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# Behavioral Science of Natural Infrastructure Investments


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**MAS-MBC Capstone**

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**Abstract**

Coastal floods are among the costliest natural disasters in the U.S, comprising nearly one-third of all billion-dollar disasters in the past decade, according to the National Climatic Data Center. Hazard mitigation policy at the federal, state and local level has historically focused investment in construction of hardened, or gray, infrastructure for shoreline protection. New legislation, such as Maryland's 2008 Living Shoreline Protection Act, shows a shift towards investment in natural infrastructure (NI), which provides the same types of services as man-made infrastructure while also providing additional benefits to people and ecosystems. Applying tools from behavioral economics, cognitive science, and psychology, this research aims to understand how people make decisions to invest in natural infrastructure for coastal risk reduction and resilience. We analyzed local and state policies of three coastal NI projects to understand the general decision context. Using established methods from social science and marketing research, we conducted in-depth interviews with decision makers, stakeholders, and experts involved with NI cases to reach a grounded theory about the influence of behavioral and institutional factors (e.g. heuristics, peer-influence, diffusion of innovation) in infrastructure investment decisions. We found that decision makers who are innovators that act as local champions are influenced by social networks to invest in NI.

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## INTRODUCTION

Coastal flood hazards are among the costliest natural disasters in the U.S. (Gall 2011). The damage from Hurricane Sandy alone is estimated to top $65 billion, comprising nearly half of the global losses from natural disasters in 2012 (NCDC 2014). An increasing coastal population is driving coastal development, with coastal shoreline counties experiencing three-times the population increase as the rest of the United States between 1970-2010 (Crossett and Ache 2013). This trend is expected to continue, even as exposure to damage from coastal flooding and storms are projected to increase due to rising sea levels (Titus 2009; Vermeer and Rahmstorf 2009; Strauss 2012). Since the first calls for action to protect the eroding shorelines of New York and New Jersey in the late 19th century, civil engineering projects have been the federal government's primary approach to shoreline protection (Hiller 2003). From the 1950's to 2002, Congress authorized the Army Corp of Engineers to construct 71 projects to protect 284 miles of what it had identified as the nation's critically eroding shoreline (Hiller 2003). These projects include beach restoration, structural projects such as levees and seawalls, and emergency construction in response to damages caused by hurricanes and storms (Hiller 2003). The Army Corps of Engineers promotes Nonstructural Flood Proofing measures, including elevation, relocation and acquisition, flood proofing and preparedness for "reducing the consequences of flooding," instead of protecting against flooding (USACE NFPC). This approach has resulted in a patchwork of aging shoreline infrastructure covering 9% of the nation's coastline (NOAA 2014). In addition to the costs of repairing and maintaining these coastal defenses, structures such as bulkheads, riprap revetments, seawalls, jetties and groins have been shown to have an adverse impact on the ecology, coastal processes and aesthetics of shoreline ecosystems (Griggs 2010).

At the same time, there is a growing body of research on the hazard protection provided by natural coastal habitats such as dunes, wetlands, oyster reefs, coral reefs, mangroves (Arkema et al. 2013; Costanza 2008). These habitats contribute to shoreline growth and stabilization and they can mitigate erosion and flood by buffering wave energy and absorbing and storing water from high tides and storm surges (Costanza 2008; Das and Vincent 2009; Gedan et al. 2011; Shepard et al. 2011; Barbier et al. 2013). Building on this research, conservation groups have been using scientific and economic evidence to build the case for incorporating habitat restoration and protection into the coastal resilience plans of communities, governments and businesses (Downing 2013; Nature.org 2013). For example, following Super Storm Sandy, Governor Cuomo's New York 2100 Commission made-up of experts from academia, government, industry, and the nonprofit sector recommended the use of habitat restoration and protection, or "natural infrastructure," for coastal resilience (Rodin 2013). The US Army Corp of engineers is also conducting a comprehensive post-Sandy study, which includes recommendations related to natural infrastructure. Here, we define natural infrastructure (NI) as natural areas that provide the same types of services that man-made infrastructure provides (e.g., mangroves and levees can both mitigate storm surges). Differences in the ecology, geology, oceanography, and economic conditions along the Atlantic, Gulf and Pacific coasts of the United States may influence what type of natural infrastructure

may be suitable for a given location. However, what all of these locations have in common is the human element: decision makers and stakeholders at the local and state level who choose whether to invest in either NI or conventional engineered infrastructure. Yet, to date the focus has largely been on the science and economics of NI and the role of individual behaviors and institutions in decision-making for NI has been largely ignored. This paper aims to fill this gap by examining how NI investment decisions are made.

Since its roots in environmental psychology in the 1960s, there have been hundreds of studies looking at human attitudes and behavior towards the environment. The field has produced multiple hypotheses and analytical frameworks to explain the connection, or sometimes the disconnect, between awareness and knowledge about the environment and conservation behavior (Vining and Ebreo 2002; Kollmuss and Agyeman 2002). Early research theorized that attitude formation and behavior change was the result of a linear relationship between information, attitude, and action (Scarlett et al. 2013; Cottrell 2003). That view has since evolved to recognize the complexity of interactions between internal factors, such as beliefs and values, and contextual factors, such as societal expectations and institutional factors that influence both conservation attitudes and behavior (Cottrell 2003; Stern 2000). We will not attempt to summarize the breadth of this research here, but rather highlight key findings and gaps in our understanding about how these factors combine to influence conservation behavior.

Research from the field of social psychology argues that perceptions and opinions are formed through two types of processes: cognitive, which entails analysis based on thought and experience, and affect, which involves emotional associations (Dolan et al. 2010). While the cognitive mind is capable of solving problems and evaluating arguments based on deep analysis on a limited basis, the majority of human decisions are made in the automatic mind (Cialdini 2009; Smith DeCoster 2000). These automatic decisions are shaped by heuristics, or mental shortcuts, that link to subconscious responses about what one 'knows' to be true (Smith and DeCoster 2000; Aronson 2007). Much scientific research is predicated on the "information deficit" model, which posits that the supply of objective information will result in changes in behavior (Sturgis and Allum 2004). This approach focuses on cognitive formation of perceptions and opinions. While there are links between education levels and knowledge in public attitudes toward science, the interaction of that knowledge and action is less concrete (Sturgis and Allum 2004). Studies from the field of behavioral economics show that environmental behavior can be influenced by working around the cognitive processes and tapping directly into automatic behavior responses (Dolan 2010; Cialdini 2009). Now, there are increasing calls for more research into how the behavioral sciences—including psychology, cognitive science, sociology, and behavioral economics-- can be used to understand and shape conservation decisions (Cowling 2014). There have been applications to environmental behavior related to purchasing environmental friendly goods like light bulbs, fuel-efficient cars, and solar panels. For example, Bollinger and Gillingham (2010) found that the adoption of solar panels was influenced by whether someone's neighbors also had adopted solar panels rather than just the financial or environmental benefits of solar panels. In contrast, there has been little research on conservation decisions that involve public resources and decision-making.

Conservation decisions often involve a mix of public and privately-owned resources. Decisions that take place at the individual level are influenced by both community and institutional

factors, such as governmental policies. In the case of coastal protection decisions, an individual property owner can choose to invest in NI on their waterfront private property, which might indirectly affect public resources such as fisheries. Or, a property owner might own land which stands at the entrance of a public harbor, which directly affects the resilience of the harbor to storms. Decisions to protect the harbor then may need to involve both the private property owner and the public. These decisions may be more highly influenced by the perceptions and automatic response processes of individuals than cognitive analysis of scientific and economic analysis information. The mental shortcuts, or heuristics, that an individual employs during the decision-making process draw on personal experiences, memories and attitudes. Individuals have been shown to use rely on these shortcuts to make decisions about unknown or unfamiliar subjects (Aronson 2007, 135-141). For instance, how much weight we give to information has been shown to be determined by perceptions of authority and likability of the 'messenger' (Aronson 2007 135-141; Dolan 2010). A study of HIV-prevention techniques showed that people were more likely to listen to messages from people who were similar to them (Durantini et al. 2012). This research suggests that heuristics may be especially important for natural infrastructure, as compared to traditional engineered infrastructure, since it is a relatively new technology with higher uncertainty.

Individuals are also part of, and influenced by, a social group or community. This can be seen in the effect of perceived social norms on behavior and the spread of information through social networks (Aronson 2007 26-27). When people are uncertain about a new technology or are faced with ambiguity about how to act in a situation, they look to others for guidance on how to fit in (Cialdini 2007). There are two types of social norms: injunctive norms refer to perceptions of what types of behavior are approved, and descriptive norms refer to perceptions of what others are actually doing (Cialdini 2007). Social norms have proven to be a powerful force in motivating behavior, as illustrated by the effectiveness of energy conservation company OPower's Home Energy Reports. Every month, customers are reminded of how their energy usage compared with their neighbors. Just making people aware of their neighbors' activity has resulting in a reduction of more than 4 billion kilowatts of energy as of May, 2014 which translates to an abatement of more than 6 billion pounds of $CO_2$ emissions, according to OPower's website (Redmon 2012).

The term 'contagion effect' has been applied to the spread of behavior through social networks and, on a wider scale, the media (Aronson 2007, 64-66). These same social networks are key to the communication of knowledge about new technology and ideas, as described in Diffusion of Innovations theory (Rogers 1983). The new technology, idea or practice flows from a source through five categories of adopters: innovators, early adopters, early majority, late majority, and laggards (Rogers 1983, 248-263). For example, in the days leading up to and immediately following Hurricane Sandy in the Northeast in 2011, there was increased media coverage of nature-based approaches to coastal resilience (Greenberg 2012; Navarro 2012; Feuer 2012; De Monchaux 2013). The town of Bradley Beach, New Jersey was widely reported to have suffered less damage due to restored dunes along the beaches (Wanko 2012). The images of this town had directly influenced managers in the city of Fort Lauderdale, Florida to incorporate dune restoration into its repairs of highway A1A, which had been damaged by tropical storms associated with Sandy and subsequent storms (Susanne M. Torriente pers. comm.).

In addition to individual and social factors, conservation decisions are influenced by the institutional context surrounding them. Governmental policy, regulations and public financing all affect conservation decisions. Investment in infrastructure can stretch across landscapes, multiple stakeholders, and multiple jurisdictions. Within each level of government, there might be multiple resource agencies, each with its own interest to protect. For instance, a single coastal development project in North Carolina might require review from 14 state and federal agencies. This can present opportunities for cooperation and collaborative planning among these agencies. However this can also present barriers when there is no pre-existing institutional framework for collaboration.

We build on this research by examining three coastal natural infrastructure decisions in the US. Using qualitative analysis of transcripts from semi-structure interviews with individuals involved in the decision, we answer two questions:

1) What are the institutional and policy processes related to coastal NI and how do they fit into the process for engineered infrastructure?

2) How important are behavioral and institutional factors as compared to scientific and economic factors in influencing decisions to invest in natural infrastructure (NI) and (decisions to not invest in NI)?

We chose three coastal NI projects from across the U.S. for the analysis. We analyzed the coastal development policy of the individual states, which allowed us to 1) construct flow diagrams of the policy/permit process and compare it with that for engineered solutions, a key step for identifying barriers and facilitating processes. We used grounded theory analysis for the interviews and 2) identified multiple themes about what affected decisions beyond science and economics, which is important for designing conservation strategies, policies, communications.

**Methods**

**Study Areas**

We define the study cases and regions as the specific NI case and the county in which NI and engineered infrastructure decisions are made. To select these study cases and regions, we first compiled a list of known NI investments in the US related to coastal hazard (Appendix 1). We started by researching natural infrastructure projects using keyword searches for “green infrastructure,” “natural infrastructure,” “coastal resilience” to find self-identified projects.

We consulted the following sources:

- Climate Adaptation Knowledge Exchange Network (CAKEX)

- Georgetown Climate Center's Adaptation Clearinghouse
- NOAA's restoration mapper
- Department of the Interior Hurricane Sandy Coastal Resiliency Competitive Grant Program
- Army Corp of Engineers
- Association of State Floodplain Managers
- The Nature Conservancy's SNAP working group and North America Risk Reduction and Resilience databases

We then chose a sub-set of these cases based on three criterion

1) Did the investment meet the condition of additionality: did the project add natural areas or avoid the destruction of natural areas?

2) Was the decision making process recorded in public meetings or hearings?

3) Is there potential to conduct follow-up interviews with decision makers?

This produced a list of 15 cases, within the continental U.S. We then applied three additional criteria to this list:

4) Were the projects motivated by flood protection?

5) Was there local authority for the decision?

6) Was there background documentation available?

This narrowed the list of cases to three: Ferry Point Park living shoreline, MD, Surfer's Point managed retreat, CA, and Durant's Point living shoreline, N.C. Background. We researched the background material on each case to identify potential interviewees and further understand the scope of project in terms of funding, timeline and space, the decision-making body. We also reviewed the public meeting agendas and minutes, articles and videos in media, government agencies and NGO involvement and public outreach literature. It should be noted that while identified as Natural Infrastructure projects, all three cases use a combination of nature-based and structural elements. The living shorelines at Ferry Point in Maryland and Durant's Point in North Carolina use constructed headlands or breakwaters to slow down wave energy combined with marsh restoration. The beach at Surfer's Point, located at the mouth of the Ventura River, was restored with a cobble berm. This constructed element used similar materials to the naturally occurring cobble found on the beach to the other side of the river mouth. These three cases are summarized here and discussed in detail in this paper.

*Ferry Point Park, Queen Anne's County, MD* – Living shoreline in 41-acre park bordered by Kent Narrows, the Chester River and Eastern Bay in Queen Anne's County. Ferry Point Park established in 2008, opened to the public in June 2014. Queen Anne's County Board of Commissioners approved land acquisition in 2006 as "targeted land acquisition" with funding from Maryland Department of Natural Resources Project Open Space.

*Surfer's Point, Ventura, Ventura County, CA* **–** Managed retreat to deal with erosion: relocation of bike path and beach parking lot further inland. Project is the result of a joint agreement between City of Ventura, County Fairgrounds, California Department of Parks and Recreation, the California Coastal Commission and the Ventura Chapter of Surfrider Foundation. Ventura City Council approval of planning and design process in 2005; Phase I construction completed and opened to the public in summer of 2011.

*Durant's Point, Dare County, NC* **–**Living shoreline at Durant's Point (privately owned land located at the entrance to Hatteras Harbor in Pamlico Sound) consisting of restored marsh and 320-foot-long low-profile granite sill, completed 2011. Durant's Point project lead: North Carolina Coastal Federation with funding from NOAA's community-based restoration partnership with Restore America's Estuaries and the Carlson Family Foundation. Dare County Commissioners assumed responsibility for maintenance of wetland in January of 2011.

## Interviews

We conducted semi-structured interviews via the phone with a total of 16 people directly and indirectly involved in the infrastructure decision process (Table 1). Interviews were conducted over a period of five weeks in April and May of 2014. The interviewees included elected officials, state and county conservation employees, staff of international and local nonprofit conservation organizations, citizens, and engineers involved with the three projects. An interview guide and a summary of the research goals were provided ahead of time to the interviewees (Appendix 2). At the start of the interview, we briefly reviewed the research goals and the terminology 'natural infrastructure,' which was included in the written summary of research goals. Interviews lasted approximately one hour and were recorded (with the subjects' permission,) and then transcribed for analysis. Limited demographic data was collected for each respondent, including occupation and the length of time working on the project. The interview guide consisted of 20 open-ended questions which focused on topics including regulatory process, project proposal evaluation, perceptions of natural infrastructure options, promotion of natural infrastructure ideas, and each respondent's personal experience with natural and built infrastructure. While the guide provided direction for the interview, the specific questioning was partly determined by the respondents' answers.

## Interview Subject Selection

The interview subjects were identified through public meeting minutes, media reports and additional background research on the projects and by referral from members of the conservation community. Each interviewee was also asked for recommendations for additional interviewees. In compiling the interviews, we tried to speak to people with similar roles in each of the study sites. Table 1 shows the list of interviewees, their occupation and the case study project.

**Table 1** Interviewees for each natural infrastructure case and their names and titles.

| | |
|---|---|
| Ferry Point Park Living Shoreline, Queen Anne's County, MD | |
| Gene Ransom | Queen Anne's County Commissioner(former) |
| Albert McCullough | Engineer, Sustainable Science |
| Dan Levan | Queen Anne's County conservation specialist |
| Steve Bunker | Director of Conservation Programs, TNC |
| Bhaskaran Subramanian, Ph.D. | Program Manager Habitat Restoration and Conservation, Maryland Department of Natural Resource |
| Surfer's Point Managed Retreat, Ventura, CA | |
| Lily Verdone | Coastal Resilience Ventura, TNC |
| Paul Jenkin | Surfrider |
| Rick Raives | City of Ventura, Public Works Chief Engineer, Vice President |
| Bob Battalio | ESA \| Environmental Hydrology |
| Durant's Point Living Shoreline, Dare County, N.C. | |
| Christine Pickens | Coastal Restoration and Adaptation Specialist, TNC |
| Aaron McCall | Northeast Regional Steward, TNC |
| Erin Fleckenstein | Coastal Scientist and Regional Manager, NCCF |
| Ernie and Lynne Foster | Coastal Federation Board Member and Wife |
| Dave Klebitz | Engineer, Bissell Professional Group |
| Allen Burrus | Dare County Commissioner |

## Assumptions and Potential Biases

The majority of interview subjects were referred to us by members of the conservation community. These interviewees were all self-identified as supporters of the NI approach and so were potentially biased toward seeing benefits, we did not ask questions to specifically test for

this bias. All of the projects, with the exception of Durant's Point in North Carolina, were funded through state and federal grant money. North Carolina received additional funds through a private family foundation. None of the property owners paid directly to build the projects, which could affect perceptions of cost. Since there was only limited demographic data collected from each interview respondent, economic, education, and other factors that might affect the success of conservation projects were not measured in this study.

This study did not examine the broader research question of efficacy of NI as an alternative to structural shoreline protection. In the N.C. and MD cases, the conservation groups leading the projects asked the engineers only to consider living shoreline approaches and not conventional alternatives. In the California case, the Ventura Fairgrounds (the land owner) preferred a structural option, however their application to build a permanent protective structure was rejected by the California Coastal Commission, which stated that the original project was temporary in nature and could not be protected.

## Institutional and Policy Process Analysis

In order to understand the context of each of the decisions to invest in an NI approach, it is imperative to understand the federal, state and local regulatory and policy conditions under which the projects were implemented. Formal policies were accessed via each State's Department of the Environment, Coastal Commission and Division of Coastal Management website. In addition, each interview respondent was asked a set of questions about the process for permitting, reviewing and approval of the project. A flow chart specific to each state was created to understand how the decision to use a natural infrastructure approach either followed or diverted from the process for a conventional, or built, approach.

## Qualitative Analysis of Specific NI Decisions

A grounded theory was developed using the "constant comparison" method, in which data is deconstructed and examined for concepts and relationships through comparison and asking questions of the data (Strauss and Corbin 1990). We used qualitative analysis software NVivo 10, beta version for Mac, to code and analyze the transcripts of interviews with people directly and indirectly involved in the infrastructure decision process. Initial coding involved conceptualizing the data by applying labels to discrete segments of the transcript and then grouping the concepts into categories (Strauss and Corbin 1990; Saldana 2013). The codes and categories were further examined through secondary coding to discover relationships between the conceptual labels and categories until major themes and a core category, or central story line, emerged (Strauss and Corbin 1990).

**Results**

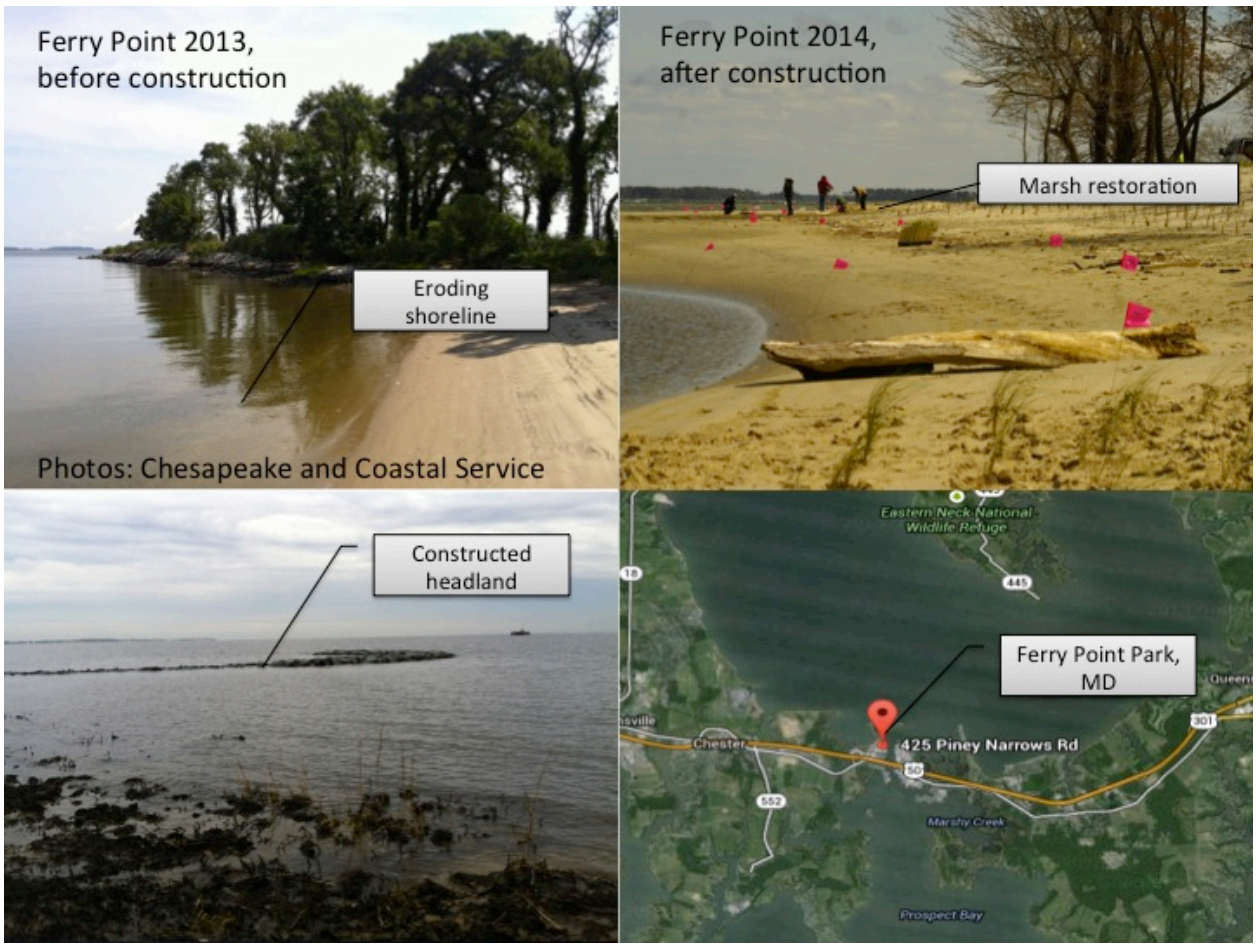
## 1. Institutional and Policy Process & Narrative of Investment Decisions

Our results show that coastal development policy had the strongest influence in Maryland and California, where state preferences and recommendations were directed at promoting the use of NI. In Maryland, the 2008 Living Shorelines Protection Act and its predecessor, the 1992 Maryland Department of the Environment's (MDE) "Shore Erosion Control Guidelines for Waterfront Property Owners," define the non-structural option as the preferred option. In addition, the Maryland Department of the Environment has determined which areas are unsuitable for a living shoreline and requires the property owner to take extra steps to apply for a waiver in order to build a protective structure outside of those areas. Similarly, in California, the Coastal Commission has defined permissible uses of structural protection for existing structures in the Coastal Act. While jurisdiction for coastal development permitting is given to the local governments through Local Coastal Programs in California, all Local Coastal Programs must conform to the Coastal Act. These policies contrast with the North Carolina Division of Coastal Management, which recommends vegetation and living shorelines as options for shoreline erosion control. However, our results show that in practice, permitting remains more streamlined for the structural option in North Carolina.

### 1.A. Ferry Point Park living shoreline, Queen Anne's County, MD

Ferry Point Park is a 41-acre peninsula located at the north end of Kent Narrows in Chesapeake Bay between the Eastern Bay and Chester River. The site had been subject to erosion at a rate of 8-10 feet per year in some areas due to exposure to about 19-miles of open water with northwest winds (Bhaskaran Subramanian pers. comm.). The living shoreline was constructed through a combination of four headland breakwaters, a low-profile sill and dune groins along approximately 2600 linear feet of shoreline. Structural components and vegetative marsh and beach plantings enhanced approximately 4000 linear feet of shoreline. The living shoreline part of the park opened to the public in June of 2014.

**Fig. 1 Map of Ferry Point Park location and photos of the living shoreline project.** Top left: eroding shoreline, bottom left: construction of headlands, top right: marsh restoration after construction, bottom right: map of Kent Narrows with Ferry Point Park labeled



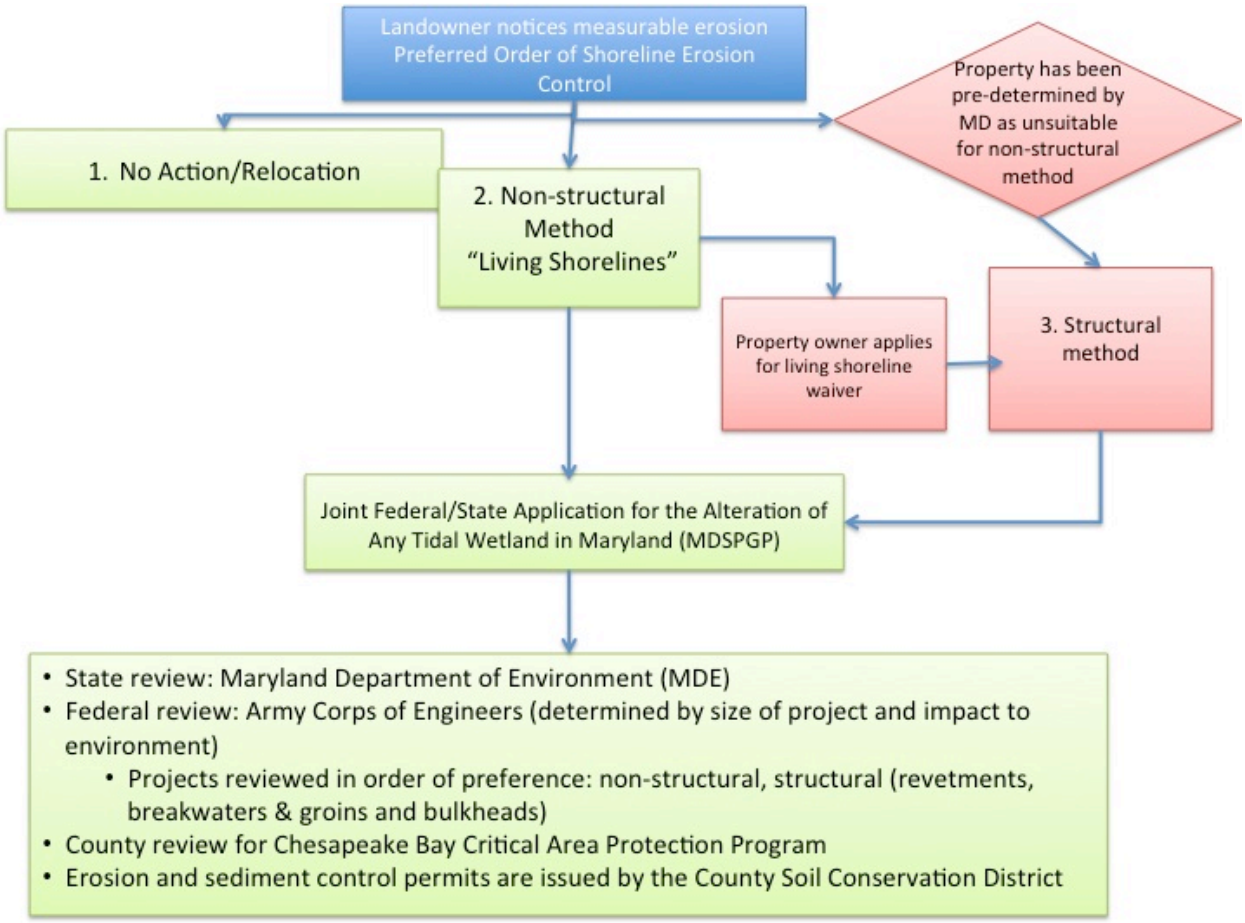

**Institutional and Policy Processes**

Maryland Department of Natural Resources' Shoreline Conservation Service, in partnership with Queen Anne's County determined that a living shoreline would be suitable to stabilize the U-shaped eroding shoreline at Ferry Point Park. The project was conceived in 2007-2008; the original application for permit was submitted at end of 2008. In 2008, Maryland Governor Martin O'Malley signed the Living Shorelines Protection Act, regulations went into effect in February 2013. This law codified what had previously been state recommendations for order of preference for shore erosion control, as documented in the 1992 Maryland Department of the Environment's (MDE) "Shore Erosion Control Guidelines for Waterfront Property Owners":

1. No Action/Relocation - Determine if erosion is severe enough to warrant installation of an erosion control measure, or can the problem be averted by moving an existing structure
2. Non-structural Method "Living Shorelines" - If stabilization is necessary, a non-structural stabilization method must be used. This includes beach nourishment, slope grading and planting and marsh establishment, with or without additional protection.
3. Structural Methods - MDE has publicly available maps that show designated areas of the shoreline that have been pre-determined to be unsuitable for non-structural stabilization. For areas that are not pre-designated for structural stabilization, applicants can apply for a

waiver by demonstrating that non-structural stabilization is not feasible. The order of preference for structural stabilization is: shoreline revetments, offshore breakwaters, groins. Federal and State permitting is administered through the Joint Federal/State Application for the Alteration of Any Tidal Wetland in Maryland (MDSPGP). Applicants must submit a description of the project, detailed vicinity map and plans including calculations of impacts to wetlands along with a processing fee to the Maryland Department of Environment. Applications are reviewed by MDE and subject to either joint or separate review by state and federal agencies. The level of review is determined by the scale of the project in both linear feet and distance channelward from the shoreline. In the case of the Ferry Point project, which exceeded 35 feet into the channel and 500 linear feet on the shore, the application was reviewed separately by the state, which issued a 45-day public notice, and Army Corps of Engineers, which issued a 30-day public notice. As determined by the Army Corps of Engineers, the application was reviewed by additional federal resource agencies. Local permits, reviewed and issued by the County, are required for Chesapeake Bay Critical Area Protection Program. The Ferry Point property was owned by Queen Anne's County and so was subject to state critical area review. Erosion and sediment control permits are issued by the County Soil Conservation District. The Department of Natural Resources' Chesapeake and Coastal Service provides financial and technical assistance for property owners who request it through low-interest loans. In addition, the Chesapeake Bay Trust Fund, a non-profit serving the Chesapeake Bay and its rivers, offers grants to qualifying non-profit and community organizations and state and local governments for living shorelines projects. The Trust is supported by donations, sale of the Maryland Treasure the Chesapeake license plate, partnerships with private foundations and federal and state agencies, according to the Chesapeake Bay Trust website.

**Fig. 2 Flow chart of permitting requirements for different types of shoreline stabilization approaches in Maryland** (MDE 1992).




**Narrative of investment decision**

Queen Anne's County acquired the land for Ferry Point Park from private owners using funds from Maryland Program Open Space, which purchases land for outdoor recreational and public use. Prior to County ownership, the parcel of land was the site of proposed residential development. One former County Commissioner describes the land as an, "unspoiled... environmentally sensitive area" with turtle nesting habitat that was a priority purchase for the County with the intention of turning it into a low-impact, natural park. A site visit by a county conservation professional revealed erosion along the east side of the property at a rate of approximately 8-10 feet per year in some spots. Prior erosion mitigation practices are described as dumping concrete and rocks in the location. Maryland Coastal Bays Shoreline Conservation Service, a division of the Department of Natural Resources (DNR) was contacted for a site visit and determined that, in order to protect "millions of dollars worth" of residential and commercial infrastructure in Kent Narrows, erosion protection measures would be appropriate (Bhaskaran Subramanian pers. Comm.). Due to physical features including approximately 19-miles of open water subject to winds from the northwest and an 8-10 foot drop-off just off shore, this site would have qualified for a state waiver to build structural protection, however DNR said they chose to pursue a NI approach for demonstration purposes. The final project design was the result of a collaborative planning process between DNR, Queen Anne's County staff and the Army Corps of Engineers. Miscommunication about the status of

the site as a mitigation project for the County led to delays in state permitting, funding and construction over a period of six years. During this time, representatives from DNR sought alternate routes for permitting and funding, including transferring the project to the Army Corps of Engineers. However, this route would have led to further delays, as it would have added the project to a national list of Army Corps projects at a low priority. The project ultimately reverted back to the state and, in consultation with the Army Corps of Engineers, Maryland DNR Boating and Waterways dredge material from the Kent Narrows was used for fill in construction of the living shoreline.

**1.B. Surfer's Point Managed Retreat, Ventura, CA**

Surfer's Point Seaside Park is located in the City of Buenaventura, east of the mouth of the Ventura River. Approximately 2,000 feet of shoreline had been subject to ongoing erosion, with significant damage during winter storms of 1992. Phase 1 involved construction of a cobble berm to 8-feet depth for back beach shoreline restoration and relocation of bike path and parking lot 60 feet landward. Relocated bike path opened to the public July, 2011.

**Fig. 3 Map of Surfer's Point location and photos of managed retreat project.** Top left: original bike path and erosion damage, bottom left: construction of cobble berm, top right: completed bike path phase 1 construction, bottom right: map of California with Surfer's Point labeled

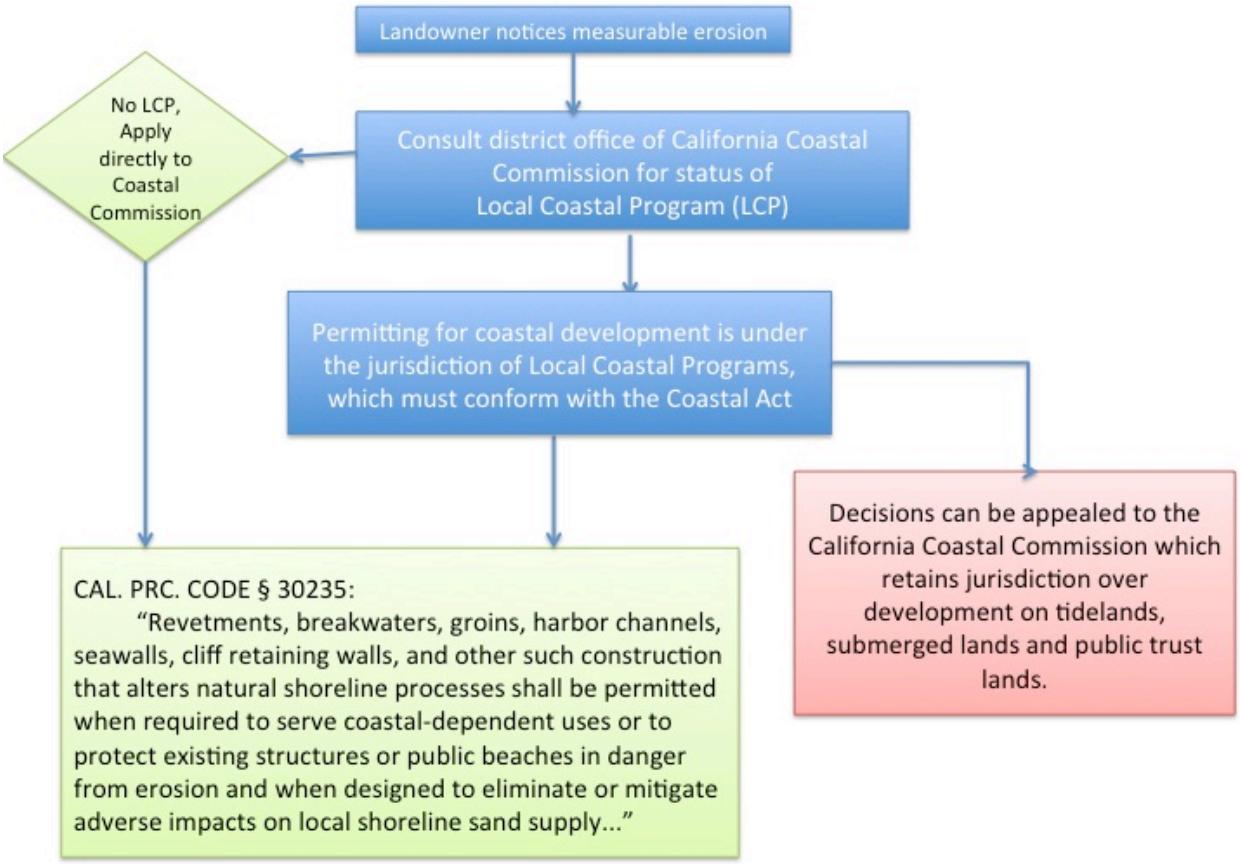
**Institutional and Policy Processes**

The Surfer's Point managed retreat project is the result of a nearly two decade-long process. The policy context for the decision can be traced back even further, to the mid-80's, when the California Coastal Commission approved an amendment to the City of San Buenaventura's (Ventura) Local Coastal Program, which addressed public access and recreation improvements at the Fairgrounds and Surfer's Point (CCC 2006). The amendment stated that the proposed public bike path be "set back sufficiently to mitigate the need for any shoreline erosion protection device" which would be determined by a study of shoreline and erosion processes (CCC 2006). In 1989, the City of Ventura officially opened the California State Park bike path and adjacent parking lot at Surfer's Point to the public (Gowenlock 1989). Two years later, erosion at the site had damaged the new construction and in 1991 the City of Ventura Fairgrounds applied to the California Coastal Commission for an emergency permit to build a permanent rock revetment at Surfer's Point to protect the bike path. The California Coastal Commission denied the request, stating that the improvements had been "constructed on the understanding that they were temporary in nature and therefore could not be protected with shoreline protective devices" (CCC 2006, 32). In 1992, the City issued itself an emergency permit and constructed a riprap revetment at the site. The Coastal Commission issued a cease & desist order to stop construction, which was later settled, and resulted in the formation of a multiagency and stakeholder working group to deal with the erosion problem in 1995.

The California Coastal Commission's website states that local governments have jurisdiction over the use of coastal resources, including land-use planning and long-term and short-term conservation goals through the certification of Local Coastal Programs (LCP). LCPs must consider regional and statewide interests and conform with the Coastal Act and, once approved, transfers the Coastal Commission's coastal permitting authority to the local government over most new developments. The Coastal Commission retains jurisdiction over development on tidelands, submerged lands and public trust lands. In addition, local government coastal permit decisions can be appealed to the Coastal Commission. The Coastal Commission administers the Coastal Act, which addresses shoreline structures directly in Chapter 3, Coastal Resources Planning and Management Policies, Article 4, Marine Environment, Section 30235:

> "Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public beaches in danger from erosion and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply..."

**Fig. 4 Flow chart of permitting process for shoreline stabilization projects in California** (CCC 2014)




**Narrative of investment**

In response to the denial of a permit for a permanent rock revetment, a working group was formed in 1995 by then State Senator Jack O'Connell and Assembly Member Brooks Firestone and included the City of Ventura, the Ventura County Fairgrounds, The California Department of Parks and Recreation, the California Coastal Commission and the Ventura Chapter of Surfrider Foundation. Surfrider Foundation had long been a vocal advocate of relocating the bike path at Surfer's Point further inland, so as to avoid the need for structural protection and potential disturbance of the surf break. The idea of managed retreat was first proposed and conceptually agreed to in the late 90s and the City of Ventura was brought in to manage the project and access grant funding. A scientific and technical analysis of cobble transport from the Ventura River watershed was conducted and it was determined that the shoreline at Surfer's Point could be stabilized by constructing a cobble berm to, "mimic nature in providing some erosion protection" (Rick Raives pers. comm.). According to Surfrider, an Environmental Impact Report performed by the City of Ventura included the structural element, but did not consider retreat. During the public comment period, Surfrider attended with hundreds of supporters and presented a sketch of the managed retreat idea to apply public pressure. The working group subsequently reconsidered the managed retreat approach, agreeing to relocate the bike path and parking lot inland to account for wave height and an increase in future sea level rise of one and a half feet (Rick Raives pers. comm.). In order to

compensate the Fairgrounds, which was giving up land to accommodate the retreat, and satisfy public access requirements of the Coastal Act, the City reconfigured a public street to create additional parking. This approach resulted in an unplanned benefit of updating and improving the Fairgrounds' storm water system. The planning period continued over the course of a decade and a half and sustained through multiple election cycles that included changes in the representation of the Fairgrounds and delays in state and federal funding. Construction on Phase 1, which included restoration of the backbeach with a cobble berm, relocation of the bike path and parking lot, began in 2010 and was completed in July 2011.

**1.C. Durant's Point living shoreline, Dare County, N.C.**

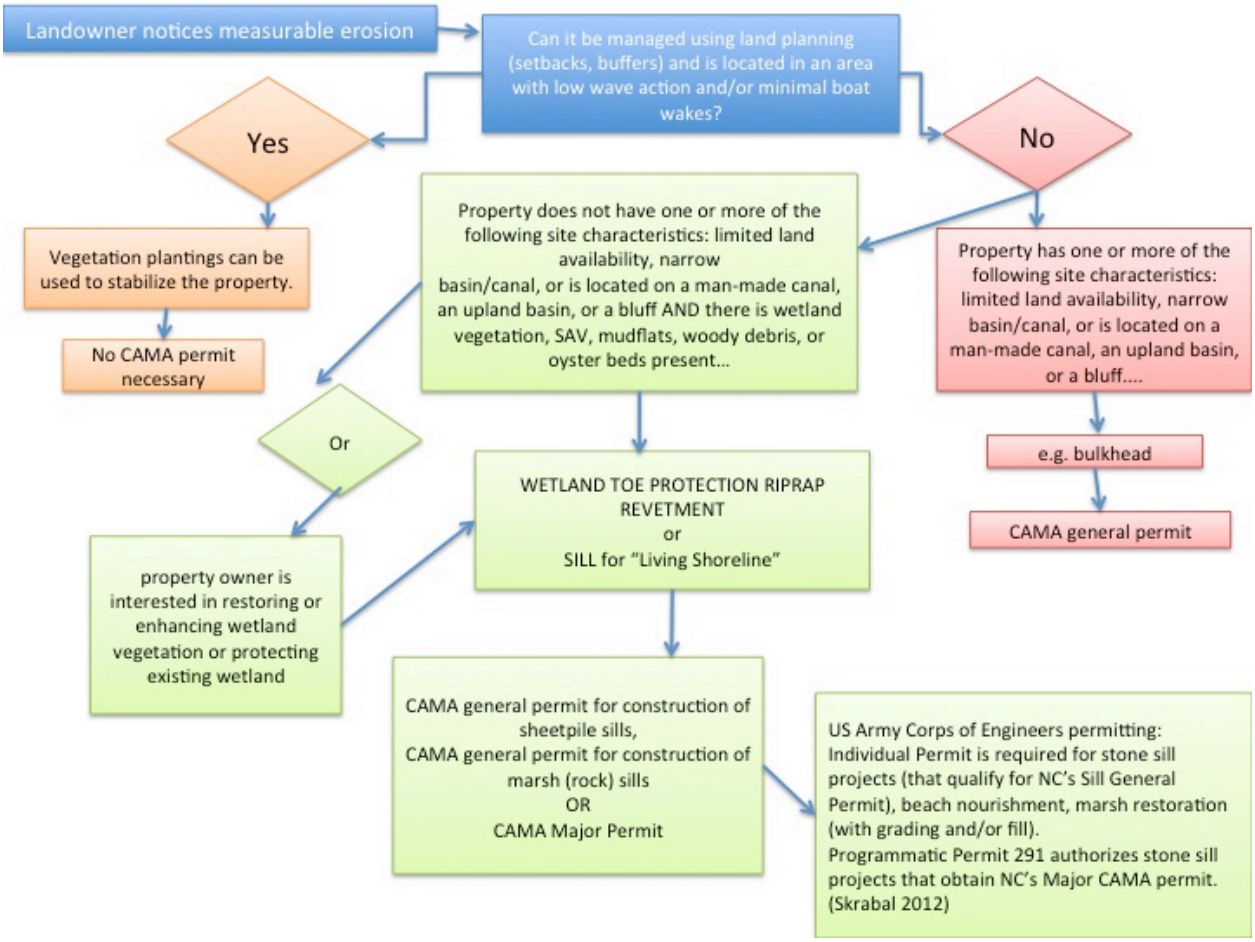
Durant's point is located on a peninsula at the entrance to Hatteras Harbor in Pamlico Sound. The southern tip of the point is protected by a rock revetment previously built by the Army Corps of Engineers, the remaining unprotected piece of land had been subject to noticeable erosion from a combination of boat wakes and storm events at a rate of one to three feet a year. The project involved construction of 320-foot long low-profile granite sill with restored marsh. Work began in March of 2011, a two-year status update presented to Dare County Board of Commissioners September, 2013.

**Fig. 5 Map of Durant's Point location and photos of living shoreline project**. Top left: eroding shoreline, bottom left: construction of low-profile granite sill, top right: marsh restoration, bottom right: map of Hatteras with Durant's Point labeled


**Institutional and Policy Processes**

Dare County is one of 20 counties that are under the jurisdiction of the Coastal Resources Commission, which administers the Coastal Area Management Act (CAMA). The North Carolina Division of Coastal Management website lists three types of permitting for development in a designated estuarine Area of Environmental Concern: a general permit, a minor permit and a major permit. Conventional shoreline infrastructure such as docks, piers, simple boat ramps, bulkheads and riprap revetments are included in the general permit. As of 2005, CAMA lists a general permit for the construction of a riprap sill for wetland enhancement and a general permit for timber or vinyl sheet pile sills for wetland enhancement. However, when the CAMA office was contacted about the Durant's Point living shoreline project, the engineer was told that the project would require a CAMA major permit due to concerns from the Army Corps of Engineers over the use of a rock sill and the Division of Marine Fisheries were concerned about impacts to Submerged Aquatic Vegetation.

**Fig. 6 Flow chart of permitting requirements for different types of shoreline stabilization approaches in North Carolina** (NCDCM 2014)




**Narrative of investment decision**

The idea for a living shoreline approach at the Durant's Point site came from Ernie and Lynne Foster, citizens of Hatteras Island. Lynne Foster served on the northeast regional advisory committee for the North Carolina Coastal Federation (NCCF), a local NGO dedicated to fostering citizen stewardship of North Carolina's coastal water quality and resources, according to its website. Ernie Foster is a former high school biology teacher who runs a commercial fishing operation out of Hatteras Harbor. Ernie Foster grew up in Hatteras and observed changes in the environment over his lifetime, including increased bulkheading. He was invited to join the board of the NCCF following a 2002 article he wrote titled, "Thoughts on Watching a Village Die," in the Island Breeze, expressing his concerns about overdevelopment in Hatteras Island. The Fosters had heard about living shorelines through their involvement with the NCCF and Ernie suggested the idea as a potential approach to the erosion at Durant's Point. NCCF hired Bissell Professional Group to design the project and secure the permits through the NC Division of Coastal Management. The undeveloped land was under private ownership by several owners and NCCF had to secure memorandums of understanding from the property owners prior to receiving funding through a grant from NOAA's Restore America's Estuaries, which supports community-based restoration projects. The engineering firm did a site evaluation based on cost, longevity and exposure and offered three design options to the private property owners and NCCF. A decision to use a more expensive rock sill over timber

was due to property owners' concerns about long-term maintenance needs. A general technical analysis, based on the work of the engineering firm, was presented to the Dare County Board of Commissioners by NCCF at a public meeting. In January of 2011, the Dare County Board of Commissioners agreed to assume responsibility for maintenance of the living shoreline.

## Qualitative Analysis of Behavioral and Institutional Factors

We found five common themes in our analysis of the interview transcripts: 1) perceived benefits; 2) social networks and social norms; 3) local champion; 4) diffusion of innovation 5) institutional context. Below we describe the evidence that supports these themes.

### 1) Perceived Benefits

**The theme perceived benefits is defined as… Decision makers act in a way that is consistent with a rational economic actor. They make investments based perceived costs and benefits of investment in NI, but the perceptions of costs and benefits are likely formed by emotional associations and heuristics rather than objective information or data.**

Respondents who support NI made 46 references to perceived benefits as compared to 31 perceived costs. Tangible benefits were most frequently discussed in terms of gains for commercial and recreational fishing from habitat conservation, recreational use, water filtration and discouraging development of the land.

Respondent (a citizen, N.C.) *"I'm also a fisherman. My family, we are all fishermen. And commercial fishermen have to have a future. You know, if you don't have a nursery area, you don't have -- you don't have fish in the future."*

Respondent (a former county commissioner, MD) *"... we're excited about having such an environmentally sensitive piece of property at the center of the area.... people are kayaking and what they want to see that. I think it just kind of made sense given the characteristics and the nature of the property."*

Respondent (a county commissioner, N.C.) *"... it's natural, it will tend to stay there, the grass and stuff like that works like they need to... the environment is not hurt its enhanced... it does not encourage development on it either, it encourages it to stay what it is, a marsh or a beach..."*

References to intangible benefits were discussed in terms of aesthetic improvements, preserving coastal heritage and a way of life. Surfing and beach culture in this context appear to be a lifestyle, rather than actual activities. These references also seem to stem from emotional associations with a strong sense of place and history with a desire to maintain or return to a "more natural" state.

Respondent (an engineer, CA) *"... surfing and going to the beach is part of the Southern California culture. And I think the City of Ventura got it. I don't think it was that hard for them. I mean, because they are all those same people, right?"*

Respondent (a citizen, N.C.) *"... especially the local people, they don't really want to see a whole lot of fake stuff around. They have all grown up with water lapping in their yards, you know. A natural solution is going to be a better choice for most of the people who grew up here or who have lived here a long time."*

Benefits were often referenced in comparison to a conventional infrastructure alternative. When questioned about how participants arrived at the decision, respondents spoke in terms of logical, or rational, choice. The use of phrases such as "better fit" and "made sense" indicates that these decisions may be based on heuristics about the location or community.

Respondent (a former county commissioner, MD) *"I think it just kind of made sense given the characteristics and the nature of the property."*

Participants were not asked to quantify the perceived benefits or costs associated with NI. With the exception of Surfer's Point, where the land owner perceived the managed retreat as a loss of land, none of the other property owners were personally connected to the financial aspects of the project. Discussion of perceived costs were frequently in terms of NI projects taking longer due to design and permitting and maintenance needs.

Respondent (an engineer, N.C.) "*I think that maybe people feel like it's going to be a lengthy process and probably a little more expensive up front and then the maintenance of it...I mean you've got to go back to the site you've got to get more plantings every year and you've got to get the manpower to do it so there's certainly expense associated with that..."*

### 2) Social Networks and Social Norms

**This theme is defined or means… Learning about other natural infrastructure projects influences decision makers to invest in similar projects in their community, with visuals making the deepest impression.**

When asked directly about seeing other NI projects, respondents made 30 references to visiting other sites, reading and hearing about similar projects, or seeing photos of other projects prior to implementing their own.

Respondent (a citizen, N.C.) *"It has been in the papers, the local papers and so forth, with pictures. Not only did it make ecological sense, it also looked better."*

Participants discussed the effect of seeing other projects, referring to before-and-after photos. These photos appeared to help participants understand the technical aspects of the approach. Seeing other projects also seemed to help build trust in the technology and by seeing that others had done it tapping into perceptions of social norms.

Respondent (a conservation professional, N.C.) *"there is more comfort maybe with the concept once you have a few demonstration projects, but showing it has worked elsewhere has definitely seemed to be key..."*

Respondent (a state conservation professional, MD) "...*we did workshops, we did the pamphlets, brochures we funded a lot of demonstration projects... we did living shores for 30 years, but the structural folks have been doing it for hundreds of years... we're not going to change overnight..."*

Respondent (a county commissioner, MD) *"...we all took a look and the more we looked at it the more we liked it... once we went around to the one in Edenton and we realized it did not have the dynamics that we did but it still would have done pretty well... "*

Participants discussed seeing projects in similar communities as motivation to build one in their own community. This response may indicate the effect of contagion, inspiring similar behavior, or social norms as a competitive motivation.

Respondent (a county conservation professional, MD) *"You knew what was over there, so you kind of wanted to do something kind of really neat or cool here, you know what I mean, that would be different."*

### 3) Local champion

**This theme is defined as… Learning about natural infrastructure from a source with ties to the local culture and through social networks enhances trust, community buy-in and political will.**

When asked about an individual or group that championed the use of NI, respondents made 46 references to local actors, community engagement and active communication with the local community.

Respondent (an engineer, CA) *"I think the most important factor was that there were people that really cared about what happened, and they worked diligently to have a positive effect."*

Participants discussed the role of local actors to gain cultural acceptance within a small community. These responses indicate the influence of the "messenger," a familiar peer, to spread an idea.

Respondent (a citizen, N.C.) *"all we have to do is go sit on the porch at the grocery store. And there is -- the vice chairman of the committee of the county commissioners is on the porch, too..."*

References were made to the employment of local vendors and volunteers, which resulted in further engagement and a sense of local ownership over the project.

Respondent (a citizen, N.C.) *"I really do think that because it was perceived at least as a local project, they used local volunteers, and so it didn't seem like someone was coming in and telling us what we had to do. They were coming in and helping us do what we wanted."*

Participants discussed the role of local advocates to build political will for NI projects. References were made to individuals working within government and those with ties to the local community.

Respondent (a former county commissioner, MD) *"... the county staff that worked on this and state employees ... they were very much leaders... "*

Respondent (a conservation advocate, CA) *"You know, sometimes we use the saying constant pressure endlessly applied. And so having a strong local advocate that was willing to endure I think was really the key."*

### 4) Diffusion of Innovation

**This theme is defined as… Decision makers in all three NI investment cases have characteristics of innovators as described in Diffusion of Innovation theory**

Respondents made 34 references to "doing something different," with another 14 references to a willingness to take a risk and "try it." These references were frequently anchored to a sense of pride.

Respondent (a county commissioner, N.C.) *"I look at it a little differently and think out of the box and have not always succeeded but we continue to try to do so."*

Respondent (a county conservation professional, MD) *"They like to be out in front. It's kind of like the -- kind of like to rub the nose -- rub the other counties' noses. See what we did?"*

Participants also discussed motivations for investing in NI in terms of the opportunity for their community to serve as a demonstration site and educational tool for others, increasing further adoption of the new technology.

Respondent (a conservation advocate, CA) *"so my goal from the get-go of this, you know, 20 years ago, was always to create a demonstration project that could demonstrate the efficiency and long-term benefits of managed retreat over shoreline armoring."*

Respondent (a state conservation professional, MD) *"... we wanted to make this as a demonstration project to basically say that some of these things are possible even if it is an extreme situation..."*

Respondent (a citizen, N.C.) *"it made so much sense that all the fishermen and the locals that were going in and out of the harbor would look up there and see that. And their initial reaction would be, what in the hell are they doing? And then once it was in place, they would quietly say,*

*that makes sense... and they would then become ambassadors of good will for any other projects that came along..."*

Participants did address the drawbacks of being the first to adopt a new technology. These references were related to institutional factors such as encountering complicated review and permitting processes and the perception of additional risks for engineers who attach themselves to such a project.

Respondent (a county conservation professional, MD) "*it just seemed like every time -- maybe because we were ahead of our time doing this... And I'm sure they didn't feel comfortable with some of the stuff that we wanted to do because, really, nobody had ever done it before."*

Respondent (an engineer, CA) *"So one way professionals are protected is through insurance, obviously, but the standard is the standard of practice in the industry, and that means that you are using published guidelines... Now, you know, by definition if you are being innovative, you are out on a limb, so to speak."*

**5) Institutional factors**

**The last theme… Institutional factors both promote and discourage investment in NI**

When asked about the influence of state and local policy in promoting the use of NI, respondents spoke about preference of non-structural solutions and the role of collaborative planning to design a project that would offer benefits to multiple stakeholders.

Respondent (a county employee, CA) *"what was driving this was what could we get a permit for... and what could we get a permit for that would also put the project back that met everyone's goals?"*

Respondent (an engineer, MD) "... *ultimately, the project became what it is. Defined by regulatory consensus building, and also framed in by how far you can go technically, you know, to make sure the project works like you want it to work."*

Challenges were frequently discussed in terms of navigating between multiple agencies and jurisdictions for application review and permitting, funding delays and changes in politicians over the duration of a project.

Respondent (a county conservation employee, MD) *"... I just wish that government agencies would use more common sense than what they do... we are all working for the same goal. You know what I mean? And I just wish they would kind of work together as a team instead of working as individuals against each other."*

Respondent (a county employee, CA) "... *every time there is a new governor, they would change the majority of the group. And I had to start over at least three different times getting that new*

*board up to speed and getting them to approve the project because new board members would come in and they would say, why are we doing this?"*

Respondents pointed to project "visionaries" who worked through sometimes decades-long processes to see an NI project realized.

Respondent (an engineer, MD) *"I mean, it takes perseverance to hang in there for six years on a project."*

## *Discussion*

We found that the decision to invest in NI for coastal flood protection is influenced, in part, by an understanding of scientific and economic information about the approach as an alternative to conventional options. Beyond that, our analysis finds these conservation decisions are subject to the same psychological, social and emotional associations that influence other environmental behaviors (Cowling 2014). The decision makers we interviewed perceive benefits from NI, they are also innovators who are willing to take the risk on a new technology or idea and are tapped into social networks where they can learn about NI and help spread information about it to others. In addition, these decision makers also acted as local champions for NI in their communities and local governments. When combined with institutional factors, such as policies that promote non-structural options and ease permitting, we argue that these behavioral factors are as important as scientific and economic factors in influencing the decision to invest in NI.

The results we found showed that decision makers chose to invest in NI because perceived benefits outweighed perceived costs. This is consistent with a rational actor and assumptions underlying economic efficiency: a choice is determined by the option that offers the greatest utility, or benefit (Keohane and Olmstead 2007). Participants frequently discussed anthropocentric benefits such as recreational opportunity and improved aesthetics along with services, such as nurseries for fish, provided by conserving habitat. These benefits are what have been called ecosystem services (Alcamo et al. 2003) and lend support to new strategies by conservation organizations to motivate investment in conservation for the benefits it provides people. Importantly, participants appeared to perceive these benefits and weigh them against perceived costs without attaching a monetary value and without scientific or economic data. The observation that monetary values were not needed for decision making is consistent with results from a study of demonstration sites that used the ecosystem service approach in hazard mitigation and climate adaptation decisions (Ruckelshaus et al. 2013). Discussions about benefits were rarely based on specific or objective scientific information, even though we did ask questions about how scientific and technical analyses were considered in the investment. These results support previous studies showing that increased scientific knowledge does not necessarily lead to environmental attitude formation and behavior (Sturgis and Allum 2004). When asked about the decision respondents frequently said that NI "just made sense" and was a "better fit" than conventional infrastructure. These answers indicate that these perceptions were based less on cognitive processes and more on affect. The discussions of perceived

benefits from NI also reflected emotions about coastal heritage, lifestyle, personal memories and observations of changes in the environment over time along with the desire to return to a more natural state or discourage development. These references to the environment remembered from one's childhood and the desire to maintain a particular beach lifestyle are indicative of emotional associations and possibly, loss aversion, in which people place a higher value on keeping what they have (Dolan 2010).

The decision makers appeared to be 'innovators,' who are the first to employ a new idea, practice or technology as described in diffusion of innovation theory (Wejnert 2002; Rogers 1983). As individual decision makers, the adoption of NI in this context is likely dependent on close social interactions, such as site visits and interactions with conservation professionals (Wejnert 2002). This is an indicator that social networks and perceived social norms contributed to the spread of information about NI. Discussions of visiting demonstration sites are consistent with findings from other studies that indicate that decision makers may learn about the new technology by modeling what others are doing or through social networks (Bollinger and Gillingham 2010; McKenzie-Mohr 2000). However, since these sites are chosen by the conservation professional, it would be difficult to separate out the influence of these particular sites as opposed to what decision makers might learn from peers.

Repeated references to learning about NI from local personalities and local advocates illustrate the importance of a familiar messenger, with similarities to the decision maker (Dolan 2010). In each case, the project was championed by someone with close ties to the local community or local government which taps into automatic responses to 'liking' the source of information (Cialdini 2009, ch.5). This supports evidence from health education research that people are more open to information from sources who are familiar to themselves (Durantini 2006). The emphasis on open communication and community engagement further supports efforts within the conservation community to identify a local champion and foster local ownership of projects (Horwich 2011; Shanee 2013).

Our results also reflect concerns about private consequences associated with adoption of new technology. For example, the engineers we interviewed discussed the private costs of being involved with a NI project in terms of professional liability. It is important to note that there were fewer references to financial risk, as the projects were funded through public money or grants. These participants also reflected a feeling of pride in 'thinking outside the box' and spoke about using their projects as demonstration sites to teach others about the technology. This could indicate perceptions about status conferred by being among the first to invest in NI. This would support theories of 'conspicuous conservation' in studies of consumers who purchased hybrid cars at a higher price (Sexton and Sexton 2014).

The previous discussion focused on the common behavioral factors found in all three cases. Our results were more varied when we analyzed the institutional factors, which are reflective of differing policies and regulations across the three case study sites. Participants in California and Maryland describe state policy and preference for non-structural shoreline stabilization as promoting the investment in NI. In California, the denial of a permit for a structural option,

along with the involvement of multiple entities, resulted in a collaborative planning design process. A similar approach was used in Maryland, where multiple stakeholders participated in the design of the project. Respondents spoke about how this process enabled them to access funding from multiple sources and resources from different agencies. Collaborative planning also led to creative solutions while working toward consensus among the stakeholders. For example, in California, the decision to move a parking lot further inland resulted in a loss of property for the fairgrounds. To compensate for this, the City used the opportunity to improve the fairgrounds' storm water infrastructure, creating an additional benefit for the fairgrounds. Respondents also discussed the challenges of engaging in this process without an established management or institutional structure. Our results also reflect the influence of regulatory and permitting requirements to potentially discourage investment in NI. This was described as a lack of coordination between agencies at the state and federal level, which resulted in a more extensive application and review process as compared to conventional infrastructure projects. We did not directly study individual perceptions of these institutions.

These results are limited in a few notable ways. While we did attempt to include similar types of decision makers across the three case studies, this representation is far from exhaustive. In addition, this research focused on successful NI projects. All of the respondents we spoke to had willingly participated in the NI projects and were supportive of the approach. We recognize that this presents a confirmation bias toward seeing the benefits of NI to support their decision. To address some of these limitations, future research could investigate cases of engineered infrastructure decisions and decisions where natural infrastructure was considered but not chosen as the solution. Our interviews were focused on these decisions at the individual level and so are limited to measuring the role of cognitive processes and heuristics on perceptions in individuals. In this way, the results we found support research on consumer and individual behavior. We recognize that decisions about infrastructure investment and resource conservation rarely take place solely at the individual level and so would recommend that further research be conducted to study these influences on collective behavior at the community and institutional level.

## *Conclusion*

This research makes an important first step toward applying insights from the behavioral sciences to conservation of natural resources and infrastructure investment decisions, in particular. Our findings offer a glimpse into the emotional connection that humans have with the ocean and how it affects decisions. As shown in this study, this connection has roots in a range of emotional associations that draw us to the coast, despite the hazards we know come from living and building so close to the shore. These connections range from the traditions of a fishing community in North Carolina to surfer culture in California to the desire to preserve a pristine piece of land free from residential development in Maryland. The interviewees we spoke with appeared to perceive maintaining these connections as a benefit of NI, without placing a dollar value on these benefits. Our findings support efforts to study and communicate ecosystem services for conservation decisions, but our research also suggests that this is just one piece of a larger puzzle. This study raises questions about the role of data

in driving these investment decisions, and while we are not suggesting that data are not essential, we argue that understanding more about the heuristics that people employ when making conservation decisions is just as necessary. Our findings show that before and after images and visits to demonstration sites can communicate the technical aspects of NI. In addition, our findings show that decision makers who learn about these projects through social networks appear to trust the technology enough to invest in a similar project in their community. We recommend further study on social networks of decision makers to gain a deeper understanding of how the right innovators and local champions can work to spread information about NI.

At the institutional level, our findings suggest that local and state policies have a strong influence on conservation decisions and would recommend the Maryland Living Shoreline Protection Act as a potential model. By setting living shorelines as the preferred option, the permitting process is designed to promote investment in NI. We would also suggest further study of the collaborative planning process in the Surfer's Point managed retreat and Ferry Point living shoreline projects. Our findings show that by working toward consensus among multiple stakeholders, these projects produced additional benefits. These examples also illustrate the need for an institutional framework for multi-objective projects.

This line of inquiry has applications for conservation, hazard mitigation, coastal adaptation and resilience to rising sea levels and coastal development policy. Research in this area could support the development of social learning networks for coastal residents and decision makers. At the institutional level, it could create opportunities for resource managers to work together across jurisdictions, increasing efficiency in conservation efforts and maximizing tight budgets. This research also has the potential to shift the way we think about coastal resilience, instead of building higher and stronger to hold our ground and avoid losses, we might work with nature to achieve greater gains. As one participant in California put it, "...by retreating, we gained the beach."

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**Appendix 1: Natural Infrastructure Cases** *TNC NA RRR Demonstration Sites. Grayed-out cases indicate cases that are similar to another case or TNC has been the primary decision-maker.

| Case | Type of NI | Activity | Primary Decision-Maker | Project Dates | Selection Criteria | | |
|---|---|---|---|---|---|---|---|
| | | | | | Addition-ality | Public Meeting Minutes | Potential for Interviews |
| ***Coastal*** | | | | | | | |
| Ferry Point Park, MD | Living Shoreline | headland breakwaters, dune stabilization, low-profile sills, marsh reinforcement using a variety of plants, and containment berms made up of concrete, sand and dredged material | MD Department of Natural Resources | Construction started 9/13 | Yes | TBD: MD Living shoreline policy (2008) (see references below) | TBD |
| Jockey's Ridge State Park Shoreline Restoration, NC | Living Shoreline | planting marsh grass and creating oyster reef barriers | North Carolina Coastal Federation | Restoration, 2009-2010 | Yes | TBD | TBD |
| Durant's Point, Hatteras Harbor NC | Living Shoreline | restored marsh, 320-foot-long, low-profile granite sill | North Carolina Coastal Federation | Restoration, 2011 | Yes | Yes | TBD |
| Grand Liard Marsh and Ridge Restoration, LA | Ridge restoration/ marsh creation | restoration of a ridge on the east bank of Bayou Grand Liard and the creation of new marsh to the east | Coastal Protection and Restoration Authority | Approved: 2009, Request for funds: 2011, Bids for Contracts: Dec 2013 | Yes (In future) | TBD | TBD |
| Prime Hook National Wildlife Refuge Coastal Tidal Marsh /Barrier Beach Restoration, DE | Marsh restoration | repair breach, build up dunes, building up the marshes' elevation, removing water control structures, and creating channels in the marsh to manage how water flow, plant marsh grasses (planned) | U.S. Fish and Wildlife Service http://www.fws.gov/refuge/Prime_Hook/what_we_do/marshrestoration.html | Hurricane Sandy Disaster Relief appropriations approved 10/2013, Hydrological Modeling of impacts to flooding completed 2/2014 | Yes (In future) | TBD | TBD |
| Dyke Marsh restoration, VA | Marsh restoration | Restore marsh | U.S. National Park Service | Hurricane Sandy Disaster Relief appropriations approved 10/2013, plan for public comment | Yes (In future) | TBD | TBD |
| San Francisco Bay Tidal Marsh, CA | Marsh restoration | Temperate salt marsh restoration (16000 ha as of 1998) for surge and wave reduction, plus habitat and carbon sequestration | See ESA PWA 2013 - Analysis of the Costs and Benefits of Using Tidal Marsh Restoration as a SLR | Multiple restoration projects on-going for 20 years | Yes | TBD | TBD |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | Adaptation Strategy in SF Bay, Final Report and SNAP database | | | | |
| Avalon Dune Nourishment, NJ | Dune restoration | Wave attenuation via dune nourishment and maintenance (7.3 km coastline; dune width from 0 - 100 m and cyclical) | See Nordstrom_2001_Municipal Initiatives for managing dunes in residential areas; a case-study of Avalon, NJ, USA and Avalon_1998 and SNAP database | 1987 | Yes | TBD | TBD |
| Surfers Point, Ventura, CA | Beach nourishment | Managed retreat and erosion mitigation (and maintaining recreational values) through beach nourishment (cobble beach and dunes, 1800 ft of coastal path and parking lot) | See TNC California Gray-vs-Green Report, 2013 Case-Study 5 (also SNAP database) | 2001-2011 | Yes | TBD | TBD |
| Albermarle-Pamlico Climate Change Adaptation Project* | Marsh and oyster reef restoration | Restore and enhance marsh (salt-tolerant tree planting, hydrology, invasive species control) and install nearshore oyster reef at Alligator River NWR | US Fish and Wildlife Service (with TNC) | Completed 2010-2011, additional activities at other sites continuing | Yes | TBD | Yes |
| Oyster Habitat Restoration in Southwest Florida* | Oyster restoration | Restore 18 acres of oyster habitat in Charlotte Harbor Estuary | Southwest Florida National Estuary Programs, Charlotte Harbor Estuary Program (with TNC) | RESTORE SW FL Shellfish Restoration Proposals - April 2013, Draft permit language - Feb 2013 | Yes (In future) | TBD | Yes |
| Virginia Coast Reserve, VA* | Living shoreline | Protected 14 barrier islands, restored oyster reefs and wetlands. Working with UVA LTER to show benefits of oyster reefs and eelgrass (200->2,400 acres) in dampening wave energy and protecting marsh. | TNC (original intent was not for "natural infrastructure"?) | 1999-2009? | Yes? | TBD | Yes |
| South Cape May Meadows Preserve and Cape May Point State Park* | Living shoreline | Restored freshwater wetland and beach ecosystems in order to restore landscape to benefit wildlife and local communities by adding protection from coastal flooding | TNC, USACE, NJ Dept of Environmental Protection | 2004 | Yes | TBD | Yes |
| Alabama Coastal Resilience Project* | Oyster restoration | "100-1000: Restore Coastal Alabama" restore 100 miles of oyster reefs and enhance 1,000 acres of marsh; ARRA funds from NOAA (2009) used to build 1/4 mile ( 2011), goal: 2 miles | TNC, Alabama Dept of Conservation and Natural Resources State Lands Division, Dauphin Island Sea Lab, Mobile County, University of South Alabama | 2001-present | Yes | TBD | Yes |
| ***Riverine***[+] | | | | | | | |

**Appendix 2**

Interview Guide: Questions

**We are interested in understanding both the formal process (current policies, proposal requirements, permits, etc.) and other behavioral and institutional factors that go into making the decision to invest in a natural infrastructure project for coastal protection/hazard mitigation.**

1. How does the process work for investing and implementing a natural infrastructure project?

2. How does the process work for other forms of coastal flood hazard mitigation infrastructure?

3. How did this particular project fit into that conventional process, did you have to go outside of the regular permitting structure?

4. Where do you get your information about flood hazard mitigation options?

5. When did the idea first come about for a natural infrastructure option in this location?

**This next set of questions will deal with how project proposals are evaluated**

6. Was there a technical evaluation and if so, how was that performed? (How was it presented to decision makers?)

7. Was there scientific or economic evaluation of the option, was it compared to other options?

8. What was the decision criteria that was used to evaluate this?

9. What other factors were involved in the consideration?

**This set of questions will focus on perceptions of natural infrastructure options**

10. How was the community or government involved in evaluating or providing comment on this option?

11. How was the idea received by political officials?

12. How was it received by the community?

13. What is people's opinion of this as an option – what benefits do they feel it provides for the community?

**This next set of questions will focus on how natural infrastructure ideas are promoted**

14. Was there a key individual or group who was instrumental in championing the use of natural infrastructure?

15. What role did external policies, practices, and conditions (e.g., associated with FEMA and USACE) play in promoting the use of a natural infrastructure strategy?

16. Is there a state or local policy that influenced your decision to use a natural infrastructure strategy?

17. Have you learned about natural infrastructure projects in other communities facing risks similar to ones in your community?

**This set of questions will focus your personal experience with natural infrastructure**

18. What do you know about the history of flood hazard mitigation/prevention in this area?

19. What is your opinion of previous efforts?

20. Has this community had an experience with built infrastructure that influenced the decision to use natural infrastructure in this project (e.g., levee failure)?

21. Were decision-makers influenced by examples of successful NI projects in other places? How did you learn about those examples?

22. What were keys to success and what were barriers to a natural infrastructure solution? What kind of barriers have you encountered?

23. In your opinion, what was the most important factor?