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Factors influencing local decisions to use habitats to protect coastal communities from hazards

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ABSTRACT

Coastal hazard mitigation policy in the US has historically focused on construction of hardened, or gray, infrastructure. Recently, there is increased public interest and policy supporting the use of habitats, or natural infrastructure (NI), following decades of increasingly supportive ecological, engineering, and economic evidence. This trend suggests that behavioral and institutional factors may also be important for mainstreaming NI. To understand what factors affected decisions to use NI, we conducted semi-structured interviews with a total of 16 individuals associated with three NI cases: Ferry Point Park Living Shoreline, Maryland (MD); Surfer's Point Managed Retreat, California (CA); and Durant's Point Living Shoreline, North Carolina (NC). Our grounded theory analysis of the interview transcripts revealed four common themes across the decisions: 1) perception of benefits (N = 45) and costs (N = 31), 2) diffusion of innovation led by innovators (N = 34), 3) local champions (N = 46), and 4) social networks and norms (N = 30). This grounded theory suggests that the decisions to use NI were driven by innovators (citizens, local non-governmental organization (NGO) staff, and/or state government resource managers) who were influenced by seeing NI successes implemented by trusted experts and perceived NI benefits beyond protecting coastlines (e.g., maintaining coastal heritage and sense of place). Innovators also acted as local champions, getting others "comfortable" with NI and connecting to local interests. In addition, our analysis shows the role of regulatory permitting requirements in perpetuating or controlling biases against innovations like NI. In 2008, MD passed a policy that helped address biases against NI by changing NI from a preferred option to the required option except in places where scientific analysis suggested that gray infrastructure would be needed, while in CA and NC gray infrastructure remains only a preferred option. These results suggest an opportunity to harness heuristics, such as visual demonstrations and messaging from trusted persons, in addition to policy tools to mainstream NI in places where there is evidence that it would be effective. These results also suggest that heuristics could result in biases that not only lead to underuse but also to inappropriate use of NI; and, policies, similar to the policy in Maryland, are needed to control these biases.

1. Introduction

Coastal flood hazards are among the costliest natural disasters in the US (Gall et al., 2011). The losses from Hurricanes Katrina (2005) and Sandy (2012) make up two of the top 10 costliest natural disasters worldwide since 1980 (Munich Re, 2014). US hazard mitigation policy at the federal, state, and local level has historically focused investment on construction of hardened, or gray, infrastructure for shoreline protection, resulting in a patchwork of aging shoreline infrastructure covering 9% of the nation's coastline (Hiller, 2003; 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 (Schlacher et al., 2007; Griggs, 2010). At the same time, there is a growing body of research on the hazard protection provided by natural coastal habitats such as

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dunes, wetlands, oyster reefs, coral reefs, and mangroves. These habitats have been shown to mitigate erosion and floods by buffering wave energy and absorbing and storing water from high tides and storm surges (Costanza et al., 2008; Das and Vincent, 2009; Gedan et al., 2010; Shepard et al., 2011; Arkema et al., 2013; Barbier et al., 2013; Ferrario et al., 2014). Conservation groups have been generating and using ecological, engineering, and economic evidence to argue for incorporating habitat restoration and protection, or natural infrastructure, into the coastal resilience plans of communities, governments, and businesses (e.g., Downing, 2013; Reddy et al., 2015). Internationally, "managed realignment," setting back or repositioning the coastal or riverine flood defense line to improve sustainability of the defense, is gaining momentum especially in the UK, where a strong legal basis supports removal or realignment of hardened infrastructure to create new or restored intertidal habitat (DEFRA, 2004, Esteves, 2014).

Here, we define natural infrastructure (NI) as natural areas, or a combination of natural areas and hardened structures, that provide the same types of services that gray infrastructure provides (e.g., marshes and bulkheads can both reduce erosion caused by waves (Gedan et al., 2010; Bridges et al., 2015)). Studies have shown that differences in coastal hazard, geomorphological, ecological, and economic conditions may influence what methods of adaptation and type of NI may be suitable for a given location and the potential protection it provides (Inman and Nordstrom, 1971; Fairbridge, 2004; Arkema et al., 2013; Bridges et al., 2015). However, little attention has been paid to how institutional or behavioral differences influence decisions to choose whether to invest in NI or gray infrastructure.

In the US, private and public responses to coastal erosion are governed by a complex framework of legislation and court decisions, with national policies and practices interacting with state and local policies (Ricketts, 1986). Although there has been a general trend in the US of expanding coastal hazard management beyond gray infrastructure to include flood insurance, land use regulations, and beach nourishment (Platt, 1994), differences in state and local policies have the potential to influence the adoption of NI. The influence of these different state and local institutional contexts may be increasing because of the central role that state and local governments are now playing in climate change policy, including policies on adaptation (Wood et al., 2014).

Within these institutional contexts, decisions to use NI may be determined or influenced by the behavior of individuals, including private landowners, engineers, environmental non-governmental organization (NGO) staff, government staff, and elected officials. The field of environmental psychology has produced multiple hypotheses and analytical frameworks that could help explain the connection between an individual's awareness and knowledge about the environment and their conservation behavior (Kollmuss and Agyeman, 2002; Vining and Ebreo, 2002). Social psychology studies have also shown that the majority of human decisions are shaped by heuristics, or mental shortcuts, that link to subconscious or automatic responses (Smith DeCoster, 2000; Aronson and Aronson, 2008; Cialdini, 2009). Individuals have been shown to rely on heuristics to make decisions about unknown or unfamiliar subjects (Aronson and Aronson, 2008), suggesting that technical information does not play a key role in many decisions. An individual's neighborhood or community also influences his or her decisions via social structures and processes (Sampson et al., 2002). This includes the role of social networks that facilitate the spread of behaviors and emergence of social norms (i.e., cultural phenomena that determine context-specific behavior) (Hechter and Opp, 2005). The term social network refers to both the metaphor describing the interconnections between people and the formal definition of these connections by the number of people involved, the distance between people, and the character of the connections between people (Scott, 2002). For instance, perceptions of authority and likeability of the 'messenger' has been shown to influence how much weight we give to information (Aronson and Aronson, 2008; Dolan et al., 2012). 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., 2006).

The "diffusion of innovation theory" specifically describes how new innovations, such as technology, spread between people (Rogers, 1983; Aronson and Aronson, 2008). 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). Innovators are the first to try an innovation; they are risk takers and naturally interested in new technology. Early adopters are opinion leaders that are comfortable adopting a new innovation because they recognize a need for a change. The early majority needs to see evidence that an innovation is successful before they adopt. In contrast, the late majority is more skeptical and needs to see that many others have successfully adopted an innovation before they adopt it. Lastly, laggards are entrenched in tradition and skeptical of change. These social-psychological and context models of human decision-making are in stark contrast to the "information deficit" model that motivates much of current conservation science and practice. The "information deficit" model assumes conscious cognitive processes dominate and posits that the supply of objective information, in this case on the physical or economic performance of a technology, will result in changes in behavior (Sturgis and Allum, 2004).

Environmental behavior can be influenced by working around the conscious cognitive processes and tapping directly into automatic behavior responses or unconscious cognitive processes (Cialdini, 2009; Dolan et al., 2012). A growing body of studies on energy efficiency supports the idea that this sort of behavioral nudge (involving positive and indirect reinforcement) (Thaler and Sunstein, 2008) may be more effective and efficient than traditional information campaigns or enforcement. For example, solar panels in a neighborhood increase the likelihood that other neighbors get solar panels (Bollinger and Gillingham 2012). Providing reports that compare neighbors' home energy use reduces a person's own energy use (Allcott and Rogers, 2014). In contrast, there has been little empirical research on how behavioral processes affect decisions involving nature conservation (Scarlett et al., 2013; Cowling, 2014; except see Chen et al., 2009; Frank et al., 2011; Asah et al., 2012; Lubell et al., 2013; Reddy et al., 2014). This may be because studying human behavior and conservation poses additional challenges not faced when studying individual consumer behavior —namely, smaller sample sizes, group decision making, externalities, and no systematic record of decisions (e.g., in contrast to records of consumer purchases, etc.).

We advance this research by using a grounded theory approach (Strauss and Corbin, 1990) to examine the decision processes for three coastal NI cases. Grounded theory is a qualitative analysis method that enables researchers to develop a new understanding of social processes that is grounded in observation (Glaser and Holton, 2005). Grounded theory analyses can help generate hypotheses for future quantitative analysis, which makes it especially appropriate for emerging research on human decisions and nature conservation (Marincola, 2007). The qualitative analysis involves coding and categorizing text from interviews or other sources into common themes (Strauss and Corbin, 1990). We used semi-structured interviews with individuals who were involved in each NI case to identify the common themes in the decision processes. The results from this research advanced our understanding of coastal hazard management, with specific implications for conservation practice, policy, and communications. It also generated specific testable hypotheses for future research on NI decisions.

2. Methods

The methods for developing the grounded theory involved three major steps (Fig. 1). First, we selected cases for analysis from a list of known coastal NI cases. Second, we collected qualitative data on each case through semi-structured interviews. Third, we conducted qualitative data analysis of the interview transcripts to identify common themes that form the grounded theory.

2.1. Case selection

Given that the intention of this study was to identify common themes in decision processes that resulted in NI being used, we used purposive sampling to select three cases where communities chose NI to address problems of shoreline erosion and associated coastal flood hazards. We first compiled a list of known cases in the US where NI was used to address shoreline erosion and coastal flood hazards (Appendix A). The list was compiled by reviewing the peer review and gray literature as well as by asking staff of The Nature Conservancy (TNC) who work on NI projects for successful cases. We recognize that this list is not exhaustive and may have been biased against including beach nourishment and dune restoration projects because it appears that some researchers and practitioners do not consider these NI projects.

Before choosing NI cases for study, we excluded NI cases where TNC played a key role in the decision because we specifically wanted to understand local decision processes. We then chose NI cases from our compiled list based on the following criteria: the project 1) was designed for coastal protection (defined here as protection against shoreline erosion and associated coastal flood hazards), 2) restored or avoided the destruction of natural areas, 3) involved local authorities in the decision, 4) was documented in publicly available materials, and 5) had the potential for stakeholder interviews. This selection process resulted in three cases for study: Ferry Point Park Living Shoreline, Maryland (MD); Surfer's Point Managed Retreat, California (CA); and Durant's Point Living Shoreline, North Carolina (NC) (Fig. 2).

2.2. Qualitative data collection: interviews

We conducted semi-structured phone interviews with a total of 16 people directly and indirectly involved in each of the three cases over a period of five weeks in April and May of 2014 (Appendix B). Purposive and snowball sampling were used to identify interviewees. We were particularly interested in individuals that influenced the infrastructure decisions (e.g., local community members who helped build support for the decision) or had formal decision-making authority (e.g., government officials who approved aspects of the project). We identified an initial set of these individuals via background research in which we reviewed public meeting minutes, media reports, and gray literature on the projects. We then got recommendations from staff of TNC that work in the same geography as the project. During the interview process, we also asked each interviewee for recommendations for additional interviewees.

For consistency across cases, we tried to speak to people with similar roles for each of the cases. These roles included elected officials, state and county government employees, staff of international and local environmental NGOs, citizens, and engineers involved with the three cases. Appendix B includes a table of interviewees, their occupation and the case with which they were involved.

We provided an interview guide and a summary of the research goals to the interviewees in advance of the interview (Appendix C). The interview guide included questions about how the idea for the project came about, the project permitting process and how the project fit into that process; how the project was evaluated;

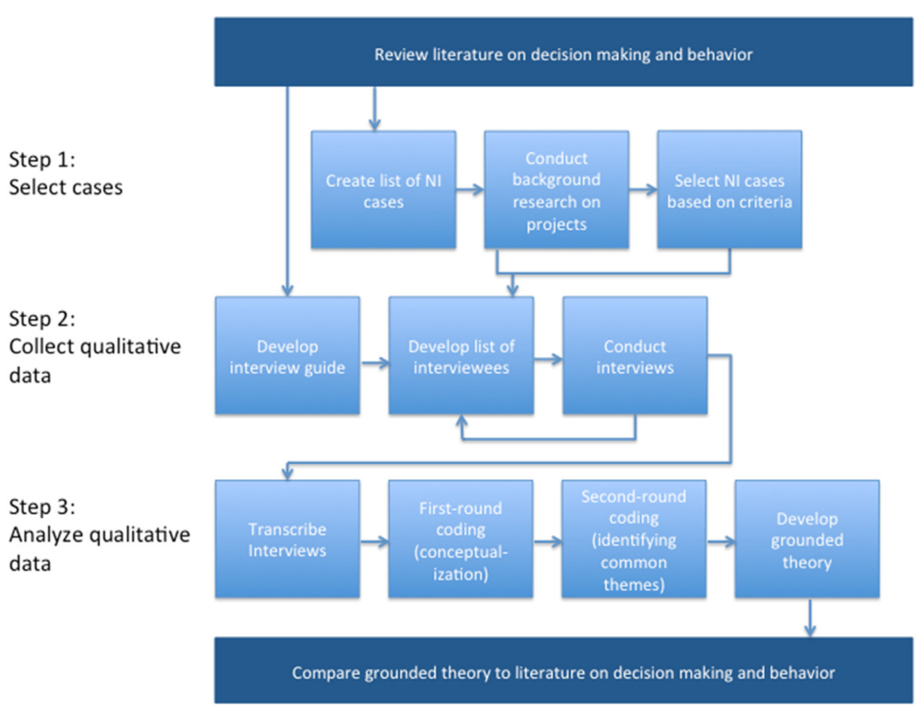

Fig. 1. Flow chart of methodology. The methods for developing the grounded theory involved three major steps: 1) case selection, 2) collection of qualitative data through interviews, and 3) analysis of qualitative data using a constant comparison method.

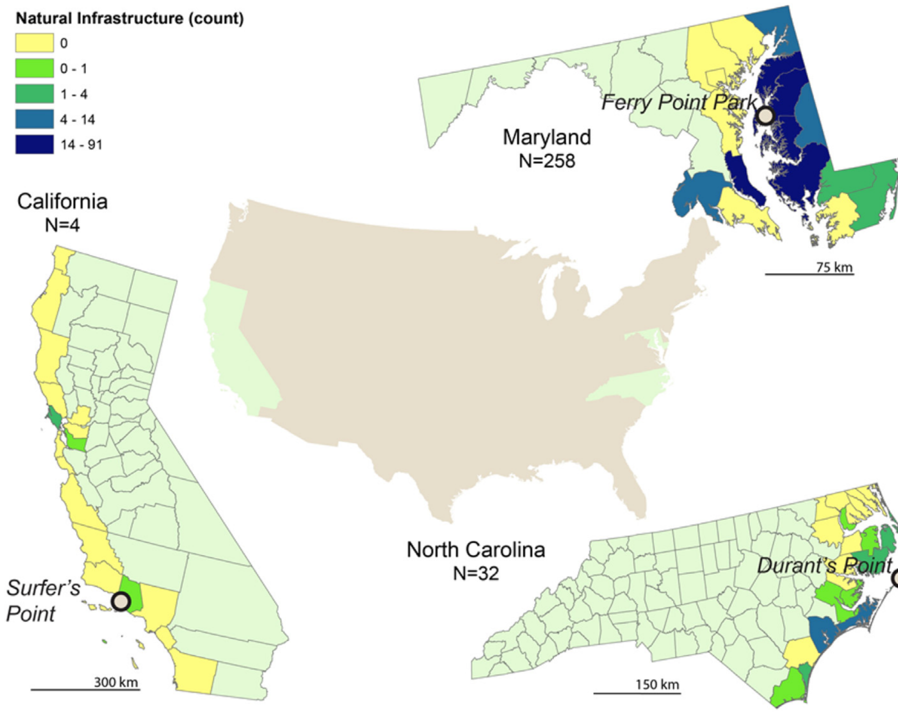

Fig. 2. The three natural infrastructure cases selected for the grounded theory analysis from a list of natural infrastructure cases in the US compiled by the authors (Appendix A): Ferry Point Park Living Shoreline, Maryland; Surfer's Point Managed Retreat, California; and Durant's Point Living Shoreline, North Carolina. The total number of natural infrastructure cases by county in the three states is also shown. The list of natural infrastructure cases may be biased against including beach nourishment and dune restoration projects because it appears that some researchers and practitioners do not consider these natural infrastructure projects. Note, based on this list, Maryland has an order of magnitude more cases than North Carolina and two orders of magnitude more cases than California.

perceptions of NI; how NI is promoted or inhibited by policies, individuals, communities, or organizations; personal experience with NI; and key barriers or success factors. While the guide provided direction, specific questioning was partly determined by the respondents' answers. At the start of the interview, we briefly reviewed the research goals and the terminology 'natural infrastructure.' The questions were open ended. Depending on the course of the interview, we asked follow-up questions and not every interviewee was asked every question in the guide. Interviews lasted approximately 1 h and were recorded (with the subjects' permission) and transcribed for analysis.

2.3. Qualitative data analysis: grounded theory approach

We employed a grounded theory approach to analyzing the interview transcripts 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 applied this method using the qualitative analysis software NVivo 10, beta version for Mac and NVivo for Mac Version 10.1.2. We conducted an initial round of coding that involved conceptualizing the data by applying labels to discrete segments of the transcripts and then grouping the concepts into categories (Strauss and Corbin, 1990; Saldana, 2013). For example, in initial coding, we coded the quote, "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." under the labels "doing something different," "taking a risk" and "comfort level." We further examined the codes and categories 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). In secondary coding, these three example codes were grouped under the category "innovators."

2.4. Assumptions and potential biases

Our research focuses on decision processes that led to the successful adoption of NI as an alternative to gray infrastructure by using purposive sampling. Purposive sampling could bias our results if successful NI cases only occur in particular institutional settings that enable NI. If this were true, the institutional factors that enabled NI in our cases might not be relevant elsewhere. We expect that this potential bias is of minimal concern and does not limit the lessons that can be learned from this analysis for two reasons. First, national policies and institutions related to natural infrastructure apply across the US, laying a common foundation for state and local policies. Second, states and local governments have the capacity to create new policies that could replicate the institutional conditions observed here.

Many of these interviewees were 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. The interviews did include engineers that worked on each project and provided a technical perspective on the costs associated with NI, the challenges of using a new technology without an industry standard of practice and published guidelines, and the permitting challenges of the NI approach. Samples of these responses are represented in Table 1 below. In addition, one of the coastal commissioners discussed not having been a supporter of NI initially. Importantly, however, the decision process, if not the specific factors influencing the decisions, should be similar regardless of whether an interviewee was a supporter or opponent of NI. In addition, socioeconomic status, education, and other attributes of

Table 1
The four themes identified through the grounded theory analysis, the number of times referenced, and representative quotes.

Theme	References	Ferry Point Park, MD	Surfer's Point, CA	Durant's Point, NC
Perceived benefits outweigh perceived costs	46 (benefits)	*"… there was a lot of sensitivity in not harming a natural habitat there … 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"* - former county commissioner, MD	*"Because we were retreating, we were able to create a bit of a beach."* - county public works employee, CA	*"… 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."* - citizen, NC
	31 (costs)	*"… maybe I'm wrong about this but I certainly know that typically living shorelines are more expensive to install then the alternatives."* - former county commissioner, MD	*"… typically soft solutions are not intended to last without a lot of maintenance. So going into it … it's also realizing that you will need money periodically to keep that soft solution going.“* - county public works employee, CA	*"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 … 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 …"* - engineer, NC
Diffusion of innovation led by innovators	48	*" … we kept going forward and said … this is a great opportunity need to do something a little out of the box … we went around the table let's try to do something different."* - state conservation professional, MD	*"So my goal from the get-go of this, you know, 20 years ago, was always to create a demonstration project."* - environmental NGO employee, CA	*"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."* - county commissioner, NC
Local champions	46	"(names of state conservation employees*) … they really, truly believe in what they do, which I know is hard to find in a lot of government employees. But they really, truly believe in what they are doing."* - county conservation employee, MD	*"it was Surfrider who really had the guts and the vision. But you know, surfing and going to the beach is part of the Southern California culture. And I think the City of Ventura got it … I mean, because they are all those same people, right?"* - engineer, CA	*"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 …"* - citizen, NC
Social networks and social norms	30	*"You knew what was over there, so you kind of wanted to do something kind of really neat or cool here …"* - county conservation employee, MD	Not applicable: Surfer's Point was not influenced by seeing other projects; however, the local champions used visual demonstrations to gain support from others in the community. *"I actually had a volunteer draw up the concept. And then we made flyers with that concept on there … And like I said, we had over a hundred people show up to the public meeting in support of the Surfrider alternative …. So I think that having a graphic depiction of these ideas is very, very important."* - environmental NGO employee, CA	*"I took the opportunity to go to Edenton and saw eight or nine before and after pictures in other places and realized maybe this would work and from that point on I was a very huge advocate …"* - county commissioner, NC

the interviewees that might affect the decision process were not assessed in this study because the study used purposive sampling with the intent of exploring decision processes and not random sampling that would allow for drawing inference between the decision process and interviewee or study area attributes.

All of the projects, with the exception of Durant's Point in North Carolina, were funded exclusively 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.

2.5. Background on cases

In all three cases, the recognition of a need to address shoreline erosion and associated coastal flood hazards was a starting point for the projects. Each project involved multiple stakeholders through formal and informal decision making processes. For instance, the design of each project involved engineers as well as stakeholders. Similarly, each process had to be permitted by local, state, and sometime federal agencies. At the time of these projects, all three states at least implicitly recommended or preferred NI and non-structural solutions to coastal erosion, but the permitting process was still more cumbersome for NI than for gray infrastructure and gray infrastructure continued to be the most commonly chosen option (CCC, 1976; CCC, 2013; Griggs, 2010; NCDCM, 2006; MDE, 1992; Skrabal, 2012). The next sections provide more specific details on each of the three cases and their decision and permitting process in order to help put the results from the ground theory analysis in context. This information was gathered through review of the gray and peer-reviewed literature, policies, and the semi-structured interviews.

2.5.1. Ferry Point Park Living Shoreline, Queen Anne's County, MD

Ferry Point Park, a Maryland State Park on the Chesapeake Bay owned by Queen Anne's County, was experiencing erosion due to wind waves (Fig. 3). In 2007–2008, staff from the Maryland Department of Natural Resources (DNR) and others conceived of the living shoreline project that combined NI and man-made elements to address the shoreline erosion and associated coastal flood hazard at the park. The original permit application for the living shoreline was submitted at end of 2008. At the time, the 1992 Maryland Department of the Environment's (MDE) “Shore Erosion Control Guidelines for Waterfront Property Owners” defined living shorelines as the preferred option for addressing shoreline erosion (MDE, 1992); however, the state found that property owners were still opting for gray infrastructure options (MDGA, 2008a). Subsequent to this project, the state addressed this bias by passing the 2008 Maryland Living Shoreline Protection Act, which created a rebuttable presumption for living shorelines except where analyses done by the state showed that structural solutions would be needed (MDGA, 2008b).

Due to physical features of the site, including approximately 19-miles of open water subject to winds from the northwest and an 8–10 foot drop-off just offshore, this site would have qualified for a state waiver to build structural protection under the 2008 law (Bhaskaran Subramanian, pers. comm.). However, DNR chose to pursue an 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. The project was funded through Maryland DNR, Chesapeake and Coastal Trust Fund, DNR Boating and Waterways, and Chesapeake Bay Trust Fund. The living shoreline was constructed through a combination of hardened structures including four headland breakwaters, a low-profile sill and dune groins and

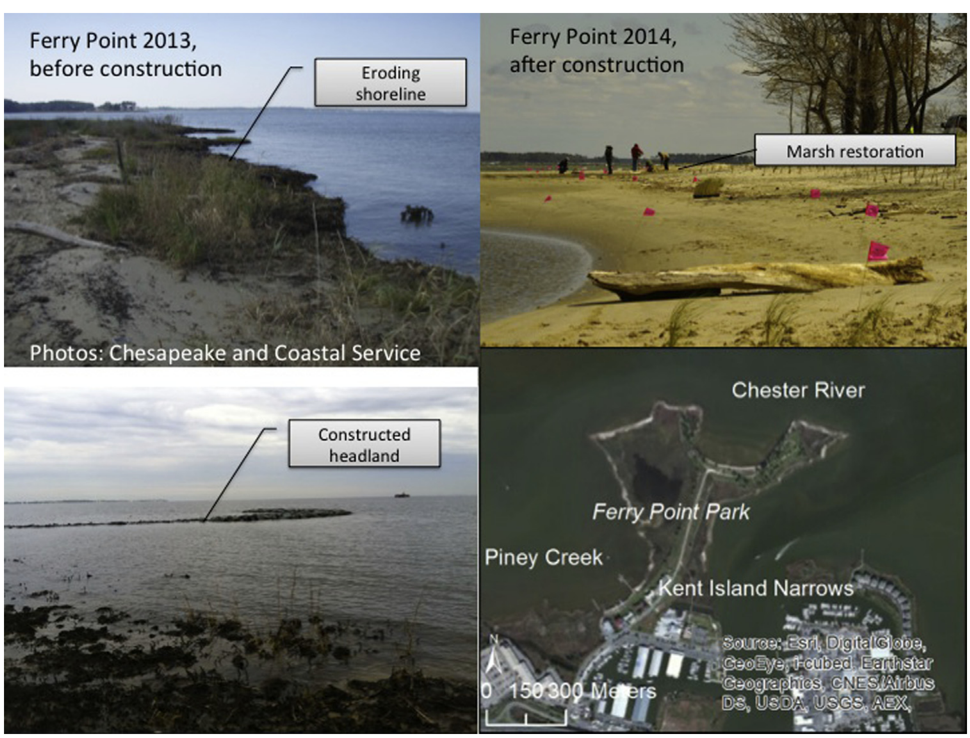

Fig. 3. Ferry Point Park Living Shoreline, Queen Anne's County, MD. The park is a 41-acre peninsula owned by Queen Anne's County and located at the north end of Kent Narrows in Chesapeake Bay between the Eastern Bay and Chester River. The living shoreline consists of a combination of four headland breakwaters, a low-profile sill and dune groins, and vegetative marsh and beach plantings along approximately 2600 linear feet of shoreline. 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.

Fig. 4. Surfer's Point Managed Retreat, Ventura, CA. The Surfer's Point property is owned by Ventura County Fairgrounds and located east of the mouth of the Ventura River in the City of Ventura. Phase 1 of the managed retreat involved construction of a cobble berm for back beach shoreline restoration and relocation of the bike path and parking lot 60 feet landward. 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.

restoration of vegetative marsh and beach plantings along approximately 2600 linear feet of shoreline. The living shoreline part of the park opened to the public in June of 2014.

2.5.2. *Surfer's Point Managed Retreat, Ventura, CA*

Surfer's Point is a ~20 acre shoreline area in the City of Ventura, CA (north of Los Angeles) that includes beach, a parking area, bikeway, public roadway, and undeveloped areas within the Ventura County Fairgrounds (Fig. 4). The bike path was impacted by erosion just two years after the City of Ventura opened the path and adjacent parking lot to the public in 1989 (Gowenlock, 1989). In response to the damage, the Ventura County Fairgrounds, which is located directly inland from the bike path and parking lot, 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 from erosion and associated coastal flood hazards. 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). 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.

Settlement resulted in the formation of a multiagency and stakeholder working group in 1995 to find an alternate approach to structural protection to deal with the erosion problem. According to Surfrider Foundation, the working group had reached a conceptual agreement in the late 1990s on the retreat approach, but it was not included in an Environmental Impact Report performed by the City of Ventura. During the public commenting period, Surfrider applied public pressure by gathering hundreds of supporters and presenting a sketch of the managed retreat idea, which combined natural features and hardened structures to halt erosion and protect the shoreline. The working group subsequently agreed to relocate the bike path and parking lot inland to account for wave height and an increase in future sea-level rise of 1.5 feet (Rick Raives, pers. comm.). Phase 1 included construction of a man-made cobble berm to 8-feet depth to stabilize the shoreline and enable back beach shoreline restoration and relocation of the bike path and parking lot 60 feet landward. Phase 1 construction began in 2010 and was completed in July 2011. The City of Ventura used funding from the U.S. Department of Transportation's TEA-21 (Transportation Equity Act for the 21st Century) program to pay for relocation of the bike path.

2.5.3. *Durant's Point Living Shoreline, Dare County, NC*

Durant's Point is privately owned land located at the entrance to Hatteras Harbor on the Outer Banks of North Carolina (Fig. 5). The idea for a living shoreline project came from two citizens (a husband and wife) of Hatteras Island who had observed erosion on the point. The couple are natives of Hatteras and own a charter fishing company. They both were also involved with the North Carolina Coastal Federation (NCCF) (the husband served on the board), a local NGO dedicated to fostering citizen stewardship of North Carolina's coastal water quality and resources (NCCF, 2015). The couple suggested NI as a potential approach to control the erosion at Durant's Point. NCCF secured funding through a grant from the National Oceanic and Atmospheric Association's (NOAA's) Restore America's Estuaries program, which supports community-based restoration projects, and additional funds from a private community foundation. NCCF also worked with an engineering firm to design the project, which includes a combination of an engineered low-profile breakwater and vegetative marsh restoration. Following a site evaluation based on cost, longevity and exposure, three design options for the living shoreline were presented to the private property owners, who chose to use a more expensive rock sill over timber due to concerns about long-term maintenance needs. The final design consisted of a 320-foot long low-profile

Fig. 5. Durant's Point Living Shoreline, Dare County, N.C. Durant's Point is a privately-owned property located on a peninsula at the entrance to Hatteras Harbor in Pamlico Sound on the Outer Banks of North Carolina. The living shoreline consists of 320-foot long low-profile granite sill with restored marsh. 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.

granite sill with restored marsh.

As of 2005, the Coastal Area Management Act (CAMA), which is administered by the NC Coastal Resources Commission, lists a general permit (as opposed to a minor or major permit) for the construction of a riprap sill for wetland enhancement, as well as for timber or vinyl sheet pile sills for wetland enhancement (NCDCM, 2015). Conventional shoreline infrastructure such as docks, piers, simple boat ramps, bulkheads and riprap revetments are also included in the general permit. However, when the engineers contacted CAMA about the Durant's Point Living Shoreline project, they were told that the project would require a CAMA major permit due to concerns from the Army Corps of Engineers and the Division of Marine Fisheries. The permit application was submitted in October of 2010 and was received in March of 2011. By requiring a CAMA major permit rather than a general permit, the NI project – which combined natural and gray features – was more time consuming and expensive than a gray infrastructure approach, such as a bulkhead or riprap revetment. The NCCF presented a general technical analysis, based on the work of the engineering firm, to the Dare County Board of Commissioners at a public meeting. In January of 2011, the Dare County Board of Commissioners agreed to assume responsibility for maintenance of the living shoreline. Construction began in March of 2011. A two-year status update that was presented to Dare County Board of Commissioners in September, 2013 by NCCF showed progress in the growth of the living shoreline project.

3. Results

Through our analysis of the interview transcripts, we found four common themes across these three NI decisions: 1) perceived benefits outweigh perceived costs, 2) diffusion of innovation led by innovators, 3) local champions, and 4) social networks and social norms. Table 1 summarizes the results for each theme with the number of times it was referenced, and a representative quote from each case.

3.1. Perceived benefits outweigh perceived costs

Interviewees' support of NI was influenced by their perception of costs and benefits of investment in NI, but the perceptions of costs and benefits were likely formed by heuristics rather than objective information or data. Interviewees made 46 references to perceived benefits as compared to 31 references to perceived costs (Table 1). Benefits were most frequently discussed in terms of enhanced ecosystem services (commercial fishing, recreational use [including recreational fishing], water filtration, esthetic improvements, sense of place, coastal heritage and lifestyle) and avoided land development. References to recreational activities, such as surfing and beach going, appeared to be supportive of a "lifestyle," rather than actual activities.

These references also seem to stem from emotional associations with a strong sense of place and history, and with a desire to maintain or return to a "more natural" state. This interpretation is based on references to childhood memories of the location, *"as a kid playing under the docks … the place wherefore the creatures and the critters to live"* and strong personal connections, *"it starts with people that care about a particular place and are willing to put effort into it."* The specificity of these references to the place, rather than to nature in general, indicates the role of place attachment in shaping perceptions of benefits of NI (Bott et al., 2003). 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 affect heuristics or emotional responses related to the location or community (Slovic et al., 2007).

Participants were not asked to quantify the perceived benefits or costs associated with NI. With the exception of Surfer's Point, where the landowner 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 was frequently in terms of NI projects taking longer due to design and permitting and maintenance needs. Engineers also perceived potential costs and risks from being professionally associated with NI projects.

3.2. Diffusion of innovation led by innovators

Supporters of NI in all three cases had characteristics of innovators as described in diffusion of innovation theory (Rogers, 1983; Aronson and Aronson, 2008). Respondents made 34 references to "doing something different," with another 14 references to a willingness to take a risk and "try it" (Table 1). These references were frequently anchored to a sense of pride. Participants also discussed motivations for investing in NI in terms of the opportunity for their community to serve as a demonstration site and provide educational tools for others, increasing further adoption of the new technology. 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.

3.3. Local champion

In all three cases, learning about NI from a source with ties to the local culture and through social networks enhanced 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 (Table 1). Participants discussed the role of local actors to gain cultural acceptance within a small community. These responses provide evidence of the influence of the "messenger," a familiar peer, to spread an idea (Aronson and Aronson, 2008; Dolan et al., 2012). 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. 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.

3.4. Social networks and social norms

Learning about other NI projects through social networks influenced 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 (Table 1). Multiple supporters of NI were able to learn about NI success cases by being socially connected to local environmental or advocacy organizations. Geographic proximity of the examples was also important in facilitating exposure. 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. Projects that were done in similar geographic or environmental conditions appeared to provide the greatest confidence in the technology. Projects that were done in similar socioeconomic and cultural conditions seemed to create a perception of NI as a growing social norm. Specifically, participants discussed seeing projects in similar communities as motivation to build one in their own community, which may indicate the effect of contagion, inspiring similar behavior, or social norms as a motivation (Aronson and Aronson, 2008).

4. Discussion

We found that behavioral, social, and institutional factors influenced how people learned about NI and formed perceptions of the benefits and costs of NI. This is not exclusive of scientific and economic information, as we found that conservation professionals and engineers involved in each project were viewed as trusted experts and used scientific and economic information to help evaluate options. However, the beliefs and actions of the trusted experts or other people in the community as well as visual demonstrations of similar projects appeared to provide important heuristic shortcuts to scientific evidence and supported adoption of the technology. These results advance our understanding of NI decisions in two key ways: by highlighting how perceptions of benefits and costs of NI are formed and by illustrating the way that information, behaviors, and norms related to NI are spread.

Decision makers chose to invest in NI because perceived benefits outweighed perceived costs, which is consistent with a rational actor and assumptions underlying economic efficiency (Keohane and Olmstead, 2007). However, discussions about benefits were rarely based on specific or objective scientific information, which was analyzed and communicated in each case by a conservation professional or engineer associated with the project. We found that these individuals were viewed as trusted experts by the other individuals involved in the projects. When asked about the decision, respondents frequently said that NI "just made sense" and was a "better fit" than conventional infrastructure alone, indicating that these perceptions were based less on conscious cognitive processes and more on affect. Perceptions formed by heuristics, with a reliance on experts, as opposed to conscious cognitive processing, may result in good decisions but they are also susceptible to cognitive bias and could lead to inaccurate judgment when weighing investment in NI vs. engineered infrastructure (Aronson and Aronson, 2008; Martin, 2012). For example, perceived costs and benefits may significantly differ if a stakeholder was part of a social group that was uncomfortable with NI.

Decision makers had characteristics of "innovators," who are defined as the first to employ a new idea, practice, or technology as described in diffusion of innovation theory (Rogers, 1983; Wejnert, 2002). We found these individuals had high social status within their communities as business people, conservation professionals, elected officials, and leaders in non-profit organizations. 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). 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 (McKenzie-Mohr, 2000; Bollinger and Gillingham 2012). However, given that these sites are chosen by the conservation professional, it would be difficult to separate out the influence of these particular sites from the influence of what decision makers might learn from peers. These peer networks are key to widespread adoption of the technology, as ideas are passed among stakeholders with similar socioeconomic status (Rogers, 1983). Our findings emphasize the importance of not only innovators who are willing to take a risk, but are also local champions for the project (Durantini et al., 2006; Cialdini, 2009; Dolan et al., 2012). The emphasis on open communication and community engagement further supports efforts within the conservation community to foster local ownership of projects (Horwich, 2011; Shanee, 2013).

The decision to invest in NI takes place within the larger context of state and federal coastal development and erosion mitigation policy. As such, our findings show that regulatory permitting requirements can either perpetuate or help control biases against innovations like NI. In Maryland, for instance, the Living Shorelines Protection Act of 2008 made NI a rebuttable presumption (MDGA, 2008a). This means that NI is presumed to be the appropriate solution except in places where analysis by the Maryland Department of the Environment has shown structural options are necessary based on biophysical conditions (MDGA, 2008a). Under this policy, the state requires the property owner to take extra steps to apply for a waiver in order to build a protective structure outside of those areas (MDGA, 2008a). This policy may explain in part why, according to our list of NI cases, Maryland appears to have an order of magnitude more NI projects than North Carolina and two orders of magnitude more than in California (Fig. 2). Unfortunately, however, we cannot have high confidence in this trend because our list of NI cases was not exhaustive and may have been biased against beach nourishment and dune restoration projects.

The shift from being a preferred option to essentially a required option in Maryland was likely critical for overcoming the fact that, even when NI is a preferred option, private landowners continue to choose cheap and ineffective engineered options (Ricketts, 1986). Due to the time of the legislation, this policy did not have a direct impact on our study case and thus was not a primary focus of investigation. However, the state of Maryland had a number of enabling conditions that may have made this policy possible and warrant further investigation. First, the environmental conditions were right. The state was aiming to address shoreline erosion from sea-level rise and day-to-day wind waves (as opposed to protecting from large hurricanes) and the state has vast areas of marshes that can help mitigate erosion from smaller hazards (MDGA, 2008a; Gedan et al., 2010; Arkema et al., 2013). Second, the staff at the MD Department of Natural Resources developed the capacity to provide technical assistance to land owners (including providing analyses and maps of where structural options were suitable), the staff were champions of NI, and there was a state funding mechanisms for NI. Third, interviewees suggested sociopolitical enabling conditions including the fact that Maryland is a liberal state and has similar prior experience via management of the Chesapeake Bay restoration efforts. Lastly, the Maryland Commission on Climate Change was a catalyst for the policy, recommending that the state require NI to address erosion and future sea-level rise (MDGA, 2008a).

This research presents a first step towards applying insights from the behavioral sciences to conservation of natural resources and, in particular, infrastructure investment decisions. This is an emerging and critical area of research that must be addressed to tackle large environmental challenges, yet it is still in its infancy with few empirical studies (Cowling, 2014). However, the results of this study are limited in a few notable ways. While we did attempt to include similar types of decision makers across the three cases, this representation is far from exhaustive. In addition, this research focused only 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. It should also be noted, that each of the cases studied included a combination of natural features and hardened structures. The inclusion of traditional engineered features may have influenced the decision to invest in these projects, as the choice between NI and gray infrastructure was not mutually exclusive. However, we did not specifically ask about this in our interviews and would not want to speculate for the purposes of this paper. To address some of these limitations, future research should investigate cases of engineered infrastructure decisions, combined NI and gray projects, 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 previous research on the role of heuristics in consumer behavior (e.g., Bollinger and Gillingham, 2012). We recognize that decisions about infrastructure investment and resource conservation rarely take place solely at the individual level and so we recommend that further research be conducted to study these influences on collective behavior at the community level with connections to the individual and institutional level. Such work will become ever more critical as anticipated acceleration in the rate of sea-level rise will force decisions about coastal protection and coastal realignment that have been avoidable for centuries.

5. Conclusion

This study highlights an important opportunity and risk related to incorporating habitat restoration and protection (i.e., NI) into coastal protection decisions. Communities may be at risk not only of underutilizing NI but also of misuse if they are heavily relying on heuristics and other automatic processes (Aronson and Aronson, 2008; Martin, 2012). In this context, policies such as the MD Living Shoreline Protection Act, standards, and decision analysis tools can help control biases that could result in underuse or misuse of NI. This suggests that conservation scientists and practitioners should specifically focus on replicating the MD Living Shoreline Protection Act in other states as appropriate, building the capacity of engineers and government scientists to develop standards to design and evaluate NI in order to support community decisions, and to continue to develop and deploy decision support tools such as Coastalresilience.org. At the same time, these results identify an opportunity to harness heuristic to mainstream NI in places where science shows NI would be effective.

Conservation practitioners can use the results of this study to inform tactics at demonstration sites (e.g., using the demonstration sites as visual aids, identifying innovators and local champions, spreading messages through social networks, connecting to emotion and sense of place). Specifically, our grounded theory provides the basis for testable hypotheses about what conservation tactics may be more likely to result in support for NI (e.g., visual aids/demonstrations vs. information campaigns). In addition, the results suggest that some of the biggest policy opportunities may be at the state level, rather than the national level, and the MD Living Shoreline Protection Act provides an important model for state-level natural infrastructure policy. In sum, our study suggests that future scientific efforts to advance our understanding of human behaviors and decisions have great potential to improve the effectiveness and efficiency of conservation practice by identifying ways to harness heuristics and control biases.

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Appendix A. Compiled list of known coastal natural infrastructure cases, selection criteria, and results of selection process.

Case [results of selection process]	Project details	Project dates	Selection criteria				
			Involvement of local authority	Addition-ality	Documented in publicly available materials	Designed for coastal protection	Potential for interviews
Ferry Point Park, MD **[selected]**	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	Construction started 9/13	Yes, Queen Anne's County	Yes	Yes, MDE website, public meeting minutes	Yes, shoreline erosion	Yes
Jockey's Ridge State Park Shoreline Restoration, NC **[excluded due to TNC involvement]**	Living Shoreline – planting marsh grass and creating oyster reef barriers	Restoration, 2009–2010	Yes, N.C. state parks	Yes	Yes	Yes, shoreline erosion	Yes
Durant's Point, Hatteras Harbor NC **[selected]**	Living Shoreline – restored marsh, 320-foot-long, low-profile granite sill	Restoration, 2011	Yes, Dare County	Yes	Yes	Yes	Yes
Grand Liard Marsh and Ridge Restoration, LA **[excluded because it is not completed and potential for interviews is unknown]**	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	Approved: 2009, Request for funds: 2011, Bids for Contracts: Dec 2013	Yes, State of Louisiana Coastal Restoration	Yes (in future)	Yes	Yes	Unknown
Prime Hook National Wildlife Refuge Coastal Tidal Marsh/ Barrier Beach Restoration, DE **[excluded due to no involvement of local authority]**	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)	Hurricane Sandy Disaster Relief appropriations approved 10/ 2013, Hydrological Modeling of impacts to flooding completed 2/2014	No, federal: U.S. Fish and Wildlife Service	Yes (in future)	Unknown	Unknown	Unknown
Dyke Marsh restoration, VA **[excluded due to no involvement of local authority]**	Marsh restoration	Hurricane Sandy Disaster Relief appropriations approved 10/ 2013, plan for public comment	No, federal: U.S. National Park Service	Yes (in future)	Unknown	Unknown	Unknown
San Fransisco Bay Tidal Marsh Restoration, CA **[excluded due to low potential for interviews because of age of project]**	Temperate Salt Marsh- Restoration of tidal marshes and salt marshes	Multiple restoration projects on-going for 20 years	Yes, California Department of Fish and Game, the U.S. Fish and Wildlife Service, and the California Coastal Conservancy	Yes	Yes	Yes	Unknown
Surfers Point Managed Retreat, CA **[selected]**	Cobble Beach and Dunes – Phase 1 – complete 2011Removal of damaged parking lot, widening of beach by 60-feet, construction of a new cul-de-sac on shoreline 1000-ft. to the east, relocation of multi-use bike path inland – 2012- Restoration of dunes along 3 acres	2001–2011	Yes, Surfrider Foundation, City of Ventura, Ventura County Fairgrounds (Seaside Park), California Coastal Conservancy, California State parks, the State Coastal Commission	Yes	Yes, City of Ventura City Council public meeting minutes (2/22/10 – authorized purchase of materials)	Yes	Yes
Avalon Dune Nourishment Program, NJ **[excluded due to low potential for interviews because of age of project]**	Coastal Dunes – Dune nourishment and maintenance	6 projects starting in 1987	Yes, Avalon & Stone Harbor, NJ	Yes	Likely - http://		www.mantoloking.org/ beachqa.pdf
Yes	Yes, but limited http:// www.sevenmiletimes.com/ Spring-2013/Good-Thinking/						

(*continued on next page*)

(*continued*)

Case [results of selection process]	Project details	Project dates	Selection criteria				
			Involvement of local authority	Addition-ality	Documented in publicly available materials	Designed for coastal protection	Potential for interviews
Albermarle-Pamlico Climate Change Adaptation Project, NC **[excluded due to TNC Involvement]**	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	Completed 2010–2011, additional activities at other sites continuing	No, federal: US Fish and Wildlife Service (with TNC)	Yes	Yes	Yes	Yes
Oyster Habitat Restoration, FL **[excluded due to TNC involvement]**	Oyster restoration – Restore 18 acres of oyster habitat in Charlotte Harbor Estuary	RESTORE SW FL Shellfish Restoration Proposals – April 2013, Draft permit language – Feb 2013	No, federal: Southwest Florida National Estuary Programs, Charlotte Harbor Estuary Program (with TNC)	Yes (in future)	Unknown	Yes	Yes
Virginia Coast Reserve, VA **[excluded due to TNC Involvement]**	Living shoreline – Protected 14 barrier islands, restored oyster reefs and wetlands. Working with UVA LTER to show benefits of oyster reefs and eelgrass (200 → 2400 acres) in dampening wave energy and protecting marsh.	1999–2009?	No, TNC	Uncertain	Unknown	Unknown	Yes
South Cape May Meadows Preserve and Cape May Point State Park, NJ **[excluded due to TNC Involvement]**	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	2004	Yes, NJ Dept of Environmental Protection Also, TNC, USACE	Yes	Unknown	Unknown	Yes
Alabama Coastal Resilience Project, AL **[excluded due to TNC Involvement]**	Oyster restoration – 100–1000: Restore Coastal Alabama" restore 100 miles of oyster reefs and enhance 1000 acres of marsh; ARRA funds from NOAA (2009) used to build 1/4 mile (2011), goal: 2 miles	2001-present	Yes, TNC, Alabama Dept of Conservation and Natural Resources State Lands Division, Dauphin Island Sea Lab, Mobile County, University of South Alabama	Yes	Unknown	Unknown	Yes
Grand Isle and St Bernard Marsh Shoreline Protection Project, LA **[Excluded due to TNC Involvement]**	Oyster Reefs - Restoring 3.4 miles of oyster reefs off the coast of Louisiana that border some 350 acres of marshland	2010	No, TNC	Unknown	Unknown	Unknown	Unknown

Note: Fig. 2 shows additional natural infrastructure cases by county in the three states in which the selected cases are located. These additional cases were identified after this selection process was completed during the course of interviews and further research. For example, as a result of one of the interviews, we received a database of the number of living shoreline cases by county from the Maryland Department of Natural Resources, which was used in Fig. 2. However, this database would not have provided sufficient information to select cases according to our criteria.

Appendix B. List of interviewees for each of the three natural infrastructure cases

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 Bunkar	Director of Conservation Programs, The Nature Conservancy- Maryland
Bhaskaran Subramanian	Program Manager, Habitat Restoration and Conservation, Maryland Department of Natural Resources
Surfer's Point Managed Retreat, Ventura, CA	
Lily Verdone	Los Angeles/Ventura Project Director, The Nature Conservancy- California
Paul Jenkin	Surfrider Foundation
Rick Raives	City of Ventura, Public Works
Bob Battalio	ESA | Environmental Hydrology
Durant's Point Living Shoreline, Dare County, NC	
Christine Pickens	Coastal Restoration and Adaption Specialist, The Nature Conservancy- North Carolina
Aaron McCall	Northeast Regional Steward, The Nature Conservancy- North Carolina
Erin Fleckenstein	Coastal Scientist and Regional Manager, North Carolina Coastal Federation
Ernie and Lynne Foster	Coastal Federation Board Member and Wife, Owner/Operators of Albatross Fleet (fishing charter company)
Dave Klebitz	Engineer, Bissell Professional Group
Allen Burrus	Dare County Commissioner

Appendix C. Interview guide

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?

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