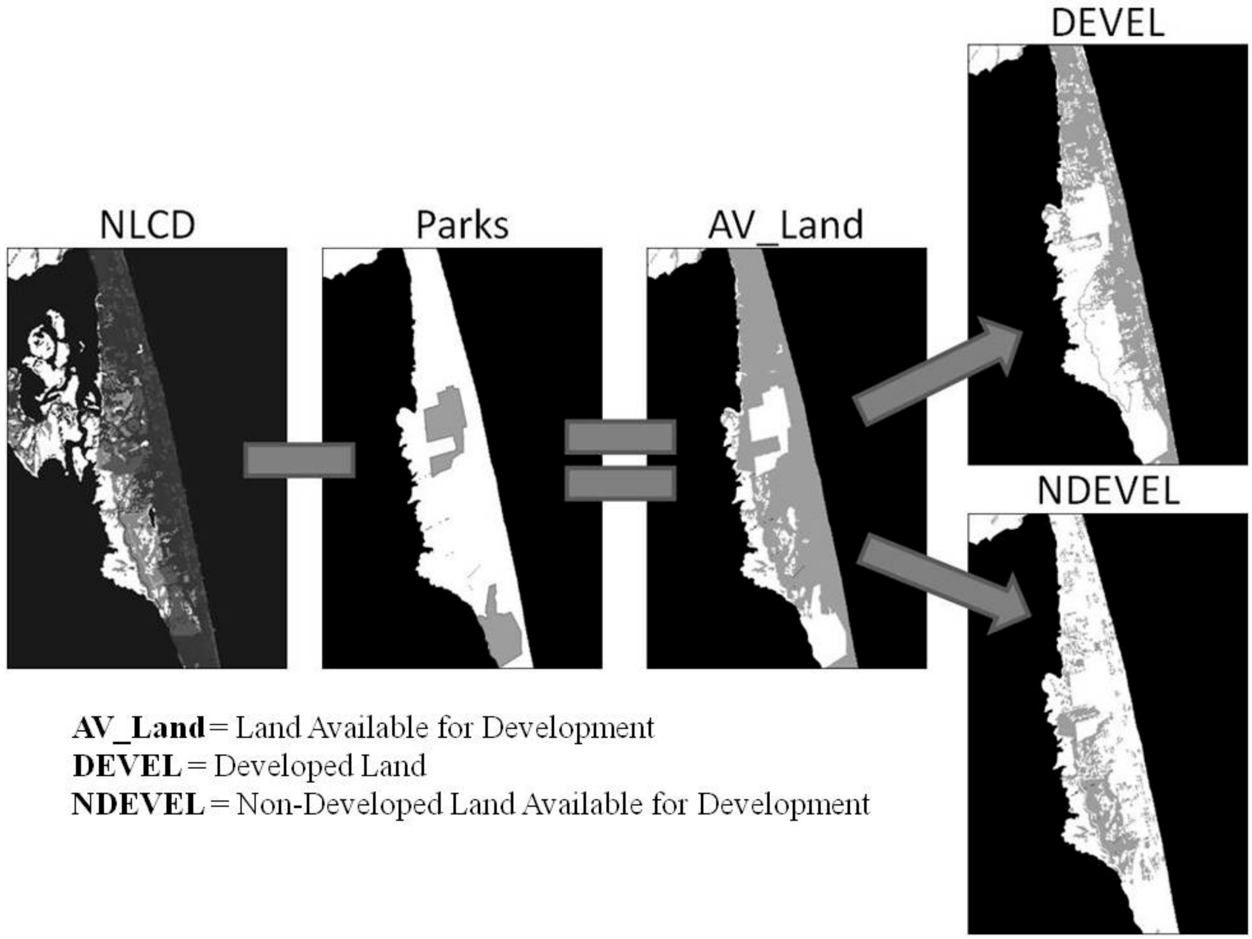


Figure 3-4: Centroid Method for Calculating Census Blocks in Units

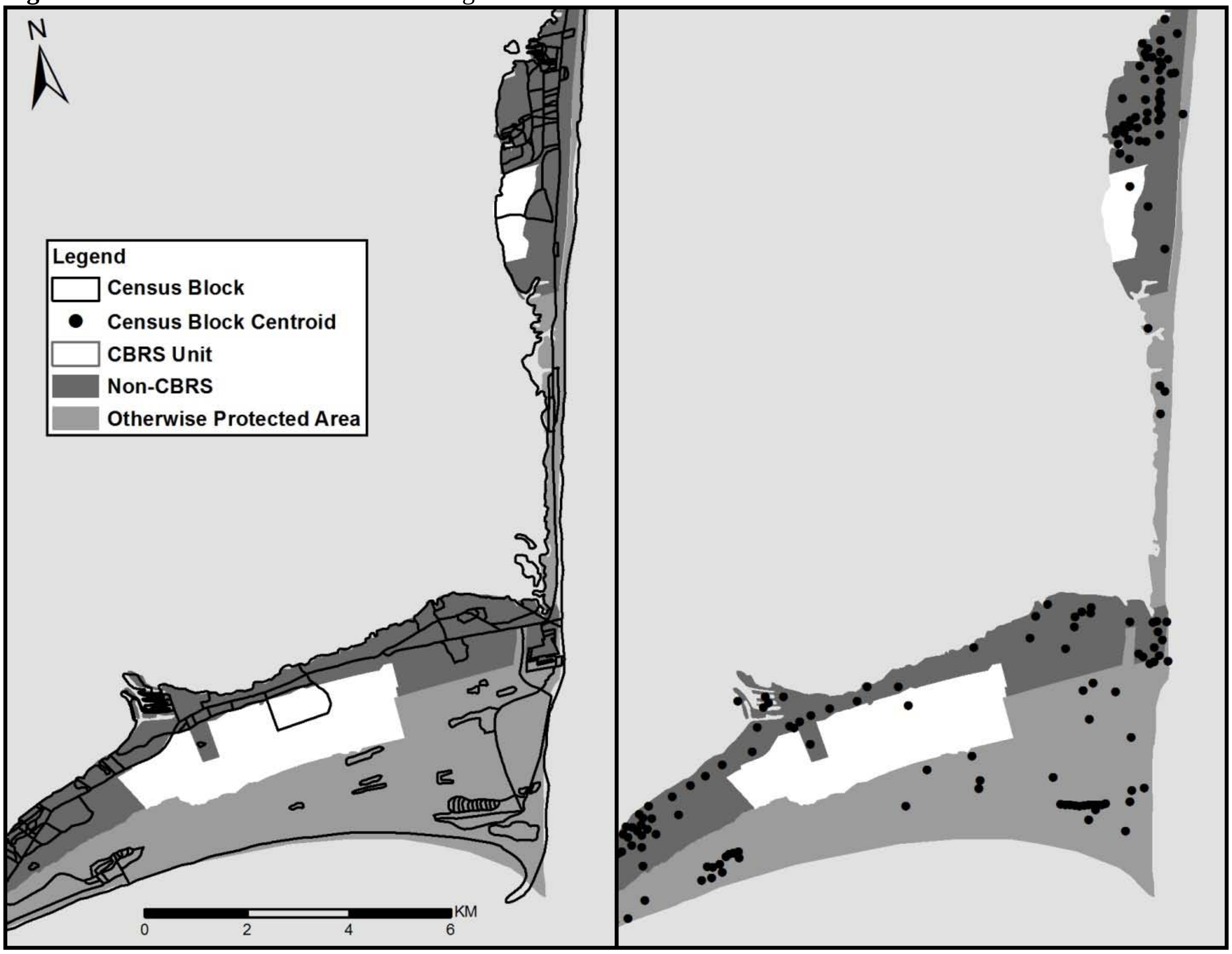


Figure 3-5: Elbow Chart to Determine K-Mean Clusters

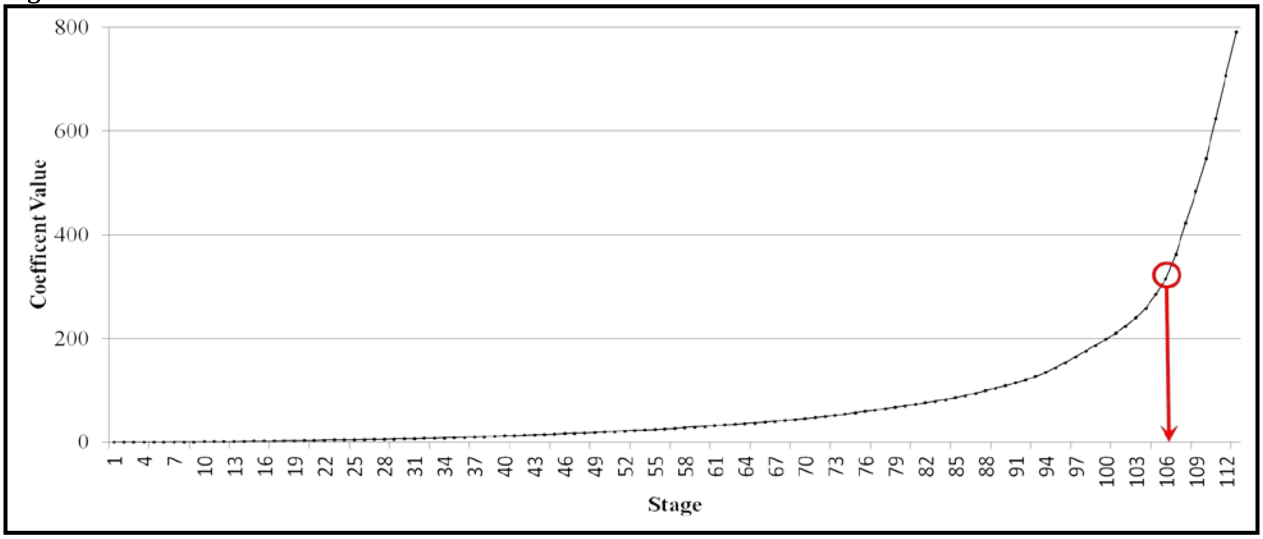


Figure 3-6: K-Means Cluster Results Comparing Principle Components PC1 to PC4

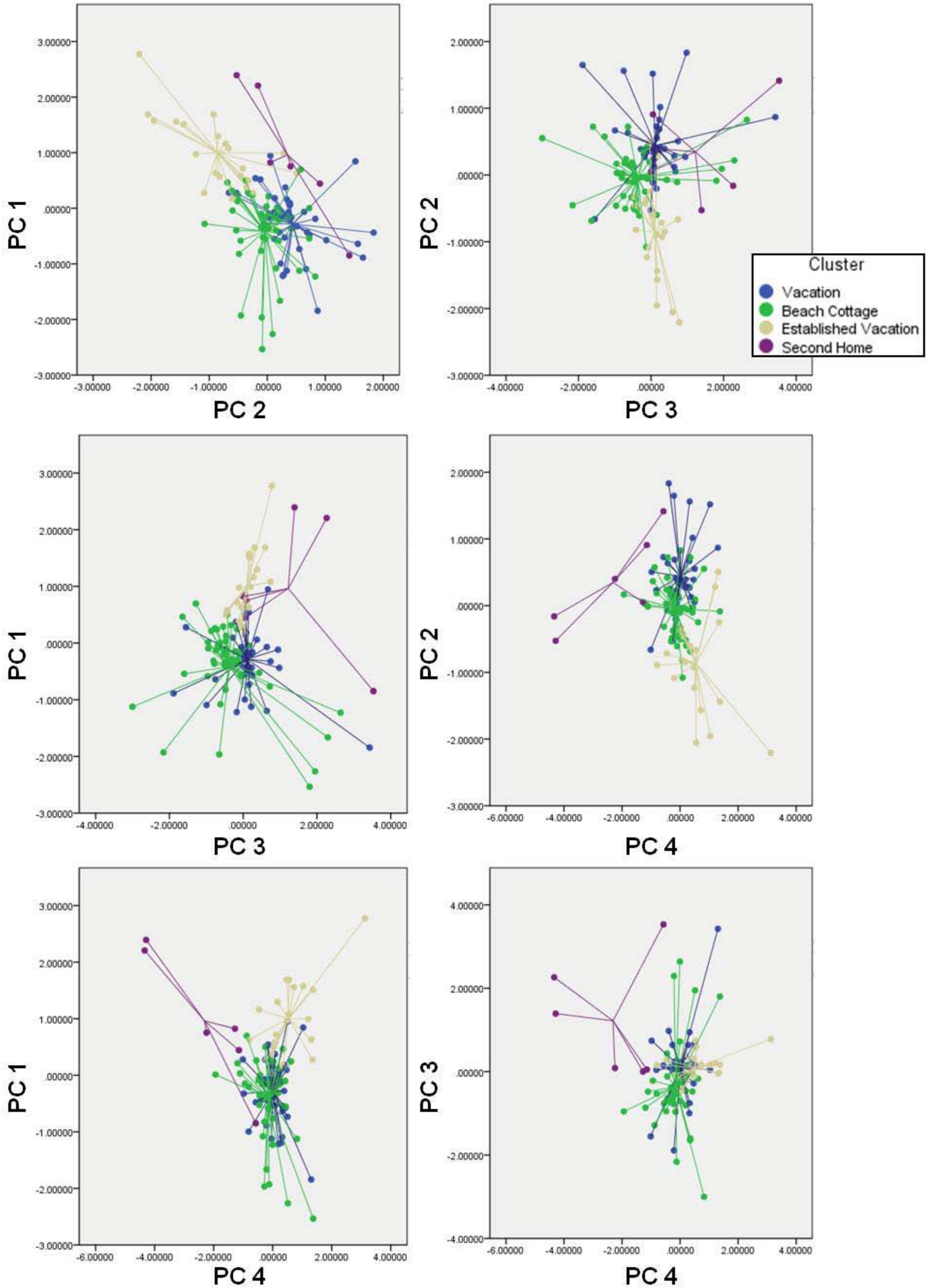
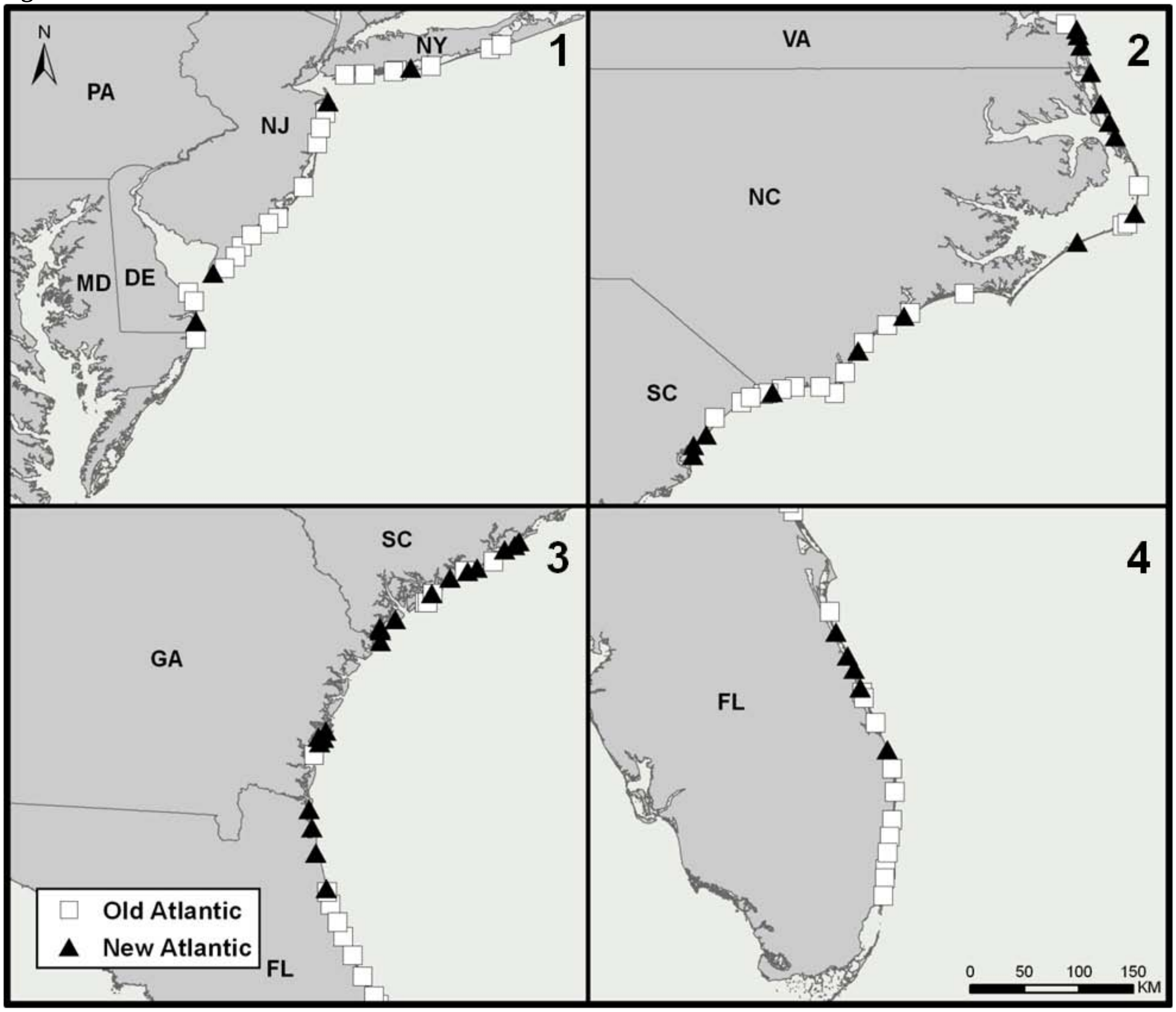


Figure 3-7: New and Old Atlantic Places



Chapter 4: Coastal Drivers on Barrier Beach Land Use/Land Cover Change

Barrier beaches are defined by Pilkey et al. (1998) as elongated bodies of sand bounded on either end by inlets that allow salt and fresh water to flow into and out of the estuary behind the system. These beaches comprise 13-15 percent of the world's coastline. The U.S. coastline from Maine to Texas contains approximately 4,350 linear kilometers of barrier beaches (USDOI 1982) and is identified by Godfrey and Leatherman as the "longest and best evolved chain of barrier beaches in the world" (Godfrey and Leatherman 1979). They provide the first line of defense to the mainland and adjacent wetlands, estuaries, inlets and near shore waters from the direct impact of wind waves and streams. Barrier beaches are also dynamic geomorphic features changing constantly by the actions of wind, waves, currents, and tides.

Barrier beaches represent beachfront property that is highly attractive for many buyers seeking a home on the beach. As accessibility to coastal barriers increased due to improved and new roads as well as an increase in popularity of beaches as vacation destination sites, demand for development on these beaches is expected to increase. From 1945 to 1973, a total of 57,000 hectares of barrier-beach land was converted into developed land cover, which is representative of over 150% increase in developed land cover on coastal barriers (Dolan et al. 1973). Much of the recent research pertaining to coastal barriers has focused on quantifying and analyzing patterns of demographic change, namely population increase. In 2010, approximately 164 million people resided within coastal counties and the population is projected to reach 195 million in 2030 (Woods and Pole Economics Inc. 2011). According to 2000 census data there are roughly 1.4 million people living on barrier beaches with a population change of 14% from 1990 to 2000 (Zhang and Leatherman 2011). The increasing population and development combined with the occurrences of coastal hazards (i.e. hurricanes, nor-easters, beach erosion) increased federal spending in rescue and rebuilding efforts in these areas (Godschalk 1984; Salvesen 2005). In addition to research examining coastal population change, another important issue to investigate is the magnitudes and drivers or how human population pressure actually transforms land use and cover in barrier beach environments.

Coastal Land Cover Change (CLCC) has been explored in past research (Klemas et al. 1993; Corssett et al. 2004; Ellis et al. 2011), but there has yet to be an accepted explanation of the processes that influence the conversion of land to become developed in coastal regions. CLCC is influenced by anthropogenic means (Dolan et al. 1973; Stiffin 1981; Crawford 2007), coastal population (Bartlet et al. 2000; Zhang and Leatherman, 2011), and coastal hazards (Cutter et al. 2000; Boruff et al. 2005). Research on CLCC has often singularly focused on either physical or social changes and in doing so ignores a holistic approach that combines physical as well as social changes that are characteristics of coupled human and natural systems such as barrier beaches. This research will measure the physical and social attributes on developed land cover change in an attempt to move towards an understanding of CLCC within the coastal U.S., more specifically on barrier beaches. These areas are of great importance and there is a growing need to understand how forces act upon these areas as well as how policies affect the trajectories of land change.

The spatial distribution of human development on coastal barriers has changed on barrier beaches through the development of roads and homes that have made once inaccessible places permanent year round communities. Along with spatial features, socioeconomic attributes such as income, age, population size, and housing value influence the CLCC. Spatial distribution and socioeconomic attributes may not have an influential impact on the magnitude of built environment, but they play a key role in developed CLCC over time. Change to developed

CLCC on barrier beaches is influenced by natural environment, which includes habitat configuration, erosion of the shoreline, coastal storms, and flood zone designation. These natural processes can act upon the land moving sediment and changing the makeup of the barrier beaches. Along with the visible processes that exist on barrier beaches there exist often forces such as policies that can inhibit and/or restrict actions that can take place.

Barrier beach habitat is one that is influenced by forces that in ways that are atypical of normal development patterns. These barrier beaches are places that have their own set of influences or drivers that affect CLCC. While we understand that these barrier beaches as fragile habitats in need of protection there is still ongoing land cover change. Understanding the underlying drivers of this change has been mentioned in specific articles mainly pertaining to population pressures (Bartlett et al. 2000; Zhang and Leatherman 2011), but very few, if any, mention other related pressures on the coast.

4.1 *Drivers of CLCC*

This study will assess the CLCC drivers on barrier beaches that induce land use conversion to developed status. Traditionally Land Change Science (LCS) research seeks to comprehend, explain, and project land use and land-cover change (Turner 2002; Turner et al. 2007). The key themes of LCS include the identification of patterns of land cover change, processes of land use change, human responses to land use/cover change, integrated global and regional models, and development of databases on land surface, biophysical processes, and their drivers (IGBP 1999). Land change science modeling has developed or adopted a variety of approaches, which include the narrative, the agent based, and the systems approach perspectives (Lambin et al. 2003). A key feature of LCS is the use of remotely sensed land cover data which creates a pixel representation of land cover features. Pixels are often used in LCS research as the unit of analysis where each pixel has a value represented its trajectory of land cover at starting and ending time periods. With multiple land classes, multiple land change trajectories are possible for the pixels comprising the landscape. Focusing on a single type of change such as conversion to developed land cover, pixels can be represented as a binary variable where 1 = change to developed status, and 0 = no change to developed status. Statistical techniques such as multinomial regression for multiple change categories or logistic regression for binary change categories can be used to assess the factors correlated with land cover change (Loveland et al. 1991; Turner et al. 1996; Wear et al. 1998; Mertens and Lambin 2000; Lu et al. 2005). Drivers are the thematic processes hypothesized to cause observed landscape changes. They are influential processes in the evolutionary trajectory of the landscape. When looking at drivers of landscape change, Ray and Gregg (1991) stated that development on coastal barriers has been made possible due in part to the exceptional recreational amenities, the proximity of urban centers, sophisticated engineering capabilities, and a growing number of corporate and individual investors. From and environmental perspective, development on coastal barriers is subject to the full brunt of winds, waves, and tides, which required increasing investments to protect the development and to repair damage from natural forces (USDI 1983). Adapted from Marcucci (2000), Bürgi and Hersperger (2004), Hersperger and Bürgi (2009), Forman et al. (2003 and 2009), Berling-Wolff and Wu (2004), driving forces for coastal landscapes include factors from the spatial, social, natural, and policy drivers that changes to developed land cover.

This research takes into account LCS studies that have determined drivers of LUCC and attempts to add to this knowledge by creating a set of CLCC drivers. There are many drivers that act on the coastal landscape from socioeconomic, spatial, and natural drivers interacting and changing the land cover change within the coastal region (Figure 4-1). Informed by the coastal literature, certain drivers overlooked in traditional LCS studies have been added to traditional findings to create a uniquely coastal set of LUCC drivers (Table 4-1) that will be empirically evaluated in statistical models aiming to explain variation in levels of Atlantic developed land cover change using a place-based quantitative approach where places, as opposed to pixels, are used as the unit of analysis. These drivers will be tested to see if they in fact play a role in change to developed land cover during the study period.

4.1.1 Natural Drivers

Natural drivers most relevant to coastal barriers according to the identified literature in Table 4-1 include a mix of both physical processes (i.e. coastal storms and coastal erosion) as well as landscape features (i.e. wetlands and elevations depicted in flood zones) of the U.S. east coast. This is important to note because barrier beaches are formed primarily of sand and generally include features such as a sandy beach, dunes (both primary and secondary), maritime forest, wetlands, and a backshore comprised mainly of marsh. Bodies of water (sounds and lagoons) generally separate the barrier beach from the mainland. Barrier beaches have an extremely dynamic nature whereby major changes in geomorphology and hydrology can occur over days, or even hours, in response to extreme episodic storm events (EESEs) such as tropical cyclones, hurricanes, and northeasters (Feagin et al. 2010). Several recent studies have addressed the vulnerability of U.S. coastal communities to contemporary natural hazards, especially extreme coastal storms (Clark et al. 1998; David et al. 1999; Mileti 1999; Morrow 1999; Cutter et al. 2000). Changes in the overall land cover change may be influenced by vulnerability of these settlements to coastal hazards, including the increasing risks due to climate change and sea-level rise, versus adaptation measures that could reduce risk (Smit et al. 2001).

Natural hazard risks in the coastal zone include storms (hurricanes and nor'easters on the east coast), with associated flooding and wind damage, as well as erosion stemming from storms and sea level rise (Bin and Kruse 2006). Filatova and Veen van der (2006) looked land cover change in relation to flooding and found that humans were influenced by areas that flooded crating a negative correlation in development in those areas. Schill (2005) stated that there are many government regulations on land use especially in wetlands that limits the development that can occur because of policies set in place on these areas.

4.1.2 Social Drivers

Literature from Meyer and Turner (1992) and Commoner (1972) argued that population changes positively influence of development in land cover change. Regional land use and land cover change is strongly related to human demands (Veldkamp and Fresco 1996). Population density and forest cover in tropical countries by Palo (1994), but he found zero correlation between population growth and forest cover. It has also been found that the age of population influences the amount of land cover change that occurs (Coressett et al. 2004; VanWey et al.2007). Millington et al. (2007) found that the mean farmer's age of a population explained for eleven percent of the variance for transition from agricultural land to scrubland. Income and housing value were also found to play influential roles in creation and curbing of developed land cover (Riebsame et al.1996; Irwin 2002; Evans and Kelley 2004). Hubacek and Sun (2001) found that in China coastal areas with high growth rates were accompanied by high income levels. York and Munroe (2004) found that including median housing value into their land change model helped to explain conversion of land to developed.

4.1.3 Spatial Drivers

Spatial drivers include aspects of the landscape that are physically changed by the interaction of humans and the natural environment. These drivers represent the spatial distribution of these drivers either within or outside of each unit. According to the literature increased road density and the existence of roads are spatial drivers that impact the CLCC to developed (Dale et al. 1993; Turner et al.1996; Clarke 1998; Fazal 2001; Hawbreaker et a. 2004; Hawbreaker 2006; Lein and Day 2008). Housing density like road density is a spatial driver that has been found to increase developed land cover change (Vitousek et al. 1997; Liu et al. 2003; Westervelt et al.2011). Proximity to populations is another spatial driver that has been found that a that land-cover change is inversely related to distance to populated areas tends where the further the population the less developed land cover change (Turner 1990; LaGro and DeGloria 1992; Bockstael 1996; Turner et al. 1996; Mertens 1997; Wear et al. 1998). Type of housing unit (i.e. seasonal or rental) existent was determined to influence change to developed land cover (Vitousek et al. 1997; Clarke 1998; Liu et al. 2003).

4.1.4 Policy Drivers

The combination of federal, state, and local policies can foster or inhibit CLCC from occurring. Local policies have a profound effect on CLCC because it can explain the variability that exists between the federal and state policies. Due to the high complexity of local policy it makes creating an effective method to measure these policies hard (Lambin 1998; Geyer and Rihani 2010). State policies, similar to local, have a varying degree of impact on CLCC based on states individual motivation and ideologies. The varying degree of policy focus and enforcing amongst states creates unique coastal policies, which, like local policy is hard to effectively measure. While local as well as state policies pertaining to CLCC have varying degrees of implementation as well as effectiveness federal policies are easier to address in terms of implementation and enforcement (Godschalk 1992; Hershman et al. 2007). At the federal level policy with no alteration is applied to all areas with consistent focus and enforcement.

This study will specifically look at the federal level policy specifically the Coastal Barrier Resources Act of 1982 (CBRA). The CBRA's stated purpose is to: (1) minimize loss of human life by discouraging development in high risk areas, (2) reduce wasteful expenditures of federal resources, and (3) protect the natural resources associated with coastal barriers. Research by Godschalk (1984) and Kuehn (1984) found that CBRA had slowed the development rate on certain undeveloped barriers where withdrawal of Federal flood insurance or infrastructure assistance coupled with local constraints. While it initial the CBRA was seen as a success Jones (1991) found that there were other forces acting upon the system that allowed development to occur. Government Office of Accountability (GOA) (1992) found that CBRA's prohibitions against new federal financial assistance have discouraged development in some CBRA units, and others are not likely to undergo significant development in the near future because of their inaccessibility and/or lack of developable land. Significant development has occurred in some attractive and/or accessible CBRA units since 1982, and extensive new development is planned in these units and other units displaying similar characteristics. Salvesen (2005) stated that some developed CBRA units, developers or local governments, rather than the federal government, have paid for infrastructure CBRA units have undergone so much development that they are virtually indistinguishable from adjacent areas that are not part of the system and in other places, the difference between CBRA and non-CBRA areas is very stark. GOA (2007) stated that the CBRA does not appear to have been a major factor in discouraging development in those CBRA units that have developable land, local government and public support for development, and access to affordable private flood insurance.

4.2 *Methods and Data*

Multiple regression analysis is used to evaluate hypothesized drivers of barrier beach development. Unlike traditional models of LCS that use pixels as the unit of analysis, this research implements a place-based analysis where a comprehensive set of Atlantic coastal barrier places is defined to be used as the unit of analysis. This work focuses on understanding what factors explain variation in amounts of new development within the place instead of explaining pixel level change trajectories. Using place as the unit analysis creates, unlike with pixels, variation in sizes of units that need to be taken into account when applying results into the regression model since, all else being equal, larger places would be expected to be associated with large amounts of new development. The study will use a set of hypothesized driving forces represent the social, spatial, and policy domains to identify impacts on barrier beach development (Table 4-2). Multi-variate regression will be used in different models to evaluate and quantitatively express which combination of drivers best explains developed CLCC.

4.3 *Study Area*

The study area for this research encompasses barrier beaches along the Atlantic coast stretching approximately 2,000 km and nine states from Long Island, New York to Miami, Florida (Figure 4-2). Barrier beaches were identified through the use of ArcGIS Bing Maps imagery with varied dates ranging from 1993 to 2010. A total of 155 barrier beaches were digitized as vector GIS polygons to conform to land/ocean interface boundaries visually evident in the Bing Maps imagery at a constant viewing scale of 1:20,000. Barrier beaches as they pertain to this study are classified as barrier islands, spits, bay barriers, or any piece of land directly in contact with the Atlantic Ocean. Other coastal landform types present in other parts of the U.S. (i.e. rocky shores, marine terraces, etc.) were excluded in order to focus solely on coastal barrier environments. The digitized vector polygon data were then combined with a U.S. Fish and Wildlife Services (USFWS) Coastal Barrier Resources shapefile containing vector polygons identifying the boundaries of formally defined units subject to the CBRA as well as Otherwise Protected Areas (OPA) (USFWS 2010). OPA areas include national wildlife refuges, national parks and seashores, state and county parks, and land owned by private groups for conservation or recreational purposes. Barrier beaches not identified as CBRA and OPA were understood to be non-CBRA. This union of geospatial datasets yielded created three different barrier unit groups: CBRA, non-CBRA, and OPA.

To capture patterns of both development change and socio-economic change, input data used were temporally organized for 1990 to 2000. This temporal framework enables only fairly recent coastal change. Ideally a longer time period with a more current end date for the temporal framework would be preferred, but data availability limited the time span. For example, required census data at the block or block group level for 2010 and similarly timed land cover data were not available at time of analysis. Even though temporal limitations exist, using the best available data enables characterization of fairly recent patterns and dynamics across the entirety of the Atlantic barrier coast.

A GIS layer defining barrier beaches was created with metrics characterizing land use/cover change, socio-economic patterns and change, and development policy attributes. The methodological process describe more fully below included: (1) creating a GIS layer defining barrier spatial units (i.e. coastal barrier places), (2) characterizing land use/cover change, socio-economic, spatial, natural, policy drivers and change, and (3) applying Ordinary Least Squares Regression (OLS) and forward stepwise regression.

4.4 ***Dependent Variable***

For each defined place, the amount of new developed land use during the study period was used as the dependent variable. Land cover data were acquired from the Multi-Resolution Land Consortium (MRLC) National Land Cover Database (NLCD). The NLCD uses image processing and classification techniques to provide land use/cover and change information at the Anderson Level II classification scale and have a pixel resolution of 30 meters (Anderson et al. 1976). The dependent variable is the raw count of pixels that changed from undeveloped to developed pixels. Undeveloped land based on Anderson Level I classification included agricultural land, range land, forests, and barren land. Developed land based on Anderson level I was any urban/built up land cover. Land cover data from 1992 and 2001, the closest available dates to 1990 and 2000 census products, were used. The data were simplified to a Level I classification because doing so creates a singular thematic classes representing development (i.e. developed) as opposed to multiple classes (i.e. high, medium or low developed). The accuracy of these simplified classes also increases as a result of generalization, which range from 93.1 % to 84.7% at Anderson Level I classification **(**Wickham et al. 2010). Taking total developed land in 1992 for each unit and subtracting it from the developed land in 2001 of that unit creates the developed dependent variable.

4.5 ***Independent Variables***

Independent variables include measures representing each hypothesized driver of development. Table 4-3 expresses the measurements that will be used for each of the independent variables to be analyzed in the OLS and forward stepwise regression while Table 4-4 provides descriptive statistics of the barrier beaches.

4.5.1 Control Variable

Due to the fact that each barrier beach is not uniform in size, a control variable defined as the amount of potentially developable land is used under the assumption that places with more developable land will, all else equal, experience more development. The control variable applied to the data was created to reflect the total land each unit. The control variable was calculated from 1992 NLCD through the removal of both water and wetland categories. This created the Total Land 1992 variable that is placed within the OLS regression. The addition of this control variable helps within the OLS regression as a way to relate the raw totals that the variables are counted in. Accounting for differing sizes of places in this way enables evaluation of the relative magnitude and importance of the main independent variables of interest.

4.5.2 Natural Variables

Natural variables were assembled representing biophysical factors from NOAA, FEMA, and NWI data sources. These variables have a special focus on natural hazards that exist on barrier beaches. Hurricane exposure was measured using NOAA's North Atlantic Hurricane Tracks along with major storms landfall in the United States from 1851-2004. The data used 1980 to 1990 as well as 1990 to 2000 hurricane tracks to create a line density raster representing hurricane exposure. The basis for this was to identify if awareness of hurricanes in an area before and during development influenced developed land cover change. A line density with a 30m raster was created in ArcGIS using wind speed in the population field and a search radius of 80.5km (50 miles). Through the use of zonal statistics the average will be calculated for each unit to give a representation of storm severity for each unit for 1980 to 1990 and 1990 to 2000.

Flood zone hazard was calculated using FEMA's National Flood Hazards Layer (NFHL) along with Q3 maps of counties not yet included in the database. The data were combined to create a seamless flood layer for the entire study area. High risk classification was given to regions identified by FEMA as high risk (A, Ae, A1-30, AH, AO, AR, A99) and coastal high risk (V, VE, V1-30) as well as any areas classified as open water. Wetlands were calculated through the use of the National Wetlands Inventory (NWI). NWI maps must depict 90 percent of all wetlands 1.0 acre or larger as well as 95 percent of the mapped features correctly classified to the Cowardin Class level to be considered acceptable (USFWS 2004). NWI polygons will be imported and clipped to the Study area units.

Erosion risk was calculated through the use of USGS transect data containing a linear erosion rate in meters per year for transects spaced approximately 50 meters apart spanning the entire extent of the study area (Himmelstoss et al. 2010). Erosion rates were extrapolated out 60 years from year 2000 to create eroded area polygons assuming a constant linear rate of erosion. Analysis was restricted to area only within 150 meters (500 feet) of the year 2000 shoreline. The final erosion risk measure was calculated as percent of the area within 150 meters (500 feet) of the shoreline (Crawford and Bennett 2012) that would be eroded assuming a linear extrapolation of historical rates into the future. Linear historical extrapolation can be critiqued due to the fact that is a simple statistical technique that does not incorporate coastal geophysical processes or human adaptive or mitigative behaviors. Despite this limitation, it relies on erosion data from a respected source (i.e. USGS) and arguably provides a first order characterization of erosion variability at the place-based level of analysis used in research.

4.5.3 Social Variables

Social data were assembled from the 1990 and 2000 U.S. Census block and block group data. A variety of GIS overlay and aggregation methods using census blocks and block groups were used to create the social variables. Total population and population over 65 were evaluated using the census block data. Population and population over 65 are determined through the centroid method, which creates a point in the center of the block group, which represents all the data for that block group. The data is then overlaid on top of the barrier beach unit boundaries and sums are calculated. To calculate population density, the population for 1990 was divided by the available land cover in 1992. Similarly, 2000 population density used 2001 available land cover to calculate density. Percent of population over 65 years old was calculated by dividing the count of population over 65 by the total population. Income and housing value information are not distributed by the Census at the block level making acquisition of median income and median housing values only available at the block group level. Block group data were transformed into 30m rasterized pixel format, and through the use of zonal statistics the average of the pixels were calculated to give the average of the median income and median housing values for the corresponding units.

4.5.4 Spatial Variables

Spatial variables were quantified using Topologically Integrated Geographic Encoding and Referencing system (TIGER) road files; census identified urban centers 1990 and 2000, and 1990 and 2000 Census housing data. Seasonal housing data were assembled from the 1990 and 2000 U.S. Census block data. Using TIGER road files, road density of major roadways were quantified as the length of the road per acres within each unit. Taking the centroids of each block that fall within the prescribed unit, housing counts were calculated for each unit. The density of development and seasonal housing units will be calculated through using the census data and dividing them by the total available land per unit.

Population accessibility will be measured using a gravitational distance decay measure to show the extent of population that has access to identified barrier beach units (Fotheringham 1981; Song 1996). Population accessibility is a quantitative metric that provides a relative measure of measures of population accessibility to a given barrier beach unit. A simple gravitational distance decay measure was applied using 1990 and 2000 census data. The formula is as follows:

$$P_{i=} \sum_{j-1}^{n} \frac{M_j}{D_{ij}}$$

Where:
P_i is the potential number of attracted to barrier beach
M_j is the population census tract j
D_{ij} is the distance between barrier unit i and place j

In the gravitational equation, *i* is identified as census-defined populated places from within the barrier beaches units. In cases where units did not contain a populated place, the barrier beach's centroid was used. Census tracts *j* were identified using radial distances of 25, 50, and 100 km from the populated place points and centroids of the barrier beach units to centroids of 1990 and 2000 census tracts. Units that had more than one populated place had their multiple P_i values averaged to get a final accessibility measure for barrier beach unit. To determine the best radial distance value (25, 50, or 100km) to select for the regression a correlation was ran to determine which measure to select. It was found that the all variables had a high correlation so 50 kilometer search radius was selected.

Housing density and seasonal housing percent were calculated using the centroid method used for population density and over 65 percent. Housing density was calculated by taking the total housing unit count in 1990 and dividing by the available land in 1992. The 2000 housing density was calculated similarly using the available land in 2001. Seasonal housing percent was calculated by taking the seasonal housing units and dividing them by the total number of housing units for 1990 and 2000 respectively.

4.5.5 Policy Variable

While local and state policies can impact development, they were omitted from this research based on statistical and logistical reasons. First, state data was left out because of the varying degrees of differences across state coastal policies. State dummy variables were used to capture state level effects that might be linked to state level policy. Actual policy-specific variables were not created for each state rather each state used a binary code based on the number one representing the state for the given variable and zero representing a state other then the selected variable. After running the regression it was found that there were no significant correlations. While local policy would be a good indicator it was found to be outside of the realm research for this study. Observing and reporting policies pertaining to over 131 individual barrier beach units would be complex as well as difficult to properly assess. State and local policy were not valid inputs for a policy variable Federal policy was used. To measure Federal policy on coastal barrier beaches the CBRA was used as the measured policy because it focuses directly on barrier beaches. The data was collected from the USFWS Coastal Barrier Resources System GIS shapefile. This shape file identified barrier beaches as either designated as CBRA units or places under protection (i.e. national sea shores). A barrier beach unit not identified as CBRA unit or place under protection it was classified as a Non-CBRA or non-policy unit. For the regression units that were identified as CBRA units were given a value of one while non-CBRA units were given a value of zero for the regression.

4.6 *Models*

The fifteen variables used were arranged into six models to explain drivers of development in eastern U.S. coastal barriers (Table 4-5). Ordinary least squares regression (OLS) and the forward stepwise regression were used to test the effects of coastal drivers in explaining developed land cover change. Model 1, the full model, included all fifteen variables. The remaining models used OLS to explain developed land cover change. Model 2 was thematically subsetted to include just the hypothesized natural drivers including hurricane exposure, area of land in flood zone, and amount of wetlands within a unit, and projected amount of erosion over 60 years. In Model 3, social drivers which include population change, population over 65 change, median income change, and median housing value change, are evaluated. The subsetted collection of spatial drivers is evaluated in Model 4 and includes road density, population accessibility, development density, and seasonal housing. The influence of CBRA policy in change to developed land cover compared to those areas that do not have CBRA designation was measured in Model 5.

4.7 *Results*

The control variable indicates an expected and positive relationship between amounts of antecedent available developable land and amounts of new development in all models. While the control variable, available land is significant and has the largest influence compared to all other variables as would be expected ceteris paribus, the focus is to assess the influence of the other variables. Variables with at least a p = 0.05 significance or lower were considered here as statistically significant.

Model 1 provides the best fit, explaining roughly 64% of the variance in development (Table 4-6). Total land in 1992, amount of wetland, and percent of seasonal housing change were found to be highly significant. Based on the standardized beta values, an increase of 10% in wetlands is associated with a 4.1% lower level of new developed land cover. An increase of 10% for percent of seasonal housing would yield an increase of 1.9% developed land cover. Erosion risk and population accessibility were also statistically significant and had exhibit positive relationship with change to developed land cover. Area of wetland and development density indicates an inverse relationship where the amount increases in a given unit the change to developed land cover decreases. Development density represents the largest change as an increase in 10% development density represents a decrease of 26.3% developed land cover. Seasonal housing change like total land has a linear relationship to change in developed land cover increase in developed land cover.

Model 2 looks at the influences of natural factors. The model was the third best model explaining 56.4% of the variation to developed land cover. Out of the five variables measured, three were found to be significant. Erosion risk and flood area expressed a positive relationship where a 10% increase in each would yield a 2.5% increase in developed land cover. The area of wetland expressed a negative relationship where 10% increase would decrease land cover change by 4.1%.

Model 3 explores the social dimensions of developed land cover change and explains 42.3% of the variation. However, the only significant variable was the control variable, amount of available developable land. In short, social drivers had very little to no influence on amount of new development during the study period. Model 4 focuses on spatial drivers and had the second highest adjusted R-square at56.8%. Percent of seasonal housing and population accessibility were two of the five independent variables were that were significant. An increase of 10% of percent of seasonal housing and population accessibility would result in a 3.1% and 2.2% increase in developed land cover change.

Policy Model 5 observes the impact of the Coastal Barrier Resources Act on change to developed land cover. The regression's adjusted R-square indication an explanation of only 0.9%. The independent variable indicating CBRA status, a federal level policy, was not statistically significant. To capture state-level effects that may be indicative of state-level coastal policy, dummy variables representing the state in which places were located were also inserted as independent variables. Results indicated no statistically significant state-level effect. Neither federal nor state-level policy indicators had significant influence on development levels. This points to the likely importance of local policy; however, no variables serving as indicators of local coastal policy regarding development were available comprehensively for the array of places along the study area's breadth. Construction of such indicators is possible in principle but would require significant time and effort beyond the scope of this study.

A Forward Stepwise regression was implemented to compare the relative importance of variables in the full Model 1. The forward regression process starts with no variables in the model and tests how the addition of each variable would improve the model. The variable that improves the model the most is selected and represents the first model. The process is then continued by combining the variable in the first model with the next greatest variable of improvement creating model two. This is continued until no observed variables are identified to improve the overall model.

The control variable available land had the largest magnitude standardized beta coefficient and independently accounted for 44% of variation (Table 4-7). The standardized beta represents the importance of the variable within the model and available land had the highest throughout all models ranging from 0.511 to 0.745. This result is expected under the notion that the more available land an area has available for development, the more developed will occur. Aside from the control variable, of the hypothesized drivers seasonal housing was the most important accounting for 8.4% of total variation and the second highest standardized beta values ranging from 0.220 to 0.306. This would make sense in a coastal setting as seasonal demand increase so does an increase in development to meet the needs. The remaining variables identified by the stepwise regression in order of importance and explain variation were erosion risk (4.4%), population accessibility (3.2%), amount of wetland (2.1%), and development density (1.6%). The total adjusted R- squared for the final stepwise regression model was 0.634 or 63.4% of the variation in the model.

Although there are many variables in the models relative to the actual number of observations in the sample of barrier beach units, problems with multicollinearity are not evident. The highest variance inflation factor (VIF) for any variable is 4.39 (Table 4-6), which is clearly within generally acceptable guidelines (Allison, 1999). The potential for biased results due to spatial autocorrelation, or relative closeness of units, was assessed using the Moran's I statistic applied to standardized residuals for all models. The formula used to calculate autocorrelation was done through the use of ArcGIS' Moran's I statistics:

$$I = \frac{n}{s_0} \frac{\sum_{i=1}^{n} \sum_{j-1}^{n} w_{i,z_i z_j}}{\sum_{i=1}^{n} z_i^2}$$

Where:
z_i is the deviation of an attribute for feature i from its mean $(x_i - \bar{X})$
$w_{i,j}$ is the spatial weight between feature i and
n is equal to the total number of features
S_o is the aggregate of all the spatial weights

Results of Moran's I of the residuals revealed z-scores and p-values indicating the absence of spatially autocorrelated residuals thus justifying the use of OLS regression (Table 4-8). The highest z-score was 0.6083 (Model 1) and none of the results had p-values below or even approaching $p = 0.05$. Thus, these model diagnostics indicate that the use of OLS regression was acceptable and did not violate required assumptions.

4.8 ***Discussion***

The full Model 1 accounted for nearly 64% of variation in new development. Examining subsequent models that isolate variables representing thematic categories of driving forces provides more nuanced information with which to interpret their relative influences. The spatial variables (Models 4) had the most significant variables of the individual models, but contrary to other research results indicate no influence for road density. Antecedent levels of development density, population accessibility and seasonal housing have major impacts on overall developed land cover change. Model 2 which focused on natural environment drivers has a roughly equal amount of explanatory power as Model 4's spatial drivers; however, the individual hazards variables were not significant with most of the variation was explained by the control variable representing total land area (unit size). The fact that hurricanes exposure was found to play no role in explaining development suggests that there is little attention paid to coastal storms, and instead more attention is given to coastal erosion, flood zones, and wetland area. This reveals that predictable or known natural processes/features have more of an impact then hazards like hurricanes that cannot be measured with regularity and consistency over time.

Social variables in Model 3 played little role in the explaining developed land use change. This could be attributed to the scale at which the variables are measured as well as the methods used to measure these variables. At a block group level it is hard to get an accurate assessment of value/economic attributes that could explain better developed land cover change. Ideally, a dasymetric mapping is a potential solution for the dilemma of portraying census data that have been aggregated to areal units. Eicher and Brewer (2001 p.125) stated that “Dasymetric mapping depicts quantitative areal data using boundaries that divide the mapped area into zones of relative homogeneity with the purpose of best portraying the underlying statistical surface.” Dasymetric mapping creates new zones that are directly related to the function of the map, which is to calculate census attributes within identified barrier beach units. Another dasymetric measure using address points would ideally provide the best way to allocate data, but the problem lies with data availability. Detailed address points are available for some states, but not all states as of now. The results show that policy, at least at the federal level, plays little role in explaining change to developed land cover. State level dummy variables were used as a proxy for state level policy and that they were found to have no significant effect. Problems with ineffectiveness of policy could be unobserved local level policy factors might be important. This is where a more in depth “place-based” approach are necessary in being able to quantify policy drivers. A further detailed study of local and state policies would greatly increase the argument for impact of policy as it pertains to developed land cover change.

This research is important for three main reasons. First, it contributes to the body of knowledge in land change science in a thematic region that is arguably understudied – barrier beaches. Recent discussions (Pawlukiewicz 2007; Lambin et al. 2001; Rudel et al. 2005) illustrate that a central task facing the discipline is the understanding of forces that drive land cover change especially coastal land cover change. Secondly, this study adds to the coastal resource management literature on drivers of coastal development (Bartlett et al.2000 and Crossett et al. 2004). In particular, it provides an outlook into the multiple forces that contribute to development, compares, and contrasts them. Finally, the research builds on recent efforts to analyze driving forces, including the call to study landscape change in coastal regions.

Table 4-1: Coastal Land Cover Change (CLCC) Drivers Literature

Category	Force	Work Cited
Natural	Flood Zone	Filatova and Veen van der 2006
	Erosion	Meyer and Turner 1992; Muttitanon and Tripathi 2005 and Bin and Kruse 2006
	Hurricane	Clark et al. 1998; David et al. 1999; Mileti 1999; Morrow 1999; Cutter et al. 2000; and Heinz Center 2000; Feagin et al. 2010
	Amount of Wetland	Schill 2005
Social	Population Change	Forman et al. 2003 and Doi 2002
	Population Over 65	Crossett et al. 2004; VanWey et al. 2007 and Millington et al. 2007
	Median Income	Riebsame et al.1996; Hubacek and Sun 2001; Irwin 2002; Evans and Kelley 2004; and York and Munroe 2004
	Median Housing Value	
Spatial	Road Density	Dale et al. 1993; Turner et al.1996; Clarke 1998; Fazal 2001; Hawbreaker et a. 2004; Hawbreaker 2006; and Lein and Day 2008
	Population Accessibility	Turner 1990; LaGro and DeGloria 1992; Bockstael 1996; Turner et al. 1996; Mertens 1997; Wear et al. 1998
	Housing Unit Density	Vitousek et al. 1997; Liu et al. 2003; and Westervelt et al.2011
	Seasonal Housing Units	Clarke 1998; Vitousek et al. 1997; and Liu et al. 2003

Table 4-2: Expected Relationship Table

Category	Force	Expected relationship to Developed Land Cover Change
Control	Total Land 1992	++
Natural	Flood Area	--
	Erosion Area	--
	Hurricanes 1980-1990 and 1990-2000	--
	Wetland Area	--
Social	Population	++
	Over 65	++
	Median Income	++
	Median Housing Value	++
Spatial	Seasonal Housing Percent	++
	Population Accessibility	++
	Development Density	--
	Road Density	++
Policy	CBRA	--

***Change to developed land cover is represented by ++ while no change or loss is represented by --**

Table 4-3: Coastal Driving Forces Independent Variable Measurement

Category	Force	Source	Calculated Unit of Measure	Year of Data
Control	Total Land 1992	MLRC	Total Land Cover	1992
Natural	Flood Area	FEMA	Area of unit in high risk flood zone (ha)	2011
	Erosion Area	NOAA	Area of projected erosion over the next 60years (ha)	2007
	Hurricanes 1980-1990 and 1990-2000	NOAA	Line Density with 80.5KM search radius of hurricanes 1980-1990 and 1990 to 2000	2008
	Wetland Area	NWI	Area of wetland (ha)	2011
Social	Population	U.S. Census	Change in Population (90-00)	1990 and 2000
	Over 65	U.S. Census	Change in Population over 65 (90-00)	1990 and 2000
	Median Income	U.S. Census	Change in Median Income (90-00)	1990 and 2000
	Median Housing Value	U.S. Census	Change in Median Housing Value (90-00)	1990 and 2000
Spatial	Seasonal Housing Percent	U.S. Census	Change in Seasonal Housing (90-00)	1990 and 2000
	Population Accessibility	U.S. Census	Change Distance Decay of Population (P/D) (50KM) (90-00)	1990 and 2000
	Development Density	MLRC	Total Land/Developed Land (Percent)	1992
	Road Density	U.S. TIGER	Length KM per Hectare	2000
Policy	CBRA	USFWS	CBRA or Non-CBRA	2007

Table 4-4: Descriptive statistics for Coastal Land Cover Change Drivers

Category	Force	Measure	Minimum	Maximum	Mean	Std. Deviation
Control	Total Land 1992	ha	0.08	481.37	33.45	63.82
Natural	Flood Area	ha	0.03	81.51	10.70	14.06
	Erosion Area	ha	0.00	180.50	18.87	34.02
	Hurricanes 1980-1990 exposure	*	0.48	4.27	2.20	1.00
	Hurricanes 1990-2000 exposure	*	0.52	5.96	2.31	1.54
	Wetland Area	ha	0.25	7677.02	520.19	995.79
Social	Population change	Person	-3006.00	21760.00	990.97	2707.69
	Over 65 change	Person	-12543.00	5441.00	148.25	1424.04
	Median Income change	Dollar	-81103.66	58095.00	13680.73	18823.16
	Median Housing Value change	Dollar	-89773.84	433759.13	85440.60	101656.63
Spatial	Seasonal Housing Percent change	Home	-7350.00	7384.00	352.79	1305.70
	Population Accessibility change	P/D	-79.67	95.51	5.07	24.29
	Development Density change	Percent	0.00	0.99	0.49	0.33
	Road Density	KM/ha	0.00	9.80	2.72	1.80

*Measure is based on a line density with a search radius 80.5KM with the with a population based on category of storm

Table 4-5: Coastal Land Cover Change Driving Force Models

Force	Model 1	Model 2	Model 3	Model 4	Model 5
Total Land 1992	✓	✓	✓	✓	
High Flood Area	✓	✓			
Erosion Area	✓	✓			
Hurricanes 1980-1990	✓	✓			
Hurricanes 1990-2000	✓	✓			
Wetland Area	✓	✓			
Population	✓		✓		
Over 65	✓		✓		
Median Income	✓		✓		
Median Housing Value	✓		✓		
Seasonal Housing Percent	✓			✓	
Population Accessibility	✓			✓	
Development Density	✓			✓	
Road Density	✓			✓	
CBRA	✓				✓

Table 4-6: Ordinary Least Squares (OLS) Regression Results

Independent Variables	Model 1		Model 2		Model 3		Model 4		Model 5	
	Full		Natural		Social		Spatial		Policy	
	B	(S.E.)	B	(S.E.)	B	(S.E.)	B	(S.E.)	B	(S.E.)
Total Land 1992	0.633***	0.014	0.745***	0.011	0.685***	0.014	0.532***	0.008	-	
High Flood Area	0.211*	0.061	0.247*	0.064	-		-		-	
Erosion Area	0.188**	0.015	0.254***	0.016	-		-		-	
Wetland Area	- 0.411***	0.001	- 0.405***	0.001	-		-		-	
Hurricanes 1980-1990	- 0.174*	0.392	0.032	0.381	-		-		-	
Hurricanes 1990-2000	0.100	0.709	0.023	0.564	-		-		-	
Population	0.077	0.000	-		- 0.042	0.000	-		-	
Over 65	0.010	0.000	-		0.031	0.000	-		-	
Median Income	- 0.029	0.000	-		0.016	0.000	-		-	
Median Housing Value	0.053	0.000	-		- 0.056	0.000	-		-	
Seasonal Housing Percent	0.197**	0.000	-		-		0.305***	0.000	-	
Population Accessibility	0.213**	0.024	-		-		0.218***	0.021	-	
Development Density	- 2.631**	2.141	-		-		- 0.132	1.884	-	
Road Density	0.024	0.335	-		-		0.066	0.341	-	
CBRA	0.029	1.218	-		-		-		- 0.129	1.691
Constant	2.467	2.041	- 2.628	1.193	- 0.218	0.786	- 0.196	0.932	2.904***	0.809
Adjusted R^2	0.638		0.564		0.423		0.568		0.009	
Mean VIF/ Highest VIF	2.42/4.39		2.42/3.59		1.92/3.02		1.38/1.75		1.00/1.00	

Dependent Variable: Land Change to Developed 1992-2001
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4-7: Stepwise Regression Results for Model 1

Model	Variables	B	S.E.	Sig.	VIF	Individual Adj. R^2	Total Adj. R^2
1	Constant	-	0.605	0.395	-	-	
	Available Land 1992	0.665	0.008	0.000	1.000	0.437	0.437
2	Constant	-	0.562	0.136	-	-	
	Available Land 1992	0.583	0.008	0.000	1.076	0.437	
	Seasonal Housing Percent	0.306	0.000	0.000	1.076	0.084	0.521
3	Constant	-	0.581	0.005	-	-	
	Available Land 1992	0.572	0.008	0.000	1.078	0.437	
	Seasonal Housing Percent	0.239	0.000	0.000	1.172	0.084	
	Erosion	0.226	0.015	0.000	1.107	0.044	0.565
4	Constant	-	0.559	0.004	-	-	
	Available Land 1992	0.511	0.008	0.000	1.190	0.437	
	Seasonal Housing Percent	0.243	0.000	0.000	1.172	0.084	
	Erosion	0.198	0.014	0.001	1.129	0.044	
	Population Accessibility	0.198	0.020	0.001	1.141	0.032	0.597
5	Constant	-	0.549	0.010	-	-	
	Available Land 1992	0.662	0.010	0.000	2.155	0.437	
	Seasonal Housing Percent	0.220	0.000	0.000	1.194	0.084	
	Erosion	0.229	0.014	0.000	1.170	0.044	
	Population Accessibility	0.181	0.020	0.002	1.153	0.032	
	Wetlands	-0.213	0.001	0.005	1.921	0.021	0.618
6	Constant	-	0.927	0.593	-	-	
	Available Land 1992	0.745	0.011	0.000	2.528	0.437	
	Seasonal Housing Percent	0.226	0.000	0.000	1.195	0.084	
	Erosion	0.217	0.014	0.000	1.178	0.044	
	Population Accessibility	0.171	0.019	0.003	1.159	0.032	
	Wetlands	-0.298	0.001	0.000	2.314	0.021	
	Development Density	-0.152	1.475	0.012	1.265	0.016	0.634

Dependent Variable: Developed Land Cover Change from 1992 to 2001

Table 4-8: Spatial Auto Correlation Results Using Global Morans I

Model	Model	Moran's Index	Variance	z-score	p-value	Result
Full Model	1	0.0387	0.0058	0.6083	0.5430	Random
Natural	2	0.0166	0.0046	0.3593	0.7194	Random
Social	3	0.0087	0.0022	0.3523	0.7246	Random
Spatial	4	0.0301	0.0051	0.5300	0.5961	Random
Policy	5	0.0090	0.0021	0.3663	0.7142	Random

Figure 4-1: Contributing Drivers to Barrier Beach Development

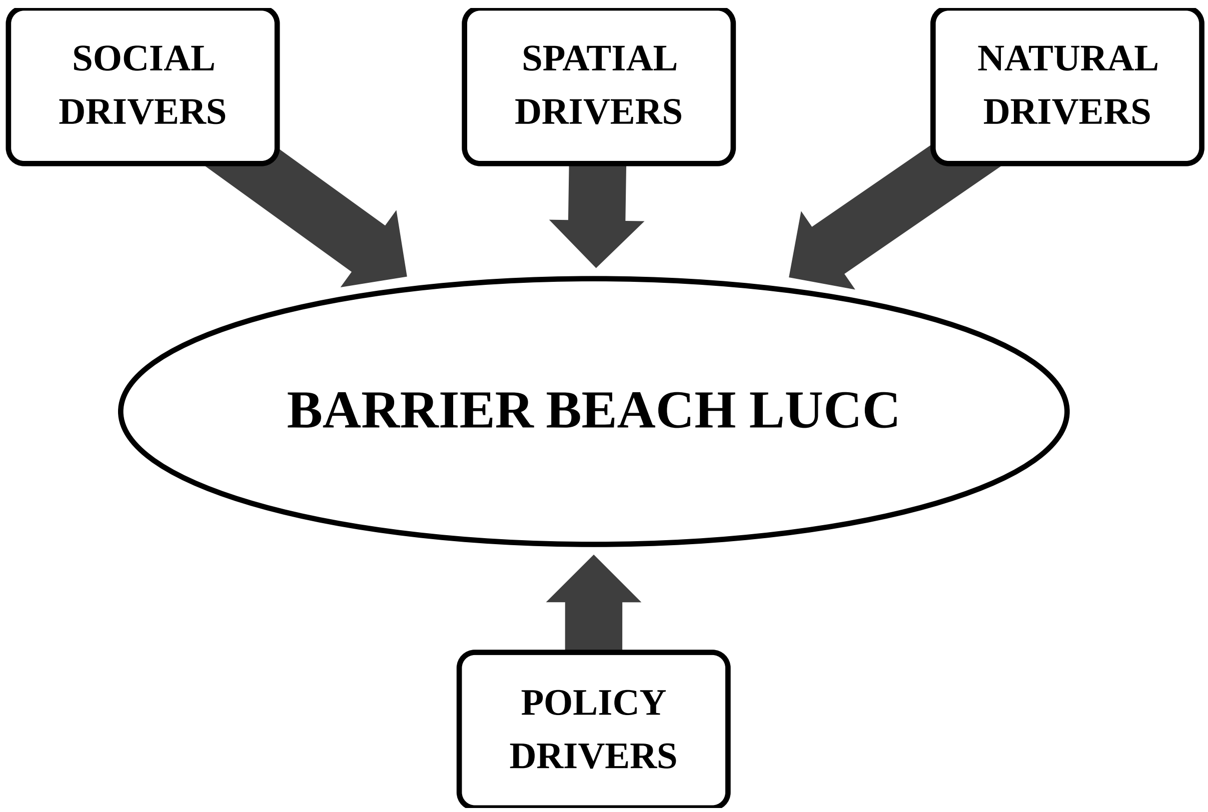
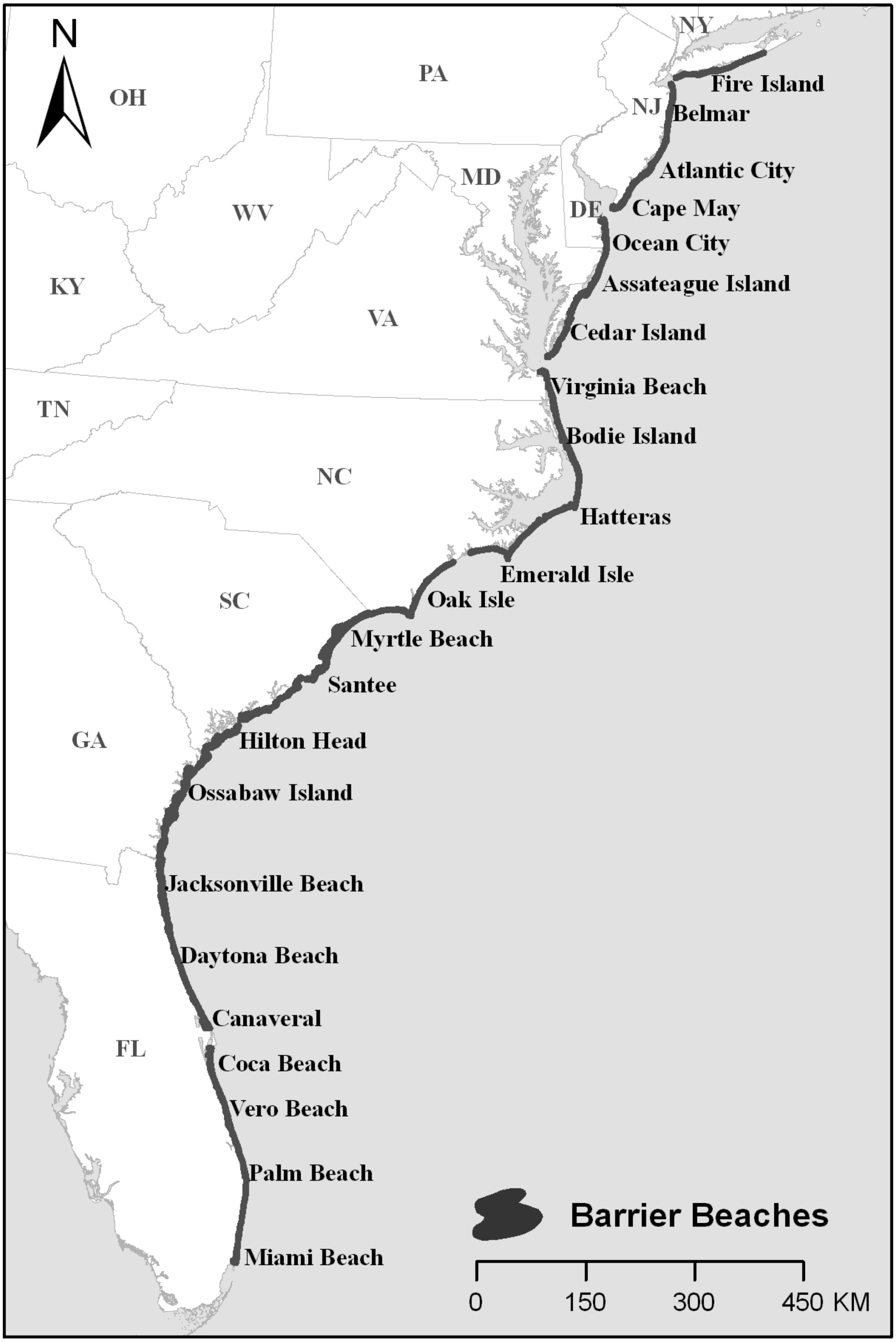


Figure 4-2: Study Area



Chapter 5: Conceptualizing and Applying a Coastal Restructuring Model to Understand Trajectories of Change in Barrier Beach Communities

The relationship of societal influence on barrier beach landscape change has often been less emphasized than investigations linking natural processes to changes occurring in barrier beach landscapes. This chapter develops and applies a conceptual model designed to provide understandings of human dimensions and societal influences on barrier beach land cover change within the field of Land Use/Cover Change (LUCC). The model and techniques put forth in this paper aim at integrating standard practices and knowledge from LUCC as well as historical narrative analysis in order to understand the societal process of barrier beach landscape transformation. The research creates a quantitative and qualitative understanding of localized land cover change in two categorically different barrier beach communities located on the U.S. Atlantic seaboard. First, a recent depiction of each of the selected places from 2000 is created to understand its current makeup followed by a historical narrative spanning from the mid 1800s ending in 2000. The use of parcel data and historical documentation will also be used as a way to quantify patterns of development and to describe important events that inhibit or restrict developed land cover change from occurring. This research will extend research efforts in classifying and determining drivers of barrier beach communities. It draws on results from the prior quantitative chapters (3 and 4) and extends them to look in a more nuanced way at particular places with particular place-based histories. This approach disentangles the nuances that quantitative and statistical approaches cannot answer. As a result this research creates descriptive analysis techniques that can be applied to any and all coastal barriers using this model. While the details of the results will differ the overarching structural framework will create a consistent method to understanding place based coastal land cover change.

Changes in the social structure during the late 19th and continuing on to the 20th century in the United States have shaped and reshaped the patterns, in which LUCC has occurred. Societal structure in terms of this research is referring to the organizational makeup of a society and their interactions and intention, within and on the landscape (Stinchcombe 1965). To assess societal structure, a historic approach is used because of its ability to explain the main groups of actors shaping the landscape change over time. Human behavior and its interaction with the landscape are cultivated by shifting of needs and the demands of society (Burgi et al. 2004). Land cover change occurs in both space as well as time, thus making the integration of LUCC practices and history a means for understanding processes (Burgi and Russell 2001). In LUCC research, people are seen as one piece amongst various others that change the region being studied. History uses land cover or setting of events as just one piece among many that are observed. Historians and landscape ecologists may view the same landscape, but draw different conclusions from the landscape making collaboration uncommon (Meine 1999). It is the collaboration between historical contexts and landscape research that allows greater detailed local land cover change to be explored and understood. It takes into account the nuances that are at many times lost through the observation of larger picture ideas or many of the times outside of the focus of the individual researcher.

Coastal zones, especially barrier beaches, have experienced the largest amounts of growth in population as well as development over the past half century. In 2010 approximately 164 million people resided within coastal counties and the population is projected to reach 195 million in 2030 (Woods and Pole Economics Inc. 2011). Based on the 2000 census approximately 1.4 million people are living on barrier beaches with an increase of 14% from 1990 to 2000 (Zhang and Leatherman 2011). From 1945 to 1973 a total of 57,000 hectares of barrier beach land was converted into developed land cover representing over 150% increase in developed land (Dolan et al. 1973). This change represents a total of raw increase of 8.3% of all barrier beach land that developed over this time period (Dolan et al. 1973; Zhang and Leatherman 2011). Since 1973 developed land cover has continued to increase on barrier beaches in support of new residents and tourism industry. In 2007 about 85% of tourist-related revenues in coastal states are largely due to the popularity of beaches (Houston 2008). Based on estimation in 2007, approximately 180 million Americans make 2 billion visits to beaches each year (Houston 2008). It is projected that population density in coastal counties from 2010 to 2020 will grow to be more than three times (93 people per square kilometers) more than that of non-coastal counties (28 people per square kilometer) (Woods and Pole Economics Inc. 2011). Increasing populations pressures and dependence on these places to generate revenue (mainly from tourism) create need to study and understand the changing trends and patterns that emerge as a result of developed land cover conversion.

Landscape dynamics and its effects on regions have been widely studied during the last two decades (Forman and Godron 1986; Lasanta, 1988; MacGarigal and Marks 1995; Poyatos et al. 2003; Lasanta et al. 2005; Farina 2006): there have been few that look at local scale. Furthermore, land cover change studies in coastal regions have occurred at different national and state and county scales (Crawford 2007). Local scale research in coastal areas is important because much of the research done is at large scales that many times include coastal and non-coastal regions but explicitly investigate differences in patterns and processes occurring for solely coastal areas. Local studies however provide the spatial and temporal resolution required to identify and account for major variations that may occur in land cover change (Turner II et al. 1994). There are few place based studies compared to larger scale studies because they require more time to investigate and demand high quality land cover data to observe change (Geist and Lambin 2002). The mass produced 30-meter raster data sets (i.e. National Land Cover Database and NOAA C-CAP) are used more readily and reported on because of availability, cost, and scale of many studies. Research at the local scale has the ability to identify different land cover indicators that are only observed at the local scale (Borak et al. 2000). Local research allows for an understanding of local processes, which can in turn be applied to larger scale research and processes (Vogelmann et al. 1998).

5.1 ***Objectives***

The central thesis of this chapter is that local scale histories, spatial contexts, environments, and policies contribute to differentiated trajectories on these barrier beaches. The main objective of this paper is to develop and implement a coastal restructuring framework that enables description, interpretation, and comparison of the historical trajectory of human land use development for any barrier beach community. The secondary objective is to apply the created model to two selected barrier beach units that exhibit contrasting characteristics. The research follows similar framework set forth by Light and Dineen (1994), McCally (1999), and Solecki et al. (1999) which outlines the periodic nature of infrastructure and land use development in South Florida. This research will look at the societal influences inside the chosen locations without taking into account external forces that may exist at alternate scales. The research will address the issues of social history of interaction between people and place. It will chart the path of landscape conversion over time through quantitative and qualitative methods. Through the use of this data, the study will create an understanding of land change history that is reflective of localized events. The research will also address the role social history plays in the trajectory of land change of place. Landscape change is illustrated through creating a narrative that utilizes the historical parcel data, policy and historical documentation (Walker and Solecki 2004). This generates a perspective beyond data outputs of the key components that evaluate localized land change. It allows for an understanding of the interconnection between the region's social structure and environment, which creates a conversation of land cover change (Swyngedouw 1999). This discourse represents landscapes as a holistic manifestation of coupled human and natural elements; it follows that cultural processes can lead either to physical change or to change in the cultural system itself (Marcucci 2000).

The linkages and relationship of these components has the propensity to fill the voids in understanding and evaluating the processes of LUCC of an individual unit as well as the application for all barrier beach units. The wider breath of this research can be applied to issues of coastal management, most notably issues pertaining to social interaction on the landscape. Understanding the past trajectories and patterns that occur on the landscape can help lead to greater understanding of the dynamics that exist within an area. This is especially important in understanding how to plan and manage landscapes based on past and present uses. The trajectories also have the potential to identify conflicting uses that exist within an area. Understating the current condition provides planners and managers a vision of the social landscape for that area. Based on the current condition they can assess if they need to shift the current use or maintain the existing use. An example of this is if a tourist landscape wants to shift to a conservation landscape they would want to move that use to a managed amity. This would allow them to keep their tourism industry as well as protect their valuable natural resources that are impeded upon by tourism.

5.2 ***Coastal Restructuring Theory***

The notion of coastal restructuring is derived from current bodies of knowledge in rural landscape settings. Rural landscapes, much like coastal landscapes have become more valuable for the amenities they provide than the functionality of the landscape itself (Bell 1994; Deller et al. 2001; Whitson 2001; Fløysand and Jacobsen 2007). The change in value of land has led to the conversion of once productive farming land to developments for consumptive activities like tourism and new homes. From these changes new landscapes emerge, where through the creation of new amenities (seasonal and service-based economy) the social structure is altered and LUCC moves toward a new direction (Van Auken and Rye 2011). Coastal restructuring occurs at different temporal and spatial areas and because of this a model tailored to uniquely coastal areas is adapted from Holmes (2008 and 2006) (Figure 5-1). The model provides critical information that can be used by coastal planners and managers as to how landscape transitions over time. This would have the potential to aid in planning and predicting land use changes that have and may occur over time.

The model follows the development path of each selected coastal landscape from its original use to its current use. The model evaluates the changing uses and social patterns that exist within the selected community. The model identifies three core uses of landscapes: production, consumption, and protection. Within these three uses of landscapes, there are seven unique phases in landscape transformation, that is extractive (production dominant), extractive amenity (production and consumption), amenity (consumption dominant), marginalized extractive (production and protection), conservation (protection emphasized), managed amenity (protection and consumption), and multidimensional (production, consumption and protection all existent). The phases are representative of potential social landscape uses at a singular time period. If these landscape uses are combined with other observed uses at different times for the same landscape, potentially a path of societal landscape use can be identified.

5.2.1 Conceptual Framework of Societal LUCC

To analyze the connection between societal structure and LUCC of barrier beaches, a conceptual framework is created to explain landscape change in context to the existing societal system. This framework requires a method that explains LUCC in context to the coupling of regulating forces along with socio-economic forces on landscape alteration. This aids in explanation of the modifications to the landscape as well as the spatial and temporal trends existing within a society. This framework creates an analysis that explains the variation and development changes on a landscape based on the social system that exists on the landscape.

A societal framework was adapted from Solecki et al. (1999) who developed a historical interpretative approach for South Florida landscape trajectories to explain how coastal Florida evolved and change over time (Figure 5-2). Regulating forces and socio-economic forces work within the societal system in relation to landscape conversion. Regulating forces are forces that can restrict or expand landscape change due to societal inputs. These regulating forces include government influence, market responses, and management of resources. All these regulating forces can both limit as well as inhibit landcover change from occurring. Similar to regulating forces, socio-economic forces are taken into account through the observation of population, economy, technology, and ideals that contribute to the changing barrier beach landscape. Analysis of the socio-economic forces are not intended to cover the entire scope of societal concerns, but have significant influence on society's interactions with the landscape (Solecki et al. 1999). These forces deviate from that of regulating forces because many times regulating forces can be part of larger systems while socio-economic forces isolate local structure of area of interest. Socio-economic forces act in conjunction with controlling forces to explain the land cover change. The second part of this framework is concerned with landcover interactions on the societal system. As land cover is converted over time due to societal system forces, the model responds back in the system. Every change within the framework responds and influences all factors within the system.

Taking the societal LUCC framework along with the coastal restructuring model a visualized path of change can be expressed. Describing and accounting for observed factors over a given time period and inductively applying it to the societal LUCC framework provides a point identifying a particular landscape phase. Identifying and connecting multiple sequential points trace out a phase diagram summarizing a place's landscape evolution. The phase diagram created through this model is similar to the Tourism Life Cycle proposed by Butler (1980). The tourism life cycle found that a tourist area underwent 6 phases throughout its history. These stages included exploration, involvement, development, consolidation, stagnation, and the sixth and final phase an area range from being rejuvenated to going into decline. While the tourism lifecycle model is concerned with strictly tourism the coastal restructuring model goes beyond this because not all landscapes are used solely for tourism. An example of this is if there was a heavy concentration of fishing, farming, and hunting identified within the framework it can be implied that over that time period the landscape was extractive and productive in nature. If the societal influences were geared towards development and bringing people to the beach it would fall within amenity and consumption landscape phase for that period. By linking different time periods through both the coastal restructuring model and societal LUCC framework a path of overall societal influenced land cover change can be observed as well as explained.

5.3 ***Methods***

The research will use a descriptive analytical and interpretive approach to understand the historical trajectory of development in each unit at the local scale through the use of secondary data sources (i.e. books, newspaper articles, and land use plans). Secondary data sources are used to construct a historical narrative of land cover change spanning a period from the mid-1800s through 2000. Parcel data will be combined with the historical narratives to analyze the relative impact of historical occurrences using the conceptual framework of societal LUCC. The evolution of the regions has certain intangible traits that can influence the overall landscape and how people and policy have changed it. The historical narratives of LUCC on the selected units follow a three stage approach as where the areas' histories are broken up into distinct time periods (Solecki et al. 1999). These stages represent a physical change in development patterns as well as changes in social aspects and policy acting on the landscape. The results will then be applied to the coastal restructuring model to show the path of landscape change over the observed periods.

5.3.1 Study Area

Results from related work reported in Chapter 3 typology found there to be three main types of barrier beach communities within the Atlantic barrier beach coast. The first classification found was New Atlantic communities which represented the amenity driven second home and vacation development along the coast. The second type being Old Atlantic communities representing established slow growth slow changing communities within the region. The final classification was natural barrier beach units that were either classified as protected areas by the federal government or areas that represented no development or population characteristics. For the purpose of this paper only New and Old Atlantic communities will be looked at because natural barrier beach units have no or little development as well as people making their histories consistent over time.

Units with varying degrees of characteristics were needed for this study to validate that the model could be applied across an array/variety of barrier beach unit. Units with contrasting development, social, and physical characteristics were selected based on data from Chapter 3 and 2000 census calculations (Table 5-1). The ideal units selected would be one unit whose characteristics are greater than the average for all barrier beach units and one unit whose characteristics are lower than the average. Additional factors would include differences in location, because if two units with proximate locations were measured there would be similar forces acting upon the landscapes. Along with location differences, uses of the typological classification in Chapter 3 were included in the criteria. Different classification typologies allow for landscapes with different types of use to be examined. These differences ultimately show the utility and versatility of the method.

The first unit selected for the study was Long Beach, NY, which represents an Old Atlantic community where development has not been regulated by federal coastal policy (Figure 5-3). Long Beach is located on the southern shore of Long Island in Nassau County New York. It is known for its surfing community that has been attracted by jetties placed along the shore creating the ideal surfing atmosphere. The area also has a large accessibility to population being less than fifty kilometers from New York City. The unit has approximately 11.6 km of oceanfront coastline with a total land area of 1128.36 ha. The population of the area in 2000 was 43,556 and the total housing units were 19,885 with 5.6% being seasonal housing.

The second unit for this study is Currituck Banks, NC which is a New Atlantic community with development that has been influenced by federal and state coastal policy. Currituck Banks is located on the far northern end of North Carolina on the border of Virginia. The unit has approximately 10.8 km of oceanfront coastline with a total land area of 1928.78 ha. The unit is divided into two parts by the Currituck National Wildlife Refuge, which runs from shore to sound. The area is also known for its lack of access by paved roads and wild ponies that roam the landscape. The area is sparsely populated with only 134 permanent residents according to the 2000 census. There are 277 total housing units, over 75% of which are considered seasonal housing.

5.4 *Data*

The historical narratives are created in part through the use of historical documents and parcel data that pertain to each selected unit. Due to the historical time frame and scale of this research, remotely sensed land cover data were insufficient to create a longitudinal picture of development on the selected barrier beach units. Residential parcel data were used for this local research because they allow for space and time; two necessary attributes for localized land cover change, to be identified. The residential parcel data show both historically (the year the parcel was developed) and spatially (parcel level scale) developed land cover change over time. Due to lack of population data for the observed period aggregated at the local place level, parcel data also act as an indicator of development over time. The parcel data for Long Beach were acquired from the Nassau County Tax Assessors office, and Currituck County Planning Department provided the data for Currituck Banks.

5.4.1 Historical Narrative Stages

In order to create a reputable method to determine stages, a numerical classification, in which numbers (i.e. parcels developed) are grouped according to some criteria of similarity, is used. This classification creates uniform groups so that numerical difference within groups is less than the differences between groups (Dent 1999). To achieve this, Jenks Natural Breaks Method was applied to the parcel data for both Long Beach and Currituck Banks. The parcels developed were totaled for each year by taking the last year's total with the current year giving a cumulative total of developed parcel for that given point in time. The data were then put into Jenks Natural Breaks or Optimization Method, which creates groups that are internally homogeneous while assuring heterogeneity among classes (Dent 1999). The measure created from this method is called the Goodness of Variance Fit (GVF), which is a minimizing procedure where the smallest sum of squared deviations is sought (Jenks and Coulson 1963). The Equation is as follows:

$$GVF = \frac{SDAM - SDCM}{SDAM}$$

Where:

$SDAM\ is\ sum\ of\ squared\ devations\ or \sum (x_i - \bar{X})^2$

$SDCM\ is\ the\ sum\ of\ squared\ deviations\ for\ c\ classes\ or \sum \sum (x_i - \bar{Z}c)^2$

The completed results for the Jenks Method allows for the parcel data to be separated into distinct homogeneous stages. For this research three stages were chosen to express the simple progression of the landscape over time as seen in Solecki et al. (1999). The preferred number of stages can be adjusted and interpreted to the research parameters, keeping in mind that the larger number of stages would in turn intensify the research and focus of the study. The larger the number of stages requires increase in data to correctly identify the stage of the landscape. Names are given to each of the three stages to be reflective of the nature of the transitive landcover change occurring during each stage. The first stage is similar to Butler's (1980) first stage in the tourism life cycle model: it identifies the frontier stage, in which the origins of settlement are determined and explained. This includes, but is not limited to the original fixed/permanent settlers of the area, planning stages of the area, as well as any other activities that are related to foundation of settlement. The development stage is the second stage, Butler's (1980) third stage, it investigates the time in which the area was developed and the drivers behind that development. The post development stage is the final stage, which examines what happens after the area becomes developed. This stage can be seen as a combination of Butler's (1980) stagnation and rejuvenation/decline stages (stage 5 and 6). While in the post development stage the landscape use has the potential to move, like in Butler's last stage, towards development, stabilization, or decline. The combination of frontier, development and post development stages enable a transition of landscape use to be depicted that may have been unseen at a larger scaled approach had been taken.

5.5 ***Long Beach, NY***

5.5.1 Frontier Stage 1879-1925

Long Beach is located on the southern shore of Long Island; three miles beyond the mainland (Figure 5-4). It originally began as a "resort" of only fishermen and hunters of water fowl. Its favorable summer and winter temperatures and proximity to New York City made it an ideal place for a year-round resort (Hazelton 1925). The framework for transforming Long Beach into a year-round resort began in 1879 when the Long Island Rail Road (LIRR) employed William Laffan, publisher of the New York Sun, to negotiate a deal with the Town of Hempstead for development rights (Kellard 2010a). Laffan was able to secure a lease for $300 with the Town of Hempstead allowing access for the LIRR along with an additional clause that forbid steamboat access. That same year the Town of Hempstead secured a 100-year lease with the "Long Beach Improvement Company," developers of the Long Beach Hotel (Figure 5-5). The Hotel was 274 meters long and 152 meters wide with 27 cottages and a bathing house, which at the time was the world's largest seaside resort (Saccardi & Schiff Inc. 2007). The following year the LIRR began to bring city people to the Long Beach and Long Beach Hotel and over time the area continued to develop as a tourist resort. In 1905 access to the beach was in such high demand that a trolley line had to be run from the train station to the beach (Hazelton 1925).

The Long Beach Improvement Company, the lease holding company at the time, was purchased early in 1906 by a group of investors (Hazelton 1925). Amongst these investors was William Reynolds, a 24-year old from Brooklyn credited with the creation in 1903 of Coney Island's largest amusement park, Dreamland (Jackson 2002). Reynolds and his associates announced that they would expend a development budget from eight million to ten million dollars in building another Atlantic City. They envisioned an eight-mile chain of modern hotels and cottages adapted for year-round occupancy (Hazelton 1925). This new vision for Long Beach was halted when in 1907 a massive fire destroyed the Long Beach Hotel leaving only the sixteen foot wide fireplace that ran through the center of the hotel. About eight hundred guests escaped the inferno during which only five persons were injured with no fatalities (Hazelton 1925).

In the shadow of the fire, Reynolds continued with his new vision of an expansive boardwalk lined with lavish hotels (Figure 5-6). In the fall of 1907 Reynolds brought his vision to reality when he brought several elephants from Coney Island to haul lumber. Not only was it a spectacle to see, the elephants were capable of hauling lumber more effectively than horses could. The completed boardwalk stretched a length of 3.5 kilometers long fifteen meters wide lined by electric lights and over 3,500 concrete piles and girders (Hazelton 1925). In 1908 Reynolds continued his vision for Long Beach when he plotted the first residential parcels of his designed community, “The Estates”, built as part of the planned resort community phase (Kellard 2012). The community consisted of large villa-style formal homes regulated by strict building standards that dictated the property size and the esthetics of homes and streets (red tile roofs and white stucco walls and red brick streets) (Saccardi & Schiff Inc. 2007).

Development continued in the winter of 1908 when three steam dredges were put to work, twenty-four hours a day, to dredge the channel eight kilometers long, four meters deep, and 335 meters wide (Hazelton 1925). This dredging converted hundreds of acres of swamp and meadows into solid land on the backside of Long Beach Island. Moving roughly 46,000 cubic meters of sand a day the dredging was regarded as the biggest sand moving undertaking (Hazelton 1925). The Nassau Hotel was built in 1909 designed for year-round occupancy it was known and publicized as the fireproof hotel (Kellard 2011a) (Figure 5-7). The Hotel was built in the shape of an “H” and stretched 90 meters along the boardwalk and 15 meters back on each end (Hazelton 1925). Legal gambling came to a halt in 1910 when New York State banned all casinos and gambling. Change in regulations forced developers to shift focus from lavish resorts in favor of built seasonal communities. As neighborhoods began to develop, Long Beach became an incorporated village in 1912 and began its transition from summer to year-round community (Jackson 2002).

With new year-round homes being developed along with a trolley system bringing residents and visitors around the newly developed neighborhoods, Long Beach entered into the development stage (Jackson 2002). Starting in 1918 the Walks neighborhood was created over a ten-block span using pre-fabricated housing meant as summer bungalows. The Walks homes were unique because they were designed having no direct street access, driveways, or garages (Kellard 2011b). As the permanent resident population increased, Reynolds finally got his wish in 1922 when Long Beach was granted status of city making it the city by the sea. That very year Reynolds was elected Mayor of Long Beach. The city used its new status to get at the time the largest reduction in Suburban Fire Insurance giving Long Beach residents the lowest base rate of anyone in Nassau County (Hazelton 1925). In 1922 the city replaced the wooden bridge with what was dubbed as the "Million Dollar Bridge" which cut through the dredged Reynolds channel (Kellard 2010). The "Million Dollar Bridge" was the first of three bridges to be built over an eight year period to be built connecting Long Beach to the mainland (Figure 5-8).

5.5.2 Development Stage 1926-1950

After the Million Dollar Bridge was completed many other transportation projects became underway. These projects provided new access to Long Beach, which increased the desire of people to develop on the island. The Far Rockaway Bridge was one such project that connected Long Beach at the west end in 1927 as well as the Loop Parkway Bridge, a product of the Works Progress Administration (WPA), opened to the east in 1930 (Fiore et al. 2010). In 1935 the boardwalk was in a state of disrepair after harsh winter storms. As a way to protect the boardwalk and residents from the ocean's waves, jetties were built and the boardwalk was rebuilt by FDR's WPA (Kellard 2011a). New bridges, paved roads, hardened beach structures, and increased housing stock made Long Beach attractive to increasing numbers of year-round residents. Population change according to the US census showed that Long Beach grew from just a few hundred permanent residents in 1910 to 5,817 in 1930 and nearly doubling to 9,036 in 1940 reflecting growth due to increased access and housing availability.

The growth of the population of Long Beach was brought to a halt when the island was appropriated by the US Navy in 1942. The Navy used the Lido Hotel as a barracks, whose 300 reservations for that season had to be canceled. After World War II the beach cottages that were once meant for summer residents began to evolve into year-round residences. There was also a large increase in housing growth similar to the pre World War II development. While year-round hotels began to fall out of favor, family-oriented hotels were constructed allowing the Long Beach to accommodate a summer population of more than 70,000 residents (Saccardi & Schiff, Inc. 2007).

5.5.3 Post Development Stage 1951-2000

After World War II the appeal of Long Beach as a seasonal vacation destination began to decline in favor of more year-round communities. As more permanent residents moved into Long Beach so did the need for public facilities for them. In place of the year-round resorts, beachfront parks and clubs developed to facilitate the needs of the community. Along with increasing permanent population, new advances in technology began to sway vacation populations away from Long Beach in favor of more previously unreachable/undesirable destinations, like Florida and California. Technological advances such as air conditioning and air travel allowed populations to travel longer distances to destinations where climate is not an influencing factor (Saccardi & Schiff, Inc. 2007). These advances caused a decline in the tourist population that had once flocked to the boardwalk. This in turn has left the once lavish beachside hotels that had teemed with vacationers in the 1920s 30s and 40s vacant.

The decline of Long Beach may have begun due to advances in technology, but changes in policy and population caused the landscape to transition away from an amenity-oriented place.

Most if not all of these policies were put into place after much of the land in Long Beach had already become developed. At the federal level the Coastal Zone Management Act of 1972 (CZMA) encouraged the responsible economic, cultural and recreational growth of the coastal zones through funding for states to create their own management plans (Owens 1992). In 1973 the City of Long Beach enacted its official city codes, which included zoning regulations limiting development within the city. The New York Waterfront Revitalization and Coastal Resources Act of 1981 provided coastal municipalities, under CZMA, resources to create their own coastal policies called Local Waterfront Revitalization Plans. In 1985 a draft Local Waterfront Revitalization Plan was developed by to the City of Long Beach, but was never officially adopted (Saccardi & Schiff, Inc. 2007). Since then Long Beach has not adopted a Local Waterfront Revitalization Plan, but has set forth policies that regulate and work towards management and preservation of coastal resources.

Over time Long Beach has changed from what it was initially envisioned to be when Laffan and the Long Beach Improvement Company first set out to gain property rights. The lavish vacation getaway for the elite has transitioned over time to a version of what William Reynolds envisioned as the “City by the Sea”. While Reynolds planned communities (i.e. walks and estates) still exist today, he probably would not have envisioned them becoming year-round residences along with collapse of the tourist industry he had helped create. While the boardwalk and many of the hotel buildings remain their uses have changed from hotels to permanent residences. Today Long Beach is a year-round community with a population of 43,556 and 19,885 housing units existing all on less than 28 hectares of narrow barrier beach.

5.6 ***Currituck Banks, NC***

5.6.1 Frontier Stage 1854-1970

Currituck Banks began as a remote, isolated region cut off from the outside surrounded by large bodies of water - "an easier place to talk about than visit" (Yucom 2000). Originally hunting clubs and farming dominated the relatively undeveloped landscape. Parcel development originally occurred on the sound side of the barrier beach (Figure 5-9). The livelihood of the farmer residents along with the strong market-hunting industry created a high value for protecting any significant development occurring on the landscape (Figure 5-10). This in turn created a landscape that was focused on the production of goods through farming and hunting and the protection of the landscape. The Currituck Banks is a part of a larger barrier island spit much of the frontier history is directly connected to areas north and south of the unit.

In 1857 Valentine Hicks, a New York businessman, and 14 of his associates purchased a large piece of land and constructed the Currituck Shooting Club (Austin et al. 2006). As a way to aid shippers through the night, the Currituck Beach Lighthouse was built in 1875 at a height of 162 feet and over a million bricks. The area continued to remain untouched until after the Civil War when many more hunting clubs like Currituck Shooting Club were created. This is evident in the parcel records when in 1914 there were a reported total of 31 parcels developed, all of which were located on the sound side for hunting related purposes. Due to lack of restrictions a record kill of 892 ruddy ducks in one day was made by Russell and Vann Griggs (Critcher 1949). Subsequent to 1918 the large increase in hunting clubs along with market hunting industry of waterfowl lead to laws limiting the amount of fowl that could be hunted (Austin et al. 2006). The Migratory Bird Act of 1918 made it illegal to hunt, take, capture, kill or sell birds identified as migratory for commercial hunting. It also regulated the amount of foul that could be hunted per day. In 1922 Edward and Marie-Louise LeBell Knight, avid hunters, began work on the

Corolla Island hunting facility, a 2,100 square meter building located on the sound side just south of Currituck Banks in Corolla (later renamed as the Whalehead Club) (Austin et al. 2006) (Figure 5-11). It was finished in 1925 and employed many of the local men as hunting guides for the many visitors the club entertained.

In 1928 a group of citizens and county officials sponsored the construction of a toll bridge connecting the Currituck mainland with the Banks (Stick 1973). The Wright Memorial Bridge was constructed in 1930 by W.L. Jones Construction Co. of Elizabeth City at a cost of nearly a quarter of a million dollars (Daily Advance 1932). Just ten days after the bridge was opened, a local newspaper reported 1150 cars had passed over it (Daily Advance 1932) (Figure 5-12). Even though bridges had the means of transporting people across the water, the roads were merely trails through the wooded areas and the beach was used as the major highway across the Island (Dunbar 1959).

The inception of bridges and eventually roads to the banks began to change the landscape as well as the culture of the banks due to improved spatial accessibility. The improvements of roads allowed cars once delegated to drive in sand ruts along the beach to move freely up and down the barrier beach (Figure 5-13). The creation and improvement of access brought a new culture to the Banks. The shifting needs of the barrier islands was representative of a new demand for land and changing ideals about the ways in which these barrier islands would be used (Lee 2008). Land originally seen as least valued by current residents due to its high vulnerability was prized by new tourist-driven development, in which closeness to the ocean as well as ocean views were highly valued (Birkemeier et al. 1984). Bankers, residents of the Outer Banks, saw the land as a common space where they plotted out individual gardens and used the remaining space as commons. The Bankers reacted to the harsh coastal conditions through living reactively to the landscape moving their homes as they became placed in danger while developers in contrast sought to draw lines in the sand that insisted to investors that the land would stay in place in the face of migrating dunes and storm surges (Lee 2008).

With new development came a new shift in the economy where a Banker of many skills became a man focused on a singular occupation (Dunbar 1959). From 1870 to 1950 the leading occupation on the banks was fishing (Stick 1958). Government work programs such as the Civilian Conservation Corps, Works Progress Administration, and the National Youth Administration employed nearly a quarter of the banks population from 1920 to 1930 and in 1940 more than a third of the population (Dunbar 1959; Lee 2008). The project changed the geomorphic process of the barrier islands through the building of high dunes and plant stabilizing grasses along the oceanfront (Birkemeier et al. 1984; Senter 2003). This stabilization allowed for increased protection from storm surges in turn changing the location of new homes from the sound side to the coast. While the banks became stabilized the permanent population began to move to the mainland in search of jobs leaving many small villages and towns abandoned scattered across the northern Outer Banks (Austin et al. 2006).

In the 1960s large tracts of land previously held by hunting clubs were sold off to developers who began to develop the area into subdivisions. In 1967 the first subdivision in Currituck Banks, Currituck Banks Beach, was plotted and canals were dug and bulkheads were put in to accommodate small boats. Following Currituck Banks subdivision was Swan Beach in 1969 and North Swan Beach in 1971 (Bennett 2010). The subdivisions were designed in grid patterns and the major developer of the time, Kabler and Riggs Reality, sold off thousands of lot to individual investors (Owens 1980). Many investors in Virginia Beach saw potential in the Banks; just a short trip through Back Bay National Wildlife Refuge (BBNWLR) and plans for a paved highway increasing access to made Currituck Banks an appealing investment (Farris 1972; Bennett 2010). At the time Currituck Banks was being subdivided out Currituck County was one of the state's smallest and most rural counties in North Carolina, so rural in fact that they did not even have an incorporated village. In 1970 Currituck had no tools for managing land development other than rudimentary land use ordinances, no public water and sewer plans, and no open space or park plans (Owens 1980).

5.6.2 Development Stage 1971-1985

The Department of the Interior (USDOI) (1979) found in 1971 that 348,000 people had traveled through BBNWLR the 4.2-mile strip of refuge beach, which was used both for recreation and as a short cut by vacationers and residents to reach their property. The impact of increased traffic through BBNWRL made officials question the wisdom of permitting through traffic to cross the Virginia border North Carolina (Bennett 2010). In 1972, in response to the rapid pace of land subdivision, the county placed a one-year moratorium on development while it evaluated ways to handle the potential growth. The county commissioned the Currituck Plan to help plan for future development. The Currituck Plan examined the larger landscape of the Currituck Banks and offered strategies for managing it properly through protecting and maintaining wildlife refuge areas (Farris 1972). Its stated purpose was to define the proper development intensity that would maintain the natural attractiveness of the county while enhancing its economic situation. The plan provided for zoning controls and development standards that would discourage existing land speculation trends and encourage proper development (Owens 1980). After the development moratorium was lifted in 1973, a greater awareness of the sensitive areas of the Currituck Banks emerged and zoning regulations were put into place. The Currituck Plan was never adopted and development continued to occur, but there was a new effort to preserve some of the land that was so highly sought after (Owens 1980).

In 1974 the state of North Carolina passed the Coastal Area Management Act (CAMA), as a response to the CZMA, which made it mandatory for each coastal county to create master land use plans geared at protection of the existing coastal habitat. In adherence with the CAMA, Currituck County created its first Land Use Plan in 1976. The plan created a vision for the future direction of the county with special consideration to Currituck Banks (Currituck 1976). As a response to the increasing traffic volumes that had severely damaged habitat in BBNWLR, the U.S. Fish and Wildlife Service (USFWS) cut off access through the refuge from the Virginia border in 1979 (USDOI 1979). As a compromise for closing access existing residents of Currituck Banks were grandfathered passes to continue to travel through BBNWLR. The FWS acquired land that would become part of a new national wildlife refuge (Owens 1980). In December of 1979 the draft environmental impact statement (DEIS) was issued for the Currituck National Wildlife Refuge (CNWLR). The USFWS wanted to control all of Currituck Banks and the Wetlands to the south of Corolla to the Dare County line (USFWS 1979). The USFWS estimated that the cost to purchase the area would have exceeded $100 million, which would at the time have made it the most expensive single refuge purchase (Owens 1980 USFWS 1979). The high price of the land made purchasing all tracts unattainable.

In 1982 the U.S. Department of the Interior along with the Federal Emergency Management Agency (FEMA) identified undeveloped coastal barriers from the Atlantic coast to the Gulf of Mexico for the purpose of prohibiting new federal flood insurance (UDSDOI 1982). The federal report identified Currituck Banks along with 185 other areas as undeveloped barrier islands (UDSDOI 1982). In 1984 the Coastal Barrier Resources Act (CBRA) designated Currituck Banks for inclusion in the Coastal Barrier Resources System. This inclusion removed FEMA federal flood insurance from the area as well as prohibited federal expenditures that would encourage development, such as funding for roads and infrastructure. In 1984 the CNWLR was created and tracks of land were purchased on the sound side along with a large piece of land in the middle of Currituck Banks that spanned from the ocean to the sound. The

1979 DEIS vision of a larger CNWLR was not successful, but they were able to separate the landscape. They accomplished this by buying a tract of land in the middle of Currituck Banks, essentially creating two areas constrained by wildlife refuges. With no paved road access and bounded by wildlife refuges, Currituck Banks became a landscape cut off from the rest of the world. In 1984 the last new paved road in northern Outer Banks, NC 12, was extended to Corolla just before the Currituck Banks starts.

5.6.3 Post Development Stage 1986-2000

In the years following the extension of NC 12 to the boundary of Currituck Banks minimal improvements to infrastructure have occurred. Parcels are plotted and graded sand roads are the only physical indicators of where parcels begin and end. Today many people may identify the Currituck Banks based on the features of its landscape. These features include its lack of roads, massive beach mansions, and the wild ponies that roam the area. It is these features along with large expanse of undeveloped or natural barrier beach environment. These landscape features make the Currituck Banks a unique landscape onto itself, unlike as Orrin Pilkey and others state the New Jerseyization of the shoreline with its stabilized shoreline and boardwalk, like that of Long Beach (Pilkey et al. 1998).

Even though there is limited accessibility, people still continue to develop on Currituck Banks at greater magnitudes than that seen in decades before. Part of this could be the connection to nature, but other forces including lack of available land in southern villages has allowed for steady housing development to occur. Advances in both home building and transportation have allowed people to both live and travel to this remote place and live in relative luxury, even though they are removed from any form of supporting infrastructure. Privatized flood insurance is another important factor allowing for development to occur because NFIP is removed from this area under the CBRA legislation. The availability of private insurance from coastal hazards makes these areas worth developing to those who have the means to pay to ensure. The advancements in technology along with creation of privatized flood insurance have allowed for these homes to exist like sandcastles in the dunes jutting out of the landscape surrounded by the natural barrier beach environment.

There have been many attempts, including the Fruitville Beach Service District proposed, by developers and some land owners to create paved and improved access in Currituck Banks. To their dismay all of these attempts have been turned down in favor of preserving the area. Even with no road access there still remains a seemingly natural draw to the region and continued development in a place devoid of roads. Current Currituck County zoning regulations limit development to low-density housing with minimum lot sizes of 0.6 hectares.

5.7 ***Results and Discussion***

Applying the historical narrative and conceptual framework on the coastal restructuring model creates a path of how the societal influences on the landscape have transitioned over time. As seen in Figure 5-14 Long Beach transitions over time from an extractive amenity to amenity and finally to multidimensional landscape. These landscape uses are all reflective of the ongoing development history. Long Beach has had a long history of development beginning in the 1920's as a seaside getaway to its current permanent year-round resident population. The parcel development over the stages, as seen in Figure 5-15, show a gradual increase in development a slight pause during World War II then a tapering off as the area reached the post development stage. This path shows that current development of parcels has slowed to only a few per year, if any. Originally in the frontier stage from late 1800s to 1920s it was an extractive amenity landscape where hunting and fishing as well as tourism were important uses for the landscape. As time moved forward the development stage saw a combination of increased access and a strong tradition of non-governmental intervention allowing for Long Beach to develop rapidly. It in turn became a popular vacation destination, which vacation bungalows and expansive hotels would dominate the landscape. The creation of hardened beach structures and dredging of channels built up barrier beach height and created a larger barrier beach to develop. The change in community structure and development did not stem from policy, but from the advent of new technology. New technology in the post development stage shifted the population's ideals in turn changing their attitudes towards Long Beach as a vacation destination. Policy and regulation of Long Beach did not occur until after the boom in development and population had occurred. At the time, CBRA Long Beach had a permanent population over thirty four thousand residents and over eight thousand homes had been built according to the 1980 census. As the landscape transitioned from a tourist-driven economy to a year-round one the production of the area has become stable. Goods and services are needed, but remain the same over time because the population has become stable. The increasing demands for protection and lack of demand for consumption with a constant demand for production have shifted the landscape to become multidimensional.

The coastal restructuring model for the Currituck Banks transitions over time from a landscape that was used as marginalized extractive to multidimensional uses and finally to a managed amenity uses as seen in Figure 5-16. These stages of development take into account parcel history that has spanned over a hundred years. The Currituck Banks' frontier stage was the longest observed period spanning nearly one hundred and twenty years as seen in Figure 5-17. It was a landscape focused on extractive practices such as a hunting area for migrating waterfowl and fishing. The need and want of the hunters to keep the area for these hunting activities acted as a barrier to the incursion of development for long period of time making it a landscape managed for extractive uses. During the development stage, the social landscape values began to shift when the value of the land outweighed the profitability of hunting activities.

A major cause of this was the potential for development of the region as a suburb of Virginia Beach. As the landscape began to build momentum as seen in the parcel incline, regulating forces such as the CBRA, the closing of vehicular access through Back Bay National Wildlife Refuge, the moratorium of development imposed by Currituck County, as well as the creation of Currituck National Wildlife Refuge halted curved development from occurring. This created a multidimensional landscape where the focus of developers was tourism, there was a concerted effort for protection, and hunting/extractive activities were still taking place. The post development stage for Currituck Banks reveals that in face of protection minded practices development is in fact steadily moving forward. The pressures and demands for vacation homes in the region tied to increased access from paved roads in the south have left this area as the largest inhabited unpaved region along the Atlantic Coast. Being a remote place has made the Currituck Banks attractive in the notion that it is ideally a unique one of a kind place. It is this idea that continues to promote and encourage development and is shown in the developed parcel record. This development is not focused on permanent year-round residents; however it is centered on the tourism industry. These factors make the landscape a managed amenity because of the protection measures as well as the continued tourism-driven development.

The development history of Long Beach and Currituck Banks are a small look into history of how these barrier beaches evolved over time. The two units express vary characteristics as well as paths of development. This is important because they show that landscape use transitions over time not uniformly across these regions, but very differently over time. Not all stages fall within the same land uses but some do cross them over time. The connection created between local history and parcel records serve as a way to observe LUCC over time in coastal regions. More importantly this research can be transitive in its application to other barrier beach units. This is true because the study revealed that units with both above and below average characteristics, different proximities, and different classifications can be charted and observed successfully. This new discourse in understanding is reflective of the nature and change that has been seen in coastal regions social, political and physical make up. While researching in this manner is time consuming, the benefits of this research at the local scale explain variables many times overlooked in larger regional, national and especially global scales. Like all places these coastal units have an identity all to themselves that localized research not only explores, but explains the trends and patterns that emerge.

The conceptual framework of societal LUCC provides a tool to underrating the social factors that act upon barrier beach landscape. These factors, many times, go unseen when looking at the physical features a landscape embodies. It is the unseen socio-economic as well as regulating forces interactions with one another as well as with landscape conversion that change occurs. This change is reactant upon all features as one connected unit. Taking the historical narratives created and applying the histories to this framework that an understanding of how the landscape is used and viewed by the society is created. This in turn helps to define the created stages land uses as it transitions from one stage to another. As in all research increased knowledge of an area will result in better depiction and interpretation of landscape. The accuracy of this conceptual framework is largely dependent upon data input into it.

The coastal restructuring model shows that a places societal constructed landscape preferences could be charted over time. The model and process can be used in the future to explore other coastal LUCC process in a similar manner. Social history and its interaction with the physical landscape can be seen as one where trends and practices at the local level that have an influence as to how a landscape will move throughout the coastal restructuring model. When policy is placed into the framework it reveals that it is not as much implementation of the policy, but rather timing of implementation. Comparing Long Beach and Currituck Banks reveals that when government interaction as far as controlling growth occurred Long Beach had already been heavily developed as opposed to Currituck Banks which had been sparsely developed. This makes policy implementation acutely related to the timing in regards to impacting societal notions of land conversion.

When looking at the utility and practical application of the Coastal Restructuring Model one can look towards coastal planners and managers as key inputs into the model. Planners and managers who in their own right have vital local knowledge of the local landscape can be used in the coastal restructuring model in place of data inputs and detailed parcel data. They can take these models and sketch out paths instead of generating historical documentation and parcel data. This would in turn increase generation of models and potentially could create a complete picture for the entire coast to be done, instead of just two places. If these paths could be created for the whole coastline it would allow for planners and managers to evaluate their own paths as well as look at places with similar and different paths. They can also view places they feel who are ideal to them and see how their landscape transitioned over time. Viewing how other landscapes transitioned over time can allow planners and managers to see where they need to move towards in the future to get to their ideal landscape.

The research expands upon the work of Solecki et al. (1999), Light and Dineen (1994), and McCally (1999) adding to the existing body of knowledge of the bridging of LUCC and historical narratives as a way to assess detailed spatial and temporal change over time. This detailed spatial and temporal change allows research to be done accurately at the unit level instead of at a regional one. The study improves the understanding of human intervention in the environment because it replaces generic forces, found at a regional scale, with the primary institutional actor’s forces, found at the local scale, whose choices and pressures create the dynamic of the environment overlooked in many LUCC studies. Developed land does not change by itself over time; it is the interaction of the people with the land that changes it. Like development, policy does not act on a place without a reaction to changing. The landscape and people policy is connected will affect the overall change. If the proper degree of understanding between land use change people and policy is achieved, then these ideas and the process of change can be understood, which can ultimately be projected for future understating. The coastal restructuring model allows for this process of landscape evolution to be seen as well as predicted based on observing current and future trends ultimately charting the course for the future based on knowledge of place.

5.8 ***Epilogue***

Hurricane Sandy hit Long Beach on October 30, 2012 creating mass destruction in its path. The Boardwalk and jetties put in place along the beach were destroyed along with thousands of homes having large amounts of damage or even being destroyed. In the wake of this disaster the City of Long Beach is left with new decisions as to how to rebuild as well as how to preserve the legacies of the past. While it is for now a year-round residence for many, only time will tell if it will remain so after the rebuilding and restructuring of the community occurs.

Table 5-1: Descriptive Characteristics (2000 Census calculations)

Category	Long Beach, NY	Currituck Banks, NC	Average Atlantic Barrier Beach (n=129)
Area (ha)	1,128.36	1,928.78	1,676.27
Change To Developed Land (1992-2001) (ha)	0	5.49	2.33
Population	43,556	134	7,884
Population Density	38.60	0.07	4.70
Housing Units	19885.00	277.00	6327.80
Housing Density (Home/ha)	17.62	0.14	3.77
Seasonal Housing Percent	5.6%	76.8%	31.8%
Development Density (2001 Land Cover)	0.91	0.46	0.52
Population Accessibility (Population/Distance)	481.97	15.96	36.12
Median Income	$68,219.16	$60,893.00	$47,771.62
Median Housing Value	$302,234.88	$274,000.00	$234,217.98
Over 65 percent	0.17	0.16	0.21
Under 18 percent	0.19	0.14	0.11
Road Density (km/ha)	4.39	0	2.63

Data taken from Chapter 4

Figure 5-1: Coastal Restructuring Model (Adopted from Holmes 2008)

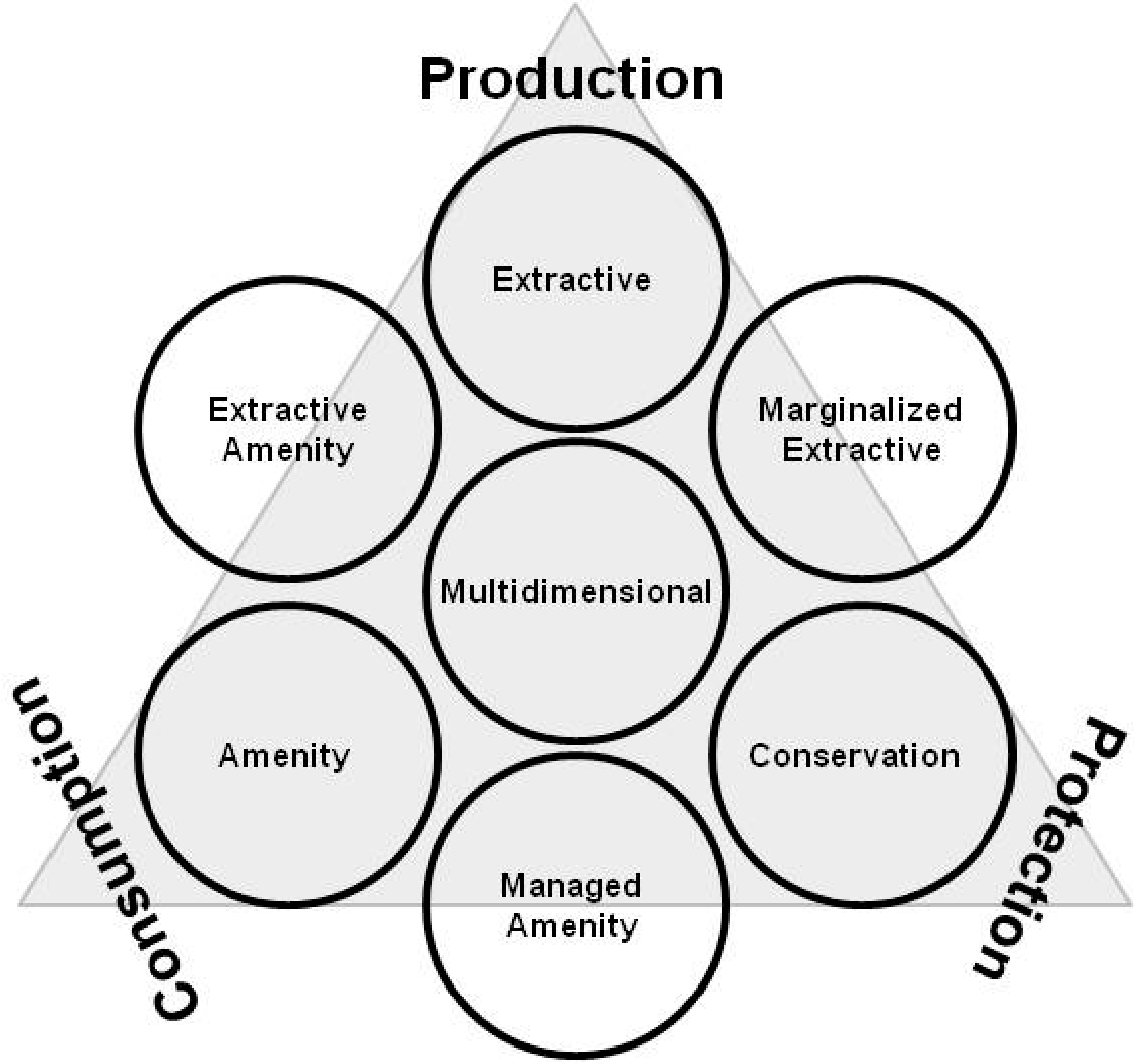


Figure 5-2: Conceptual Framework of Societal LUCC (Adapted from Solecki et al. 1999)

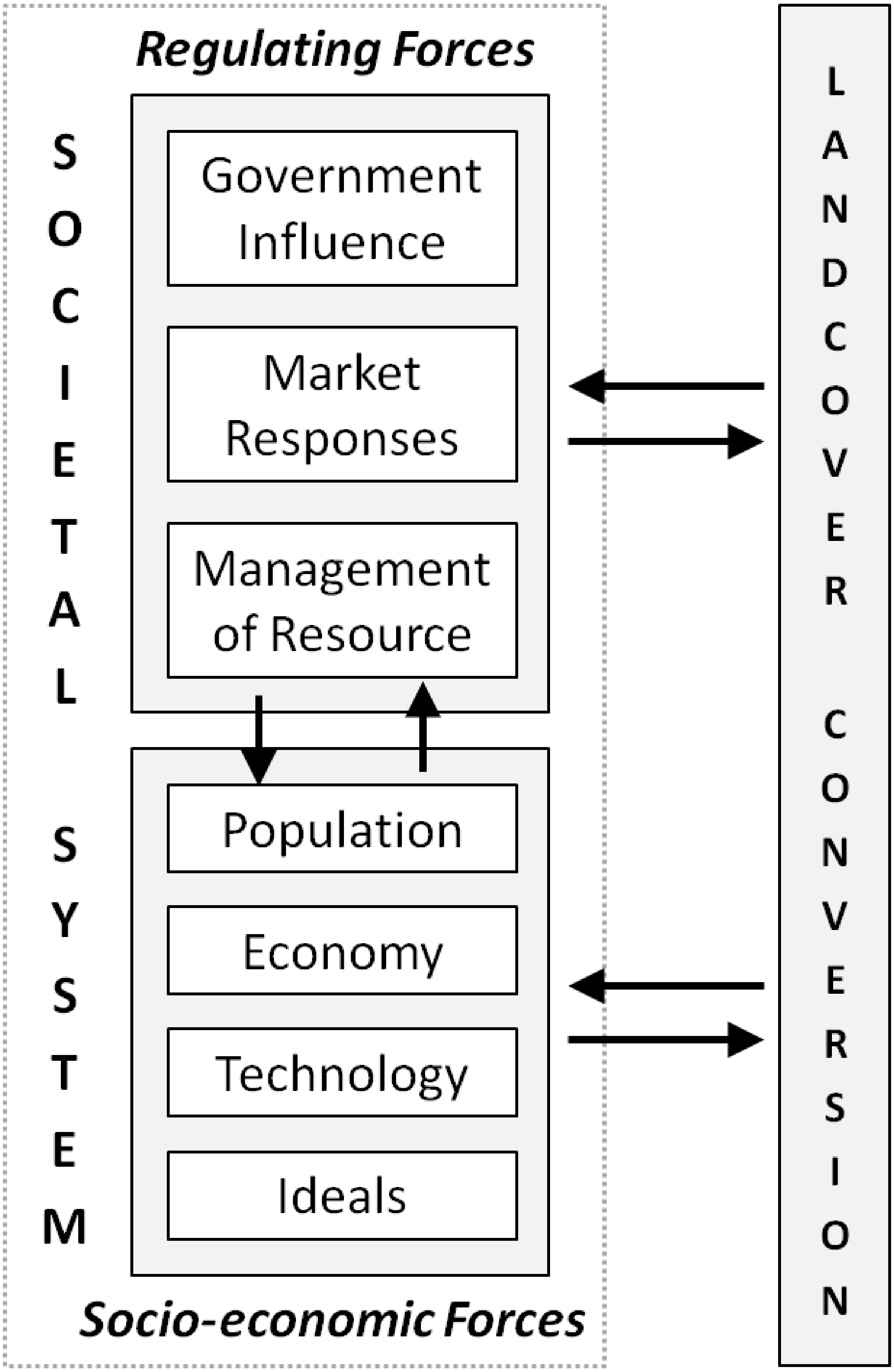


Figure 5-3: Study Area of Long Beach, NY and Currituck Banks, NC

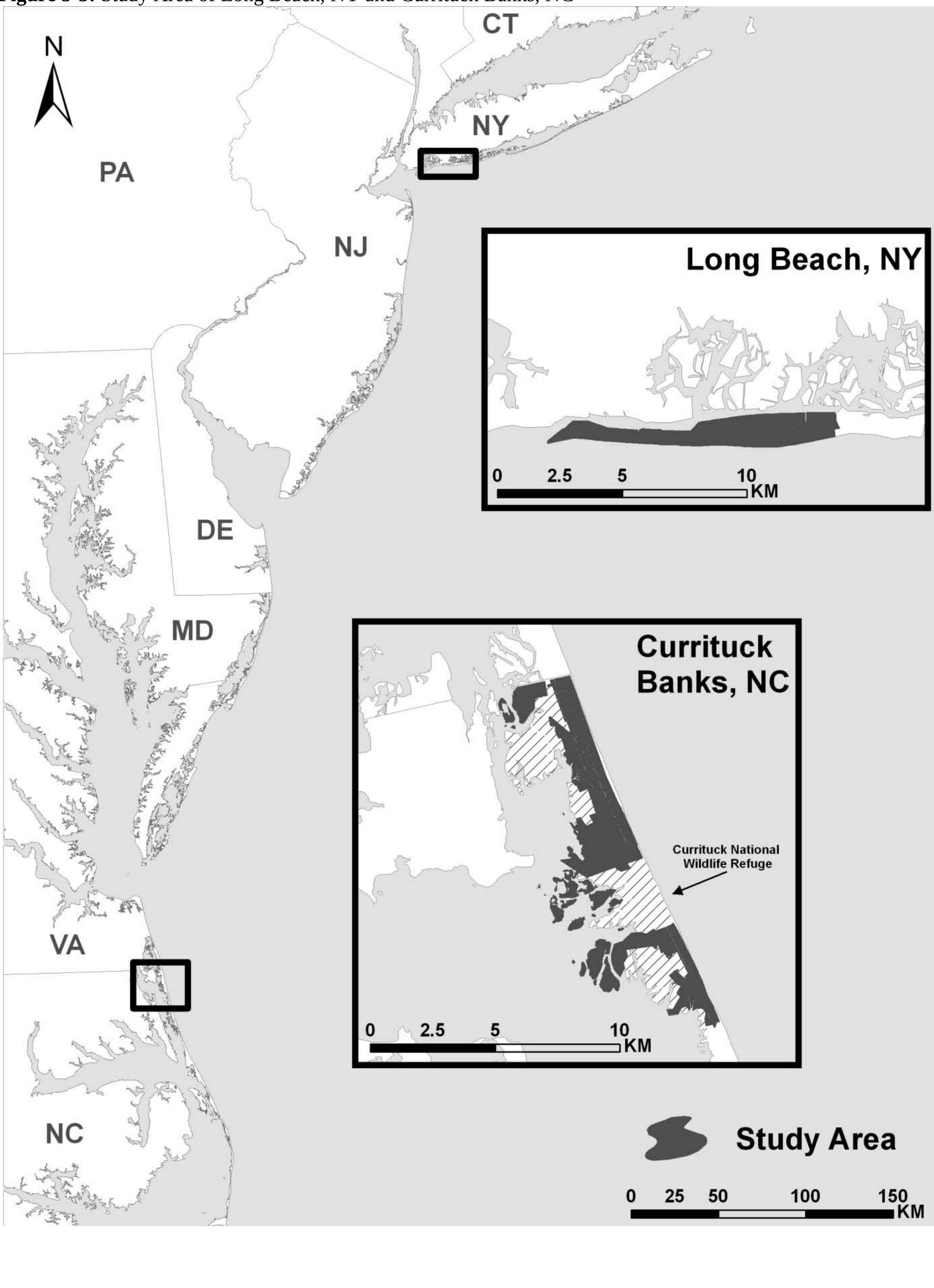


Figure 5-4: Long Beach Development Stage Parcel Development

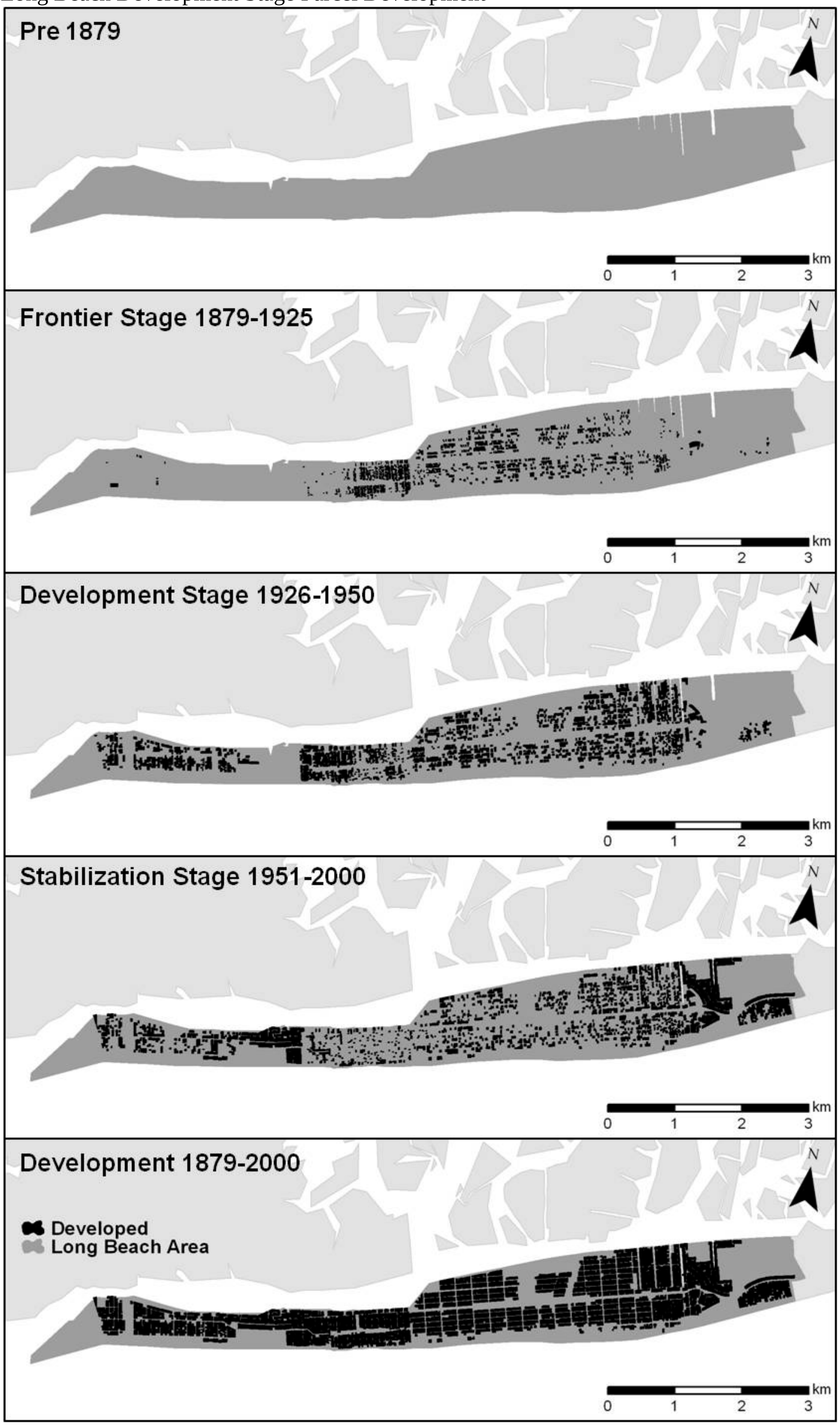


Figure 5-5: Postcard of Long Beach Hotel 1900s

Figure 5-6: Postcard of Long Beach Boardwalk 1920s

Figure 5-7: Postcard of Hotel Nassau in 1920s

Figure 5-8: Postcard of the Million Dollar Bridge in the mid 1920s

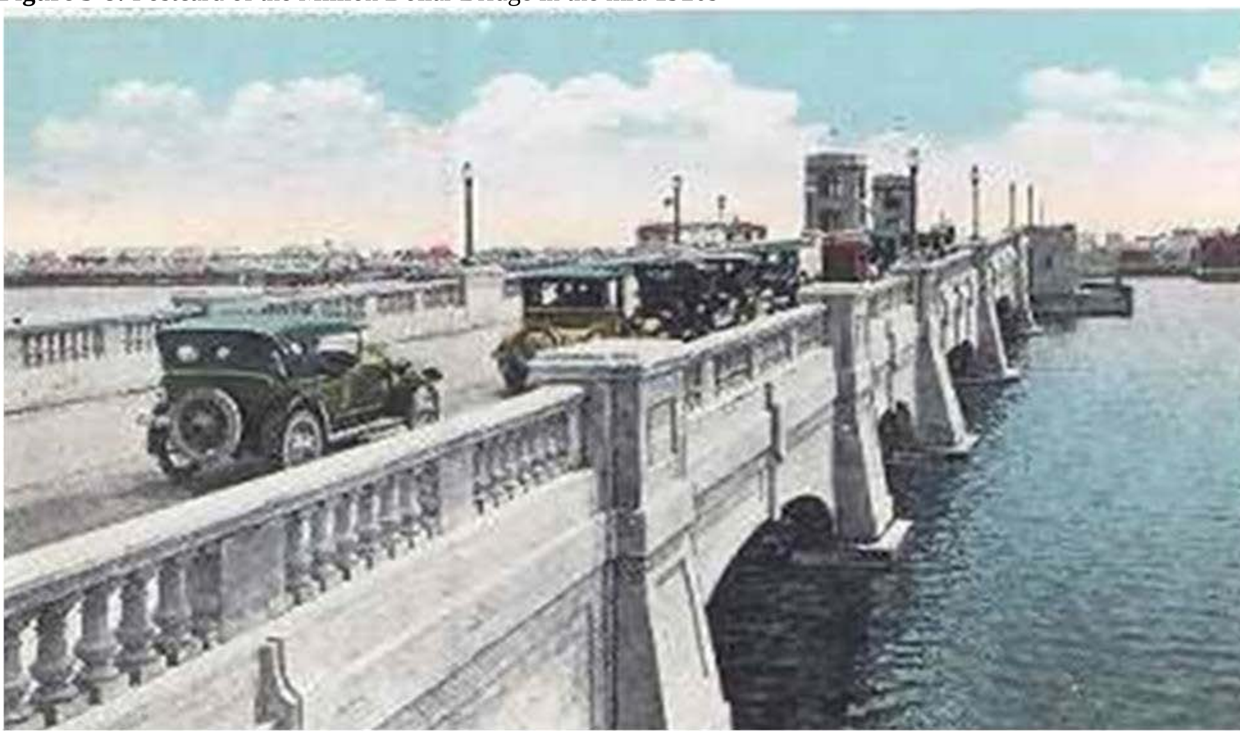


Figure 5-9: Currituck Banks Development Stage Parcel Development

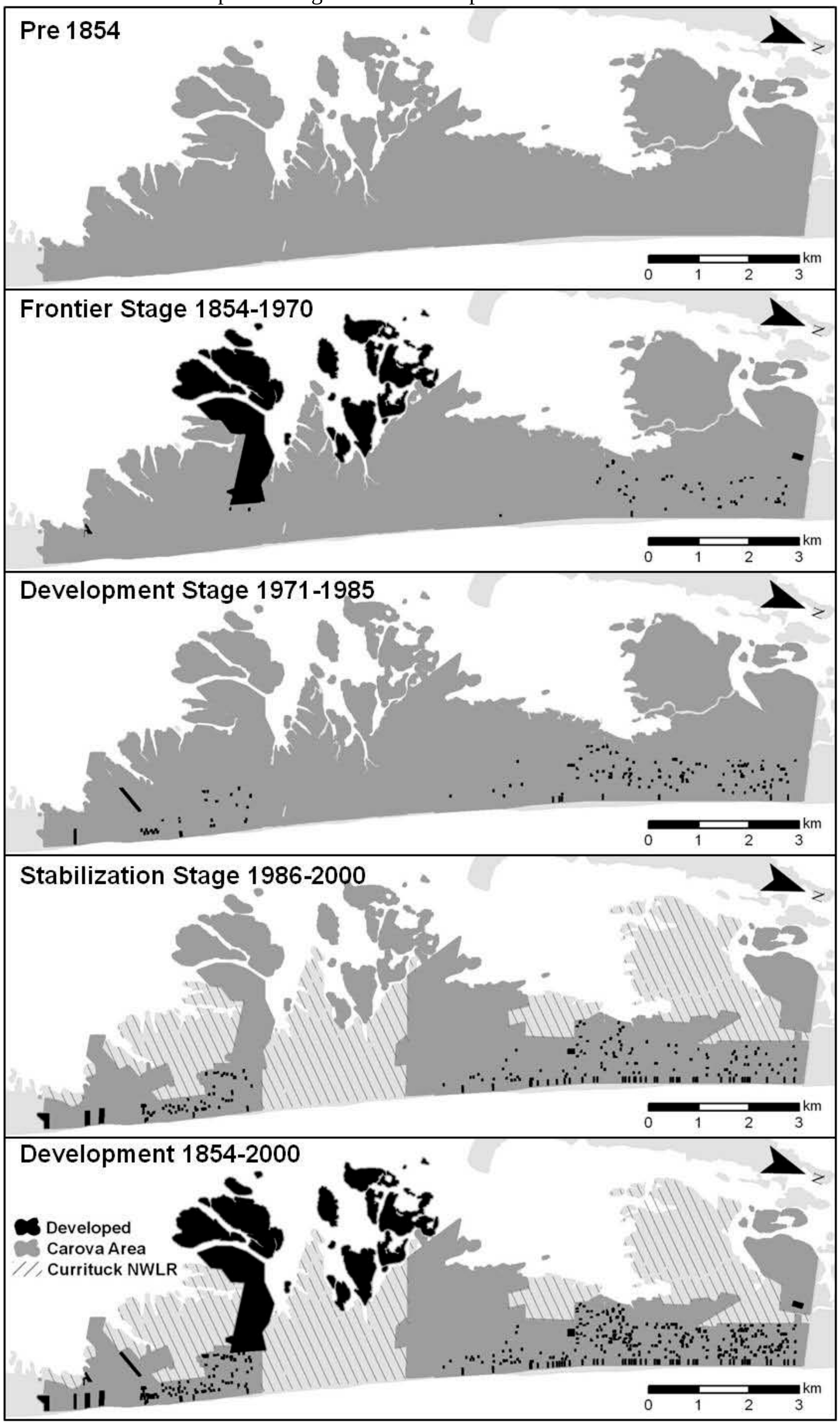


Figure 5-10: Image of Hunters after a Successful Hunting Trip

Photo courtesy of the Outer Banks Historical Society

Figure 5-11: Postcard of the Whalehead club in 1920s

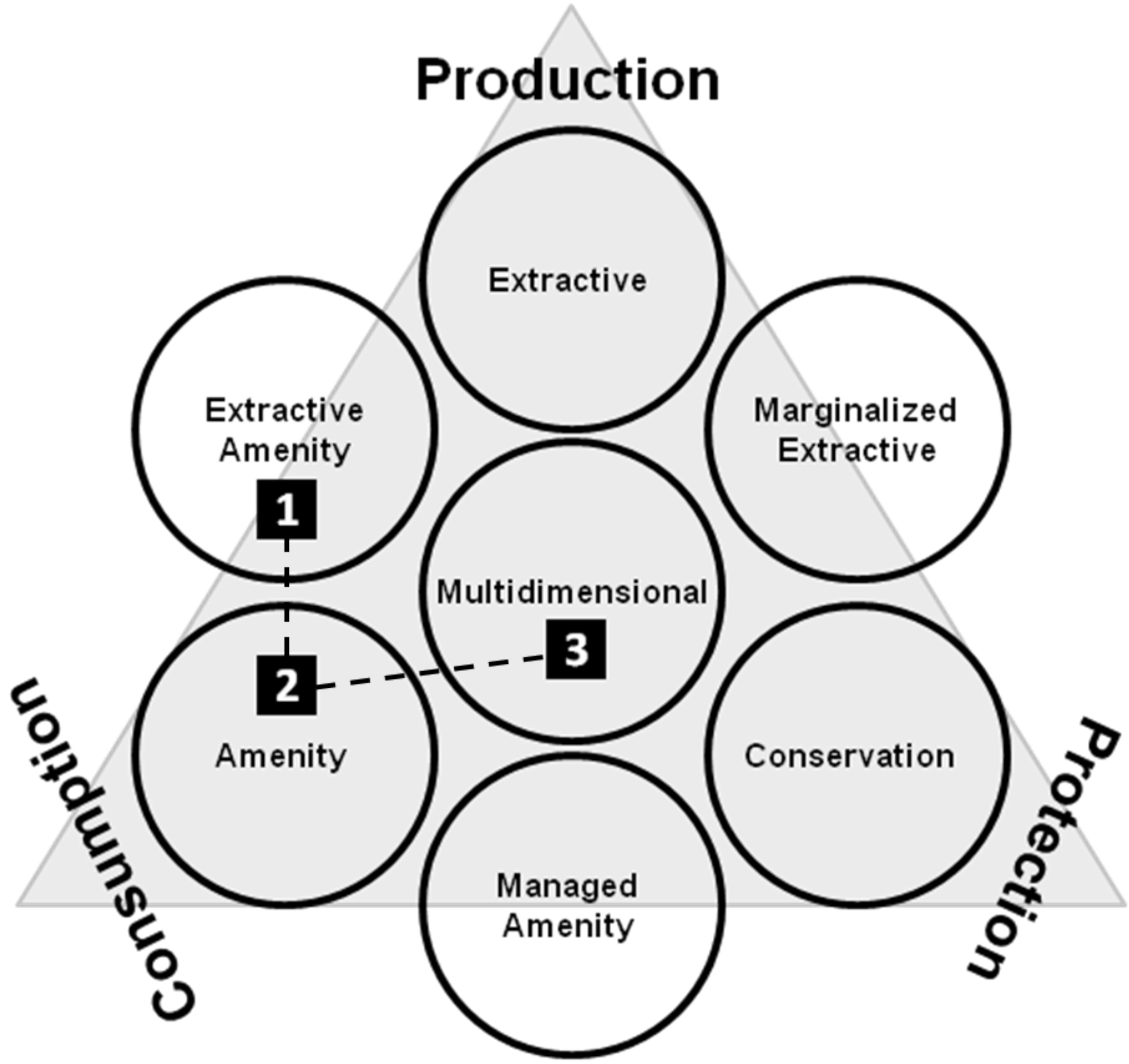
Figure 5-12: Early image of Wright Memorial Bridge

Photo courtesy of the Outer Banks Historical Society

Figure 5-13: Early Beach Driving on the Outer Banks

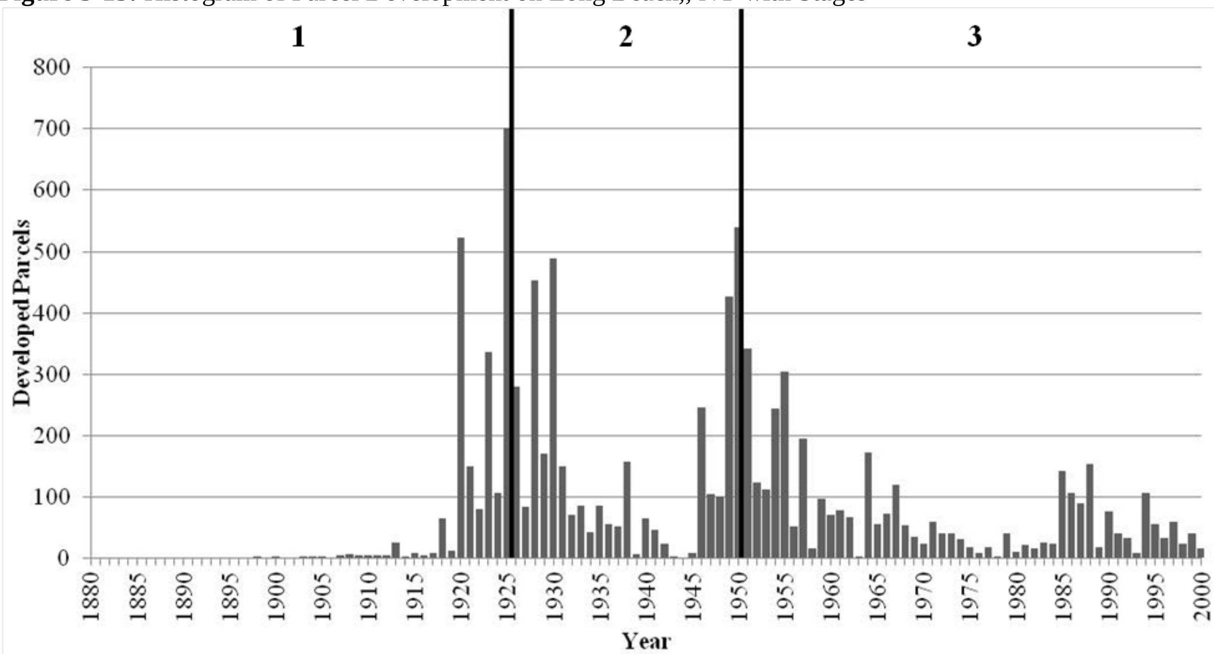
Photo courtesy of the Outer Banks Historical Society

Figure 5-14: Long Beach, NY Coastal Restructuring Path



Stages of Development
1-Frontier Stage 1879-1925
2-Development Stage 1926-1950
3-Post Development Stage 1951-2000

Figure 5-15: Histogram of Parcel Development on Long Beach,, NY with Stages



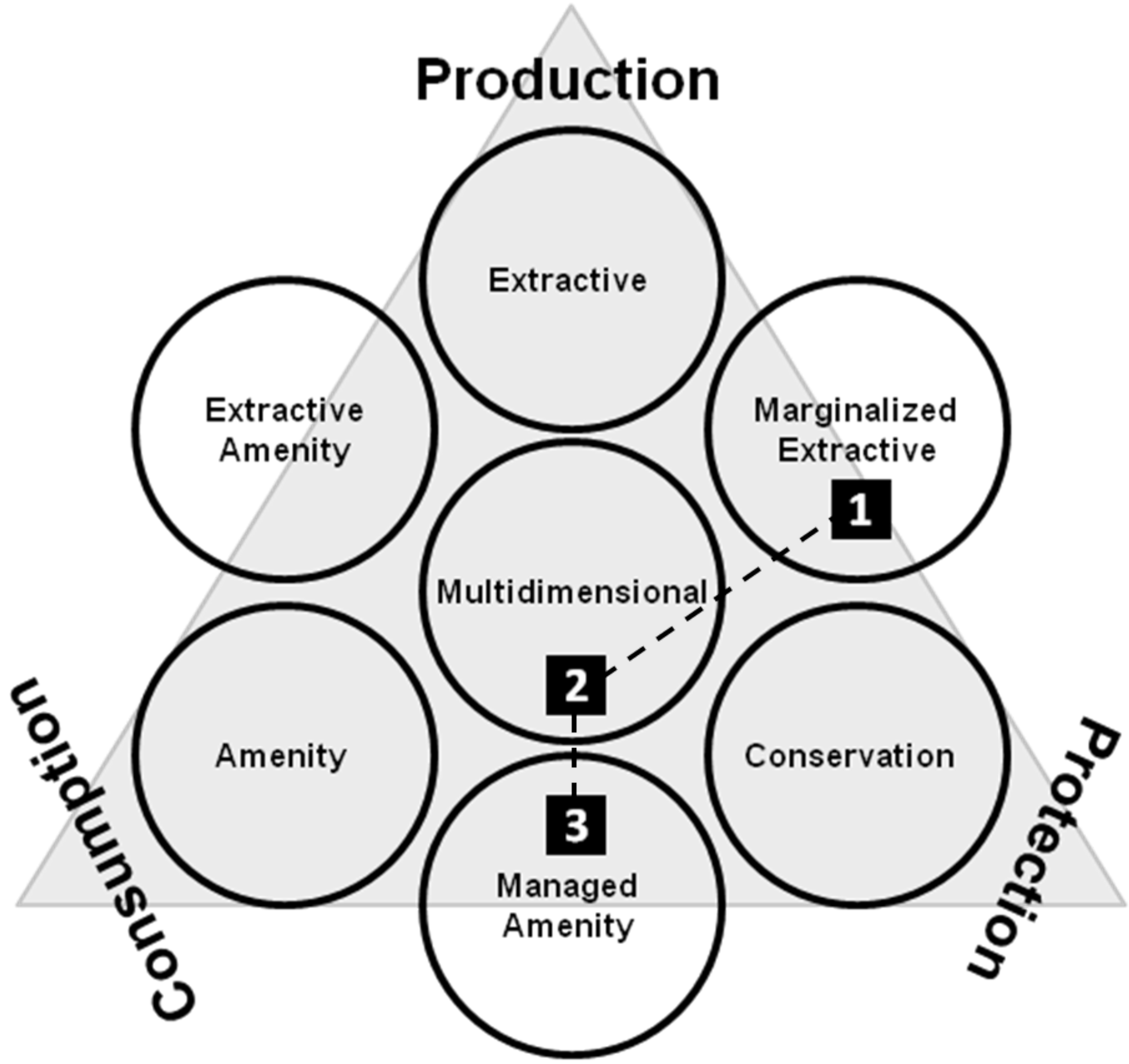
Stages of Development

1-Frontier Stage 1879-1925

2-Development Stage 1926-1950

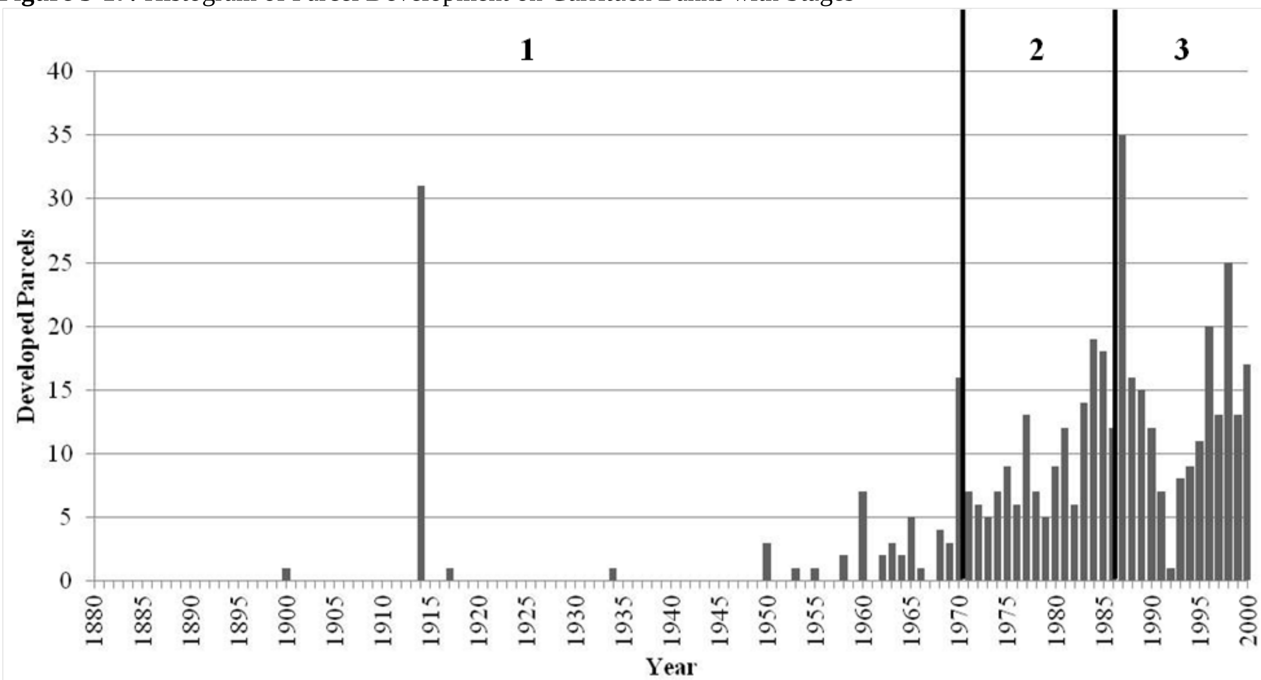
3-Post Development Stage 1951-2000

Figure 5-16: Currituck Banks, NC Coastal Restructuring Path



Stages of Development
1-Frontier Stage 1854-1970
2-Development Stage 1971-1985
3-Post Development Stage 1986-2000

Figure 5-17: Histogram of Parcel Development on Currituck Banks with Stages



Stages of Development
1-Frontier Stage 1854-1970
2-Development Stage 1971-1985
3-Post Development Stage 1986-2000

Chapter 6: Conclusion

Barrier beaches are ever evolving and moving narrow strips of land pushed back by nature and held in place by man becoming over time popular destinations to live and play. The convergence of people and place have transitioned and altered many of these places from what they once were to some form of developed coastline. Whether the development is representative of low density beach cottages or a completely urban coastline there will be an ongoing need to research the trends, influences, and histories that these places have. Understanding of the barrier beach environments is complex and multifaceted, yet many similar transitions and actions have occurred across different landscape gradients, scopes, and scales. The ability to adapt similar research practices to the coastal region, especially barrier beach environment, helps to enhance the understanding of coastal land cover change (CLCC).

The prior three analytical chapters have created a new understanding of the ways in which these barrier beaches can be identified, understood, and studied. These research methods are not the only a means to look at this region, but a starting point to continue to build upon and to create better methods of analysis to further our understanding of these dynamic places. While the methods have been adapted from research on different landscapes, they reflect a truly coastal focus and understanding. Barrier beach typologies provides a synthesized understanding of a diverse composition of barrier beach communities involving social, spatial, natural environmental, and policy dimensions. The quantitative exploration of the factors that influence CLCC via regression modeling identifies the drivers that impact coastal developed change. The coastal restructuring model allows for more nuance and place-based interpretation of the trajectories transition of coastal land cover change that strictly quantitative approaches are not able to disentangle.

6.1 ***Barrier Beach Typology***

The ever changing makeup of barrier beach communities reflects the convergence of human interaction along the coast. The linkages between demographic characteristics and land cover change are reflective of the shifting trends and patterns occurring on barrier beaches. Rooted in the idea of coastal getaways that is generated by society romanticized notion of the coastal region especially barrier beach communities. For the observed period (1990-2000) this shifting trend of undeveloped barrier beaches evolving into amenity driven tourist destinations is reflective of occurrences occur in other regions such as the New West region in the U.S. which has experience similar change albeit in a different environmental context. While these amenity driven destinations appear in this research there is also the identification of the remnants of existing coastal communities that are not experience transitions to amenity oriented destinations. This exemplifies the shifting of community over time from new to old or what has been identified as the Old Atlantic and New Atlantic. The shifting of ideology of what is new and what is old is representative of shifting paradigms of land use and sense of place along the coast.

The findings from this research reveal that there exists over the observed period a differentiation of barrier beach place types. It reveals that based on the variables explored that there is a difference between units. These differences change our understandings regarding barrier beaches communities and their homogeneity or heterogeneity in terms of socio-economic, environmental, and policy dimensions. The identified New and Old Atlantic place types are broad identifier names placed upon the two major barrier beach classifications within which sub-categories are also identified via the typological classification methodology. These place types are indicative of varying shifts for these coupled natural human systems occurring over the observed time period. If the observed period were elongated back into history it is hypothesized that one would envision many of these New Atlantic units as undeveloped and many of the old

Atlantic units being classified as New. The research starts the discourse into creating an understanding of the emerging trends with the time period. It is interesting to note that many of the same trends occurring at larger scales in the New West are happening at smaller scales along the Atlantic Coast. While these trends in land cover change to developed are occurring it leaves the question of how and what drives these changes on barrier beaches.

6.2 *Drivers of Barrier Beach CLUCC*

Understanding the influences of how barrier beaches developed land cover changes over time has challenged researchers due to the complex nature and multiple actors in the region. Approaches to understand the physical changes along the coast have been done by various researchers, but little has investigated the drivers of conversion to developed land use status explicitly for the narrow stretch of multiple places comprising the U.S. Atlantic barrier beach. Understanding people, nature and how the existing environment interacts, aids in explaining the process of conversion of barrier beach land cover to developed land use status. It is also noted that while each barrier beach is influenced individually by its surrounding forces there are a general set of forces that can explain change from undeveloped to developed land cover. While a holistic approach is necessary to account for all factors changing barrier beach land cover to developed it cannot be easily observed. It is in this understanding that drivers reflective of existing research that aids in forming a coastal understanding of actors of change. It is in this exploitation of the different drivers one would expect that socioeconomic drivers would play an important role in driving developed land cover change. This in fact was observed as false while many anthropogenic and natural drivers played a larger role in explaining change to developed land cover on barrier beaches. This reveals that at the regional scale, social indicators of change are not important factors in explaining change to developed land cover. This can be due in part to the cultural and political differences that exist across the region or for some factors unknown.

This research evaluates selected drivers from research rooted in land cover change science as well as accepted theories about coastal research. The findings show that there is a strong connection between the selected drivers and change to developed land cover on these barrier beaches with an overall explanation of change from the full model being sixty seven percent. The largest contributor to this being total land area or overall size of the unit. This reveals that above all factors the larger the land area even if it is developed or not will have the largest influence on development change. This shows that there is a strong explanation from the selected drivers that exist when land changes to developed on barrier beaches. When working with the different individual regression models, both natural and spatial models provided a strong explanation of change to developed land cover. When looking at the spatial model, the roles of seasonal housing and spatial accessibility to population are the significant factors that explain change to developed land cover. The observed factors represented in this model suggest that conversion to developed land cover is driven to a large degree driven by tourist activities. The model incorporating only natural environmental variables reveals relative magnitude of areas in flood zones, erosion rate, and presence of wetlands to be significant. High levels of flood zone area and high erosion rate have positive significant influences on conversion to developed land use leading one to believe that development in coastal areas is being pushed into high risk regions. Wetlands represent a negative significance where the more wetlands existing in an area the less change to developed status exists. Interestingly, the social (Adjusted R-Square of 44.5%) and policy (Adjusted R-Square 1.7%) models , compared to other models, showed little overall influence on developed land cover change and had no statistically significant variables other than the control variable representing size of the beach places used as the unit of analysis. These results could be an issue of both scale and scope when observing the drivers that act upon barrier beaches. Scale could present a problem with this due in part to the fact that socioeconomic data is not exact based on the boundaries created by the research with some over accounting and undercounting of variables and there change over time. Scope could be factor that presents a problem with the research is present in the extent to which policy is analyzed within the research. Due to lack of method to provide better policy information across different levels of government as well as across states federal policy was the only examined variable for the research.

6.3 ***Coastal Restructuring Model for CLCC***

History can provide us with an abundance of information about the past, but also has the propensity to provide glimpses into the future. The coastal restructuring model provides a theoretical framework tool for coastal planners and managers that allows for the transitional history of a barrier beach place to be interpreted in a way that accounts for more nuance place-based understandings of driving forces of development change. The model goes beyond the available scale and period of observation creating a new method to interpret physical land cover change. The model attempts to learn more about past land cover change through the use of historical documentation. Historical documentation ranges from narrative interpretations of the landscape to physical parcel documentation. Through the combination of historical documentation and existing quantitative data, one can apply the theoretical model of coastal restructuring within a coastal land cover change (CLCC) framework to create an understanding of how and why the coastal landscape has developed. The results from the coastal restructuring model show that there is a deep connection between people, place, and time and how they interact to impact development trajectories. It is through the motivation and intentions of the people on a location that create observed changes to the landscape. Likewise, it is the time in which these events occur that are reflective of changing societal demands. It is in demands that the change, evolution, and direction of development in a place occur.

Applying this model to specific places as was done in this research for Long Beach and Currituck Banks provides a way to decipher the trajectories of land cover change for a wider set barrier beach units representative of different beach community types. While the units selected for analysis here represented very different barrier beach characteristics, they embodied the key variation that exists along the Atlantic coast identified broadly as the New Atlantic and the Old Atlantic. The path of Long Beach exemplified a barrier beach landscape that changed from a vacation getaway reminiscent of Atlantic City, NJ to a permanent year round city in the matter of eighty years. Its landscape evolved before heightened awareness of the natural resources, especially the value of barrier beaches. Along with a strong backing from developers, development of the barrier beach moved along at a feverish pace averaging one hundred units a year until the 1970s. After 1970 much of the development on Long Beach was halted due in major part to the availability of land not policy.

The development on Currituck Banks was originally started when hunters came to the banks. Eventually the area shifted to suburban development for Virginia Beach, but it did not start until 1960s. Due in part to the time that development occurred policies were implemented in the 1970s to curve development the sandy suburb of Virginia Beach was never created. Even with government regulations people still seek to build and develop on the barrier beach. While development is not rapid it still is occurring at a faster pace than before regulation existed. This could be caused by a number of things the two of them being development pressures from the south in Corolla where development is nearly highly built out as well as people's willingness to develop. Either way, in both case studies people place and time plays roles in development, but it is really people that determine how much, how fast, and where development will occur.

6.4 ***Final Remarks***

This research has created an understanding and characterization of the existing patterns and drivers of land use/cover change on barrier beaches. The knowledge gained from this research is focuses on aiding researches, planners, and policy makers in understanding the roles of development pressures, spatial accessibility, and policy on barrier beaches. The key to this is barrier beach component because many times scale and scope to which policies and plans are implemented overlook these narrow bars of sand. While pressures from both human and natural causes act upon these barrier beaches new information is created and new understandings of how these areas evolve and change over time are needed. With an increased understanding there can be more focus created on policy and plans that take into account these barrier beaches.

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