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ORIGINAL ARTICLE

Coastal hazard mitigation considerations: perspectives from northern Gulf of Mexico coastal professionals and decision-makers

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Abstract

This paper reports on the process and results of stakeholder focus groups conducted as part of a larger multi-year, National Oceanic and Atmospheric Administration-sponsored, transdisciplinary coastal resilience research project in the northern US Gulf of Mexico. The focus groups' purpose was to better understand local coastal professionals' and decision-makers' (e.g., natural resource managers, community planners, extension and outreach specialists) views on mitigation options for coastal hazards (e.g., storm surge, nuisance flooding, sea level rise) including use of natural and nature-based features (NNBF; e.g., sand dunes, living shorelines, oyster reefs). Overall, results revealed that participants were aware of various mitigation options, had favorable views toward NNBF infrastructure, and perceived five major benefits and six major barriers or challenges with such approaches. Designing and implementing NNBF infrastructure was perceived as complex and requiring several types of ecological and socioeconomic considerations and information for decision-making. We conclude with a discussion of findings, practical implications for coastal resilience planning and management, and recommendations for future research.

Keywords Coastal hazard mitigation · Natural infrastructure · Nature-based solutions · Coastal resilience · Stakeholder engagement

Introduction

Coastal communities are vulnerable to multiple and increasing physical hazards including more frequent and severe storms, flooding, erosion, sea level rise (SLR), and anthropogenic pressures from continued population growth and urban development (Bridges et al. 2015; Reguero et al. 2018). Protection and mitigation approaches include elevating homes, relocating, acquiring property, regulating land use, installing physical barriers, and using natural infrastructure. The suite of approaches a community implements depends on many factors, such as geographic location, existing infrastructure, type of hazard, cost, and public support (Nordstrom 2014; Livingston et al. 2019).

In this paper, we report on focus group results aimed at better understanding local coastal professionals' and decision-makers' familiarity with and views on coastal hazard mitigation options for nuisance flooding, storm surge, and SLR, especially those involving natural and nature-based features (NNBFs). We conducted focus groups as part of a larger multi-year, National Oceanic and Atmospheric Association-sponsored, transdisciplinary coastal resilience research project in the northern US Gulf of Mexico. The overall project's objective was to develop and refine hydrodynamic, biological, and economic models to help local coastal professionals and decision-makers (e.g., natural resource managers, community planners, extension specialists) understand, plan for, and assess the impacts of NNBFs in the region. The focus group project component

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was designed to provide feedback to help tailor the scientific modeling results and communication strategies to the local context. The results reported here illuminate the focus group participants' concerns and informational needs as they relate to NNBFs.

Literature review

There are three general forms of coastal protection: built, natural, and hybrid infrastructure. Each has unique strengths and weaknesses (for a summary, see Sutton-Grier et al. 2015). The more established built or "gray" infrastructure involves shoreline armoring (e.g., seawalls, bulkheads, riprap revetments, jetties, and groins) solely with human-built materials (Langridge et al. 2014; Nordstrom 2014). While built infrastructure offers well-tested physical protection and tends to have stakeholder confidence (Kochnower et al. 2015; Sutton-Grier et al. 2015; Smith et al. 2017; Livingston et al. 2019), projects can require significant financial investment, will eventually need repair or replacement, and may have performance limitations or harmful consequences (e.g., exacerbating flooding, spreading invasive species, causing habitat loss) (Nordstrom 2014; Scyphers et al. 2015; Sutton-Grier et al. 2015; Nesshöver et al. 2017; Livingston et al. 2019; Lipiec 2020). Natural or "green" infrastructure relies on ecosystems for coastal protection and mitigation which are relatively long-standing in age and created through physical, biological, and chemical processes that evolve over time (e.g., barrier islands, beaches and dunes, vegetation, oyster reefs, coastal forests) (Bridges et al. 2015; Livingston et al. 2019; Lipiec 2020). Hybrid infrastructure combines built and natural components (e.g., living shorelines, artificial reefs, and marsh with rock sill) to offer relatively secure coastal protection while emulating natural features and providing the same or similar co-benefits (Bridges et al. 2015; Lipiec 2020).

In this paper, we use the term "natural and nature-based features" (NNBFs) to refer to both natural and hybrid infrastructure projects that incorporate varying degrees of built materials. All NNBFs rely on ecological processes and functions to buffer storm surge, reduce erosion and flooding, and provide co-benefits to humans and the environment (e.g., preserving wildlife habitat, regulating water quality, offering aesthetic appeal and recreational opportunities, supporting commercial fishing and tourism, maintaining sense of place) (Langridge et al. 2014; Kochnower et al. 2015; Sutton-Grier et al. 2015; Lipiec 2020). Like built infrastructure, NNBFs have drawbacks like cost, uncertain efficacy during extreme episodic events, or loss of shallow intertidal habitats (Sutton-Grier et al. 2015). Finally, built infrastructure and NNBFs can be used separately or in combination depending on the project (Nordstrom 2014; Lipiec 2020), and may work best together in an integrated coastal defense scheme to optimally respond to multiple dynamic stressors (Bridges et al. 2015).

There has been increasing interest, investment in, and applications of "engineering with nature" over the past several decades (Bridges et al. 2015; Kochnower et al. 2015; Sutton-Grier et al. 2015; Ruckelshaus et al. 2016; Arkema et al. 2017; Reguero et al. 2018; Lipiec 2020). Emerging US federal policies require more integration of built and natural infrastructure for coastal hazard mitigation (Gray et al. 2017); various NGOs (e.g., The Nature Conservancy) are advocating for NNBFs to be included in coastal resilience plans (Kochnower et al. 2015), and federal government agencies have been initiating and involved in such projects (Bridges et al. 2015).

While NNBF implementation has been gaining momentum, techniques are evolving and there is still much to be learned, including how to translate a growing body of knowledge into effective action (Ruckelshaus et al. 2016; Evans et al. 2017; Reguero et al. 2018; Livingston et al. 2019). To date, much NNBF-related research has stemmed from the physical sciences and engineering; for example, comparing characteristics of different types of shoreline protective structures (e.g., Smith et al. 2017); economic analyses (e.g., Narayan et al. 2016; Reguero et al. 2018), usage contexts (e.g., Kabisch et al. 2016; Raymond et al. 2017), or outcomes (e.g., Venkataramanan et al. 2019). Other studies examine policy implications (e.g., Ruckelshaus et al. 2016; O'Donnell 2017), provide systematic literature reviews (e.g., Nordstrom 2014; Sutton-Grier et al. 2015; O'Donnell 2017; Kumar et al. 2020; Nelson et al. 2020), and propose conceptual frameworks for NNBF project guidance (e.g., Evans et al. 2017; Nesshöver et al. 2017; Raymond et al. 2017; Santiago et al. 2021). Research has identified a need for more situated social science research to gain insight from local stakeholder communities and overcome barriers between planning and implementation (Scyphers et al. 2015; Nesshöver et al. 2017; Venkataramanan et al. 2019). Published social science studies have primarily relied on quantitative surveys. For instance, Scyphers et al. (2015) and Smith et al. (2017) both surveyed US waterfront property owners on their perceptions and decision-making on shoreline protection structures. Evans et al. (2017) surveyed British stakeholders' perceptions on multi-functional coastal defenses and potential to provide ecological and socioeconomic benefits aside from hazard protection. Mixed-methods studies include Santoro et al. (2019), who used interviews and group visualization exercises to understand practitioners' risk perceptions related to NNBFs; and Fisher et al. (2020), who examined European professionals' views on the social impacts of implementing green infrastructure projects via a survey and follow-up interviews.

A transdisciplinary research approach (e.g., Lang et al. 2012; Leavy 2011; DeLorme et al. 2016; Steger et al. 2021)

that integrates different types of expertise and local knowledge from stakeholders throughout the process is crucial for the development of viable, socially acceptable, and sustainable coastal hazard mitigation (Nordstrom 2014; Scyphers et al. 2015; Bridges et al. 2015; Evans et al. 2017; Nesshöver et al. 2017; Raymond et al. 2017; Livingston et al. 2019). Diverse types of knowledge are needed to assess tradeoffs and identify information needs to determine the best among alternative solutions (Nordstrom 2014; Raymond et al. 2017). Better understanding and incorporating stakeholder perspectives on mitigation strategies is a crucial step in NNBF project planning, implementation, and widespread acceptance (Bridges et al. 2015; Cunniff 2016; Gray et al. 2017; Nesshöver et al. 2017; Raymond et al. 2017).

The northern Gulf of Mexico (coastal Mississippi, Alabama, and northwest Florida) is characterized by low-lying topography, frequent tropical systems, and high rates of rainfall (> 60"/year; Terando et al. 2018; Wuebbles et al. 2017). Coastal hazards include but are not limited to erosion, fluvial and pluvial flooding, storm surge, saltwater intrusion, hurricane-force winds, and tornadoes. Furthermore, the region is home to a rapidly accelerating SLR that is much greater than the global average, and is among the highest in the USA (Sweet et al. 2022). Rising seas exacerbate existing hazards for more frequent and intense coastal, tidal, pluvial, and fluvial flooding (Bilskie et al. 2019; Sweet et al. 2022; Terando et al. 2018).

As outlined previously, this paper reports perspectives from local coastal professionals and decision-makers (e.g., natural resource managers, community planners, extension specialists) on mitigation options for current and future coastal hazards from the northern Gulf of Mexico. Coastal professionals in the region are well versed in coastal hazards, with multiple occurring annually on average. Many, though not all, of the coastal professionals involved had received some training around SLR and its exacerbation of coastal hazards through this project and other regional and local efforts. Finally, at the time of this study (2017–2019), there was little top-down pressure in the region to consider the impact of changing conditions on coastal hazards. For example, Florida had passed the Peril of Flood Act (Florida SB 1094: An Act Relating to the Peril of Flood, 2015) which requires all communities to include SLR in their comprehensive plans; however, there was neither guidance on how to address SLR nor was specific action regarding SLR required (Holmes and Butler 2021). Given this, efforts to pursue resilience to changing coastal hazards with or without NNBFs were largely driven by local interest and need. While coastal professionals in the region face a similar array of potential coastal hazards, different timing of these hazards, specific landscape considerations, and varied opportunities for funding and action lead to differences in the scope and structure of coastal protection regionally.

Method

Focus groups are a well-established qualitative social science method that places importance on the interaction between participants (Freeman 2006; Kitzinger 1994). Through group dynamics, focus groups can promote self-disclosure and prompt spontaneous remarks, articulation of assumptions, diverse perspectives, detailed descriptions of firsthand experiences, and contextual nuances. Furthermore, discussions can explore unanticipated topics as they arise (Hesse-Biber 2017). These methodological strengths are particularly well-suited for examining multi-faceted, context-dependent, and situationally complex processes such as NNBF decision-making (Raymond et al. 2017; Venkataramanan et al. 2019). In addition, focus groups can help build trust between researchers and stakeholders and improve research usability (Lemos et al. 2012). During focus groups, participant interaction can be complementary (e.g., sharing similar experiences) as well as argumentative (e.g., questioning, challenging, and disagreeing) (Kitzinger 1994). Being with other people who share similar experiences encourages participants to express, clarify, or develop certain views and when there is dissent in a group, the participants can be encouraged to explore the diversity of perspectives (Hesse-Biber 2017; Kitzinger 1994; Lune and Berg 2017). The focus group process allows participants to address topics and issues in the discussion that are perceived as especially relevant to them using their own words, which can minimize researcher biases and enable the emergence of unplanned insights, though careful preparation is crucial for successful outcomes (Lune and Berg 2017).

We conducted six total focus groups of between nine and twelve participants each during the project's annual workshops at National Estuarine Research Reserve (NERR) facilities in Apalachicola, Florida; Grand Bay, Mississippi; and Weeks Bay, Alabama. All study procedures were approved by the first author's Institutional Review Board. The purpose of the workshops was to reiterate the project's goals, provide updates on the research components, show adjustments to the project scope or data products resulting from stakeholders' previous feedback, and collect further input on the project process and products. Workshops consisted of presentations on scientific research and modeling and various stakeholder engagement activities such as data exploration worksheets, participatory mapping, facilitated discussions, and evaluation surveys. They involved the entire project team of natural and social scientists, engineers, and climate resilience extension specialists. Workshop participants were a volunteer project advisory board of regional stakeholders (e.g., natural resource managers, community planners, extension

specialists) and local coastal professionals and decision-makers. The advisory board was involved throughout the project from the start and engaged virtually in between annual in-person meetings, whereas local stakeholder participation varied by geographic venue.

We followed a purposive sampling strategy, a common technique in qualitative research (Lindlof and Taylor 2019) involving an intentional selection of individuals expected to be most likely to provide substantive and specific information pertinent for the project purpose (e.g., relevant knowledge and experiences) (Lindlof and Taylor 2019; Patton 2015). In our project, these were northern Gulf Coast regional stakeholders (e.g., natural resource managers, community planners, extension specialists) and certain local coastal professionals and decision-makers (e.g., city planners and administrators, regional planning councils, floodplain managers, county beach managers, transportation planners) near each of the workshop locations. These stakeholders were targeted based on their professional roles involving sharing information about or taking action due to changing coastal hazards and their knowledge of the challenges, opportunities, and needs of their communities around SLR resilience. They were identified and invited to take part in the workshops (which included the focus groups) by a PI who is a coastal engagement specialist with strong ties to the region in collaboration with others on the team using their professional judgment and extensive networks of contacts.

During each workshop, two subsets of attendees convened in separate rooms to participate in concurrent focus groups. Each year, one group, comprised of regional advisory board members, was moderated by the first author. The second group, comprised of local stakeholders, was moderated by the second author. Each focus group started with an introduction, explanation of objectives, and instructions on procedures. The moderator then asked a series of open-ended questions stemming from an interview guide that served as a flexible framework for dialogue. The participants were encouraged to interact while the moderator listened attentively, maintained nonjudgmental positive rapport, and asked probing questions when necessary for clarification or elaboration. The groups were audio-recorded; lasted about an hour each; and had a research assistant who took notes, monitored time, and managed logistics. The interview guide was constructed collaboratively by the project team and pretested. Most questions remained consistent each year and focused on participants' familiarity and experiences with different types of NNBF infrastructure, perceptions of important conditions and considerations about these mitigation options, and crucial information for decision-making.

All focus group recordings were transcribed in entirety by the moderators and checked for accuracy. The data set consisted of 159 total pages of typed transcripts and 28 total pages of notes. Data analysis involved an interpretive approach which included listening to the recordings and reading all transcripts and notes closely; coding (i.e., labeling) selected portions of text (words, phrases, sentences) based on the interpreted relevance of the data to the interview guide topics and developing categories; and making comparisons within and between the coded data to identify subcategories, relationships, and themes (Lune and Berg 2017). Preliminary results were shared with the project team for further interpretation and refinement. The following section provides a narrative summary of the findings, supported by illustrative quotations from participants in italics.

Findings

Overall, the focus groups provided insights on stakeholders' views about mitigation options for coastal hazards and considerations for NNBF decision-making. These findings illuminate the use of and concerns about NNBF implementation within the regional context of the northern Gulf of Mexico.

Planning for coastal hazard mitigation

The focus group discussions included descriptions of concerns associated with unique geographic and social characteristics in the northern Gulf coast ("a lot of places along the Gulf Coast are developing very rapidly. Land use is changing very rapidly in the face of higher sea levels and then, of course, nuisance flooding being contributed to by all of these things," "smaller communities…don't have good development practices at all. They're old and outdated," "the island…has developed so much that people are building on lots that they avoided before…there are lots that are low"). Participants also shared their own past and present experiences with multiple increasing and compounding coastal hazards in the region (i.e., major hurricanes, tropical storms, nuisance flooding, SLR). Although participants indicated some acceptance of the situation ("if you live in a coastal area in the Gulf I think you expect there to be flooding every now and again"), they thought coastal hazard mitigation in their communities was imperative and that planning was essential now and into the future. They were aware of a range of mitigation options; thought some were more easily implemented, appropriate, and effective than others; and had questions or concerns about certain types. Furthermore, they emphasized that stakeholders at different levels (e.g., individual property owners, neighborhood associations, city governments) all have responsibility in these endeavors.

For individual property owners, mitigation options mentioned included maintaining gutters and storm water drains, adding more permeable pavements (e.g., porous concrete, gravel and grass driveways), adopting eco-friendly landscaping and yard care (e.g., use of swales, rain gardens, rain

barrels), and replacing hardened shorelines with more natural features ("I installed drainage and a sump pump in my backyard…I didn't want my backyard to flood all the time," "we have installed backflow preventers at our outfalls of our storm water…You have to constantly maintain them," "I've noticed more pervious driveways"). A general consensus was that though individual practices can be effective, property owners must also act collectively to address flooding. From a community standpoint, building structures higher and stronger with hardened materials, deepening ditches, improving storm water drainage, and buying out/relocating property owners in flood-prone areas were mentioned as typical mitigation options ("cities…make the ditches that are supposed to carry the water away. They make them deeper and the sides steeper," "putting in storm water under the interstate as well as…retention ponds," "FEMA bought out property owners…a whole community and just said, 'This is always going to flood, so we need to do something about it'"). However, participants also had concerns including cost, short-term effectiveness, social justice issues, and ongoing overdevelopment cancelling the positive effects of these efforts ("pervious concrete…was just cost-prohibitive," "our agency has funded some cities to do storm water drainage management plans…but the money is not there to actually accomplish it," "if an area is prone to flooding, there's a good chance that it's a low-income area. Which also means that they don't have the resources to move to a place that is higher property value. So…there are complex issues," "as long as development is going unchecked…there's monetary investments to fix all of this. It's astronomical").

Participants also recommended long-term community planning involve better land use and storm water management, including protecting or restoring ecologically valuable but vulnerable areas (e.g., wetlands) and using more sustainable infrastructure (e.g., NNBFs), elevating or improving placement of critical infrastructure (e.g., utilities, substations, storm water drains), adopting and enforcing new or revised building codes, managing community growth, finding more appropriate places for development, and providing outreach and education (e.g., workshops, crowdsourcing, mobile apps) ("those different pieces of land that are wetlands or are in flood zones…preserve or restore it," "a lot of the restoration projects that we're seeing…are geared…to restore hydrology…increasing the local value of their ability to absorb surge and…high tides, and flooding," "elevating substations or utilities…maybe your house doesn't get flooded but maybe your substation down at the creek…gets flooded and you have a power outage," "it's going to require longer-term planning…they have to really change…and build infrastructure that's going to be sustainable," "we've been working with our elected officials…looking at…policies to encourage more sustainable building practices," "communities have to make that decision…in writing their codes to promote the use of open space as a tool for either storm water management, or flood reduction, or shoreline conservation, or whatever," "we've been doing some education to try and let people know that maybe it's better to build swales, build rain gardens."). Factors identified as important for mitigation decision-making included geographic location, topographic characteristics (e.g., soil percolation rates, drainage capabilities), proximity to other properties potentially at risk, storm and flooding situation (e.g., frequency, severity, duration, causes), and cost.

Use of NNBFs in the region

Focus group participants were familiar with the concept of NNBFs and described various projects in the region at both neighborhood-scale and for individual properties, including coastal marsh and oyster bed replenishment, stormwater management, and hybrid marsh and breakwater (i.e., living shorelines) projects. Participants believed the NNBF projects they were aware of were performing relatively well, though they acknowledged that for some, it was too early to determine effectiveness. They indicated that implementing NNBFs is often an experimental learning process requiring trial and error before eventual success ("sometimes you actually have to implement them and then…do some adaptive management afterwards," "It's an ongoing process of study with these things. They're relatively new…some of the earlier iterations of living shorelines were not very successful. But they learned. And we learned").

Furthermore, there were indications of increased community understanding of and interest in NNBF projects by some local officials, developers, and citizens' groups ("I think they're [developers] becoming more comfortable and knowledgeable about the economic benefits of doing it," "so much is constituent-driven…we see our neighborhood associations now motivated…there's a certain amount of pressure that's coming from groups that maybe wasn't always there in the past… encouraging our elected officials to be more proactive"). While some focus group participants were directly involved in NNBF projects, the majority had thus far been indirectly involved (e.g., by following the progress of existing projects). However, most are expected to be working on NNBF projects in the future, in part because of this increased community interested in "green" techniques.

Perceptions about benefits and barriers for NNBFs

Participants perceived a number of interrelated ecological and socioeconomic benefits as well as barriers or challenges with using NNBFs. They thought NNBF implementation had much complexity and uncertainty (e.g., developing projects appropriate to the physical setting and responsive to social preferences, selection of appropriate plant species,

and long-term costs), yet they believed in the importance of these approaches for coastal hazard mitigation and remained optimistic about their potential. The major perceived benefits of NNBFs (Table 1) stem from their functions including (1) storm surge protection and erosion management along with self-adaptive durability and sustainability, (2) enhanced ecosystem services such as creating habitat and providing recreation and educational opportunities, (3) better water quality, and (4) less maintenance costs over time due to self-adaptive and regenerative qualities.

Some major perceived barriers or challenges to the implementation of NNBFs for coastal communities also stem from their functions, while others relate more to public perception or acceptance of NNBF techniques (Table 2). Function-related barriers or challenges included (1) uncertainty from lack of evidence on performance and (2) questions about their ability to withstand extreme conditions and events such as hurricanes and tropical storms. Public perception-related challenges included (1) potential financial expense, (2) lack of local political support, (3) public understanding and preferences, as some property owners may have values and lifestyles incompatible with NNBF processes and effects, and (4) a perception that benefits are less quantifiable than traditional methods.

Considerations and information needs for NNBF decision-making

The focus groups thought NNBF decision-making was complex and required ecological, scientific, and engineering considerations as well understanding of the local socioeconomic and situational context. They viewed various types of information as necessary or important for planning, designing, and implementing viable NNBF projects. Each is discussed below.

First, participants thought it was essential to understand the ecological characteristics of the specific geographic location and scientific and engineering goals and parameters before implementing a NNBF project. Major types of perceived ecological, scientific, and engineering considerations and information needed for NNBF decision-making (Table 3) included (1) having a clear project purpose, (2) project time frame, (3) suitability of the spatial and physical setting and long-term understanding of the system, (4) project species characteristics and biological processes, including ecosystem service functions, (5) science and engineering issues including knowledge and resources for project design and construction, and (6) data from monitoring existing NNBF projects, including relative effectiveness and design life.

Participants articulated several needs in order to evaluate the performance of NNBFs. In general, they thought the process should be objective and include long-term monitoring during both normal and extreme weather events ("you do a normal period of monitoring for as long as you can…if it's semi-annual or annual to get sort of the variation in condition over time…if there is some atypical event you have to go out and you have to monitor that…do you have to do any corrective actions or do you have to adaptively manage it?"). Furthermore, they thought criteria for evaluating NNBF

Table 1 Major perceived benefits of NNBFs, with representative participant quotations

Perceived benefit of NNBFs	Representative quotation(s)
Sustainable flood protection and erosion management	• "The sponge effect." • "They control erosion to a certain extent." • "Under something such as a hurricane-type storm surge, the surge simply takes over the living shoreline and inundates it but doesn't destroy it. When the water recedes, the living shoreline will come back. But if you build a restrictive structure like a bulkhead or a rock revetment…it will come behind the bulkhead and wash it out and cause the bulkhead to collapse." • "You put in some of these nature-based features and it's going to protect your residences, your buildings, your economy by helping manage some of that nuisance flooding." • "The potential for them to be able to adapt naturally is a huge benefit. The wetlands. They can adapt to sea level rise, and things like that. It takes less maintenance."
Enhanced ecosystem services	• "The ecosystem services component…is really important so that you aren't just building a bulkhead. You might be building kind of a near shore intertidal habitat that's going to have fish, and crabs, and all sorts of things like that." • "Wildlife habitat…is directly related to ecotourism." • "Aesthetics, and recreation…economic development and tourism. That's huge. If you're doing things in the right way. The environmental tourism is a major economy driver."
Better water quality	• "Water quality improvements…uptake of nutrients and turbidity that you get with those. It's very important."
Less maintenance costs over time	• "…greener infrastructure. If it becomes established, it typically requires smaller, repeat maintenance." • "That great picture of the two properties right next to each other after a hurricane where the guy had a living shoreline and it was just all marsh and everything and it was exactly the same after…and the other guy had a bulkhead, and the bulkhead was gone, and half of the yard was gone."

Table 2 Major perceived barriers or challenges of NNBFs, with representative participant quotations

Type of barrier or challenge	Perceived barrier or challenge of NNBFs	Representative quotation(s)
Function-related	Uncertainty about performance	• "We're kind of engineering it by the seat of our pants because we don't really know exactly what the outcome is going to be." • "They haven't been tested in the real-world environment for long enough for people to have good confidence that they're going to get the return on their investment." • "I have a client…Convincing them to go with something that's not a tried-and-true hardened shoreline…is a little bit of a hard sell at times, particularly since there's not enough results to show…these other things could work." • "In a restoration project…it was decided to use a hardened shoreline…over what I call a natural or nature-based feature simply because of maintaining the integrity of…nearby areas and it's a high energy environment and…susceptible."
	Ability to withstand extreme events	• "You're just hoping that the next hurricane doesn't wash it away." • "How risky it is to…put in a living shoreline, or mangroves, to do any type of natural shoreline if you get a big a storm event."
Public perceptions or acceptance of techniques	Potential costs	• "Sometimes choosing natural and nature-based features, some sort of project like beach re-nourishment, is very costly." • "I think there are lots of concerns about costs and how natural infrastructure costs compare to gray infrastructure." • "I'm hearing 'Oh, this costs so much. We can't do green.'…we get so much pushback…but I'm like, 'These are simple and inexpensive retrofits'…I think it's lack of education."
	Lack of local political support	• "On the city level, if there was political will to put that into their building codes or their development codes, then…anybody…who's going to have to do construction in this area, is going to have to have a certain percentage of the nature-based infrastructure that's incorporated into their project. But I don't think that there's a lot of political will there to…require it." • "Our decision-makers – they're not listening to ecological economic benefits. They're listening to how many people are moving to my community." • "You've got people who still don't believe in sea level rise, you know, especially the ones that are in positions that could help do something about it."
	Public understanding and preferences	• "I think we have a hurdle to get over when we reference it as a NNBF or green infrastructure. Like we understand what that means but the public doesn't. 'What is that?'" • "Some people love it because it brings in the birds, and the fish, and crabs, and everything, and others hate it because it brings in snakes, and alligators, and mosquitos…they can't get to the water sometimes too." • "The freak-out effect – they don't want to go through all that nasty grass, and sea grass, and mushy stuff." • "If you go buy an expensive lot…you may or may not like marsh [on your] beach…You might want your boathouse out there…and a nice lawn that your kids can run around and play on." • "You see it on television all the time, 'This ditch is overgrown! It's overgrown! There's snakes in there!' Which is to show there's still no public appeal."
	Benefits are less quantifiable than traditional methods	• "What's the impact of a project you propose? Is this good for the economy or bad for the economy…if you put a marsh out there?" • "It's going to be incremental. The benefits that you see. It's not an entire hundred percent solution." • "It all comes down to perspective and however successfully we're going to be able to sell…this until we can quantify the benefits of it."

Table 3 Ecological and scientific information needs for implementing NNBFs, with representative participant quotations

Information need	Representative quotation(s)
Clear project purpose	• "The problem…like erosion, that's prompting it." • "Are you trying to protect the shoreline? Or are you also looking at…a parking lot or whatever to intercept…the runoff…for water quality purposes?"
Project timeframe	• "The time that it takes to get established, because with some of the natural-based features, getting them up to a point where they can withstand even everyday energy of a system can take some time and they can be more vulnerable to the large storm events."
Physical characteristics of the location	• "Those features have to be…in the right place. Trying to implement natural and nature-based features in [a] highly-dynamic, energy-packed environment…can lead to a disaster." • "You have to pick the right location, but then even after that there's all sorts of feasibility issues…whether there's existing resources like sea grasses there so you can't necessarily build there, whether you are impacting critical habitats of species, different kind of essential fish habitats." • "The system that you're working in. You need to understand that…over the long term and maybe whatever processes are in place…so you're not interrupting something that's maybe on a longer-term cycle."
Biological functions of project species	• "What's going to get put in…You might need to do more hardy species that'll survive based on your turbidity and water chemistry." • "Ancillary services like how much your marsh can denitrify or what other benefits you're providing…What's going on in the microbial community is just as important as the physical structure."
Design and engineering guidance	• "One of the big issues is not having good guidance on how to build and construct these features…what's done is kind of trial and error." • "Finding the right kind of contractors…knowing what kind of materials, knowing what kind of construction design…some technical guidance." • "Help with design…we need more information, resources…some of our local engineers maybe need a little more information about what they could do."
Data from monitoring existing projects	• "Knowing the science behind the longevity of the green vs. the grey. There's a perception that the hardened shoreline's going to last longer because it's boulders or it's concrete…the contractors…want to see data on the green options…They would feel more comfortable using it if they had data showing that it maintained the shoreline." • "If we have proper monitoring associated with all of these projects, then we can begin to develop a body of knowledge about how well certain things work, and whether certain things work, and we don't really have that yet."

performance would depend on the project goal but should involve multiple metrics. Five criteria were seen as important for NNBF evaluation: degree of wave energy reduction, shoreline erosion reduction, soil accretion, production of natural habitat, and resilience to regular conditions as well as extreme events.

Second, various socioeconomic considerations were also viewed as crucial but cumbersome for NNBF decision-making (Table 4), including (1) regulatory permitting requirements and building codes, (2) cost–benefit analysis of the project, including financial costs associated with establishing and maintaining the NNBF as well as comparative costs of impacts, (3) stakeholder engagement and public support, and (4) potential conflicts of interest among waterfront property owners and with shared community uses of the location, such as for outdoor recreation and tourism.

Third, reflecting the perceived complexity of NNBF projects, the focus groups emphasized there is no one piece of information most essential for decision-making that can be applied uniformly ("No two living shorelines projects are really going to be the same"). Rather, they believed the effectiveness of such approaches is context-dependent and that a unique combination of crucial information is needed on a case-by-case basis ("There's not just one factor…that you can say, 'Hey, this is going to make it work' …you've got to have the suitability of the site, the bathymetric profile…the direction of the water flow, the reach across the water. This will all have an effect on your design. The soil conditions that are there on the bottom. It's got to be able to sustain and hold the structures that you're putting in…You've got to have hydrologic studies performed to determine that what you put in as a nature-based feature…is not going to cause additional problems down gradient…You don't want to put in something up here that causes further erosion down the other side. You've got to take your neighbors into account.").

Fourth, the focus groups identified potential actions to address some of the above barriers and informational needs for an effective path forward in NNBF projects. Recommendations included further empirical research and developing better methods of evaluating NNBF performance and benefits ("Studies so that you can prove to the city councils that, 'Hey, this new type of ecotourism development does work and it can support your economy'"); enacting

Table 4 Socioeconomic information needs and other considerations for implementing NNBFs, with representative participant quotations

Information need	Representative quotation(s)
Regulatory permitting and building codes	• "A driver for a lot of coastal development is what can you get a permit to do." • "What you can build in terms of the…permitting processes and the public assessments of projects. It's frequently said that it doesn't matter what your science says, if it's in front of a yacht club, you're probably going to have to change it." • "Florida DEP [Department of Environmental Protection] would permit something a little bit greener than [the] Army Corps' permit would allow…Florida DEP's permitting process would override what the Corps would permit."
Cost–benefit comparisons	• "The cost…of actually building the natural or nature-based infrastructure…but also the cost of the impacts of the flood event that would occur without having that feature…versus the cost of the impacts that would occur with that feature in place." • "What do you have to do to maintain it and how much is that going to cost?" • "What is the cost versus what is the benefits that it will bring?"
Stakeholder engagement and support	• "You normally have to have local input. You have to have stakeholder consideration…or you're not going to be successful with the project going through." • "Public perception of the process. You've got to have public support or you won't get in." • "The Community Rating System…a community might be more open to protecting a habitat…if they can get some credit for that and it would reduce flood insurance for their community."
Potential conflicts of interest	• "There's a need to be very careful about where we think about putting these kinds of projects…in the past it's been easy to put those in places that are predominantly publicly owned so you're not dealing with individual landowner concerns." • "The county…requires that you ask your neighboring property before you harden your shoreline. And [two residents] were at a stalemate because the neighboring property did not want their neighbor to harden the shoreline…she was trying to force her to go green…It's an issue they grapple with." • "If you have other property…used for recreational…boating things, like skiing…they definitely don't want a living shoreline…So current use of the area is a consideration."

local regulations requiring new development to incorporate NNBFs into design; creating an NNBF project repository to share information, data, and lessons learned ("it would be nice to have an array of green infrastructure solutions and…a broad rubric of price and cost"); and improving understanding of diverse stakeholder values and community education and outreach ("some kind of feedback loop…to determine the values of the people who live here, I think is a critical piece in selling this," "I think really educating the stakeholder groups…about the benefits of natural shorelines and some of these different products and options is going to be a key part").

Discussion

Overall, the focus groups were successful in engaging stakeholders and contributing valuable local knowledge to assist in the project's scientific research, models, and decision-support tools for robust and inclusive coastal resiliency. The findings contribute to a better understanding of stakeholders' perspectives and information needs about coastal hazard mitigation options including NNBFs. This information in turn is being used to help the project team tailor project products for optimal relevance and usefulness to local circumstances. Overall, stakeholders were very interested in using NNBFs for hazard mitigation, but also expressed the need for more informational support about their construction and possible outcomes. Below, we highlight three key findings, and conclude by discussing study limitations and recommendations for future research.

Key finding one: importance of localization

One of our key findings was the importance of localization and a place-based perspective when decision-makers and coastal professionals consider and plan NNBF projects. By "localization," we refer to the process of tailoring a product to a new situational context by considering linguistic and cultural factors (Sun 2006) as well as "local knowledge systems, political issues, economic implications, and legal systems prevailing at users' sites" (Agboka 2013, p. 29). The localization process has relevance to issues surrounding the planning and development of NNBFs in that these efforts need to consider a range of place-specific social, economic, physical, and biological factors that may impact success, such as hydrodynamic conditions, plant species, and negotiation and adaptation to local cultural and communication expectations.

NNBF localization requires an understanding of the socioeconomic context, including applicable laws and regulations, potential for ecotourism, preferences of property

owners, and cost perceptions by various sectors of society (Cunniff 2016). For example, in the study region, both building codes and permitting regulations favor built infrastructure over NNBFs. Related to localization was the importance of index sites or examples of successful NNBF projects. For instance, focus group participants described photographs of existing projects as being helpful for both thinking through the decision-making process around NNBFs and persuading community members about their desirability, a finding similar to that in Kochnower et al. (2015).

Key finding two: need for a variety of tools and information

A second key finding was recognition by decision-makers and coastal professionals that a variety of tools and types of information are needed to manage the complexity of NNBF projects. This includes information about the aforementioned local social, biological, and physical conditions, as well as best practices for constructing and monitoring NNBFs, what can be expected in terms of outcomes, and how to educate lawmakers on the importance of permits and ordinance changes that would encourage NNBFs. While NNBFs have existed for several years, practitioners wanted a more centralized repository of data on outcomes and best practices, plus decision-support tools to help them manage complexity. For example, while one of the described benefits of NNBFs was storm surge or flood protection over a broader area, flood reduction was not mentioned as a measurable metric of project success. We suggest that monitoring primarily to demonstrate that the structures themselves are durable creates a disconnect with the postulated broader benefits of NNBFs, and that best practices should include larger-scale monitoring. Importantly, practitioners overwhelmingly suggested that there is no one "most important" type of information needed to help manage the proper placement and construction of NNBFs, a finding that reflects other studies (e.g., Sutton-Grier et al. 2018). They recognized the need to build community buy-in among a variety of interest groups and actors and acknowledged that many types of information and social connections might be required to build such buy-in.

Key finding three: informational gaps

A third key finding is the specific informational gaps among coastal decision-makers and coastal professionals that can inform future research, education, outreach, advocacy, and extension work in the region. There are multiple efforts across the USA and specific to the northern Gulf intended to foster greater understanding and awareness of NNBF effectiveness and costs. For example, there are several sources, clearinghouses, and implementation guides for NNBFs regionally and nationally (e.g., Florida Living Shorelines, 2021; RAE and NCCF 2017; Webb et al. 2018; USACE 2021). Additionally, previous studies have examined the comparative costs and performance of natural versus built infrastructure (e.g., Keesstra et al. 2018; Narayan et al. 2016; Smith et al. 2017), and multiple regional extension programs and centers support the application of NNBFs (e.g., Coastal Conservation and Restoration Extension program, Gulf Coast Community Design Studio). Although many of these reports, websites, and programs have become more common while our data collection was underway, it suggests that an important gap may be effectively connecting coastal decision-makers and professionals with this information. Another potential barrier to this information being applied could be that the aforementioned importance of localization prevents stakeholders from viewing it as relevant to their particular project.

Conclusions, study limitations, and recommendations for future research

This study provides a better understanding of current perceptions around barriers, effectiveness, and planning for NNBFs in the northern Gulf within a key stakeholder group. Furthermore, explicit recommendations for how to address some of these gaps were presented.

Like all studies, ours has methodological limitations which we have addressed in various ways. Participant self-report data is likely to have biases and does not always correspond with behavior. Our study design involved multiple techniques to address threats to internal validity including prolonged engagement (focus groups conducted annually for three years), investigator triangulation (focus groups were planned and implemented by two trained and experienced moderators with input from the interdisciplinary team), peer debriefing (held immediately after each focus group), member checks (summaries of focus groups findings were shared with regional stakeholders on the project advisory board for their feedback), and reflexivity (researchers maintained individual and collective reflections on their roles and research process) (Ravitch and Carl 2021).

Regarding external validity or transferability, our purposive sampling strategy is nonrandom and thus not statistically generalizable. However, this type of sampling is appropriate for qualitative research when the goal is to provide a deeper understanding of a phenomenon, reveal commonalities within the groups studied, and lead to key study findings with likely application in similar contexts (Patton 2015). Our techniques to address threats to external validity included thick description (detailed data including direct quotations from participants and sufficient context for comparisons and applications to other situations), an adequate data set (entire

verbatim transcripts of the six focus groups), and researcher reflexivity (Ravitch and Carl 2021).

While not comprehensive of all actions required for effective implementation of NNBFs, this study provides insight into areas of future research and educational programming. It is hoped that our study findings will help enhance decision-making processes by local policymakers and community organizations regarding funding, designing, implementing, and evaluating NNBF coastal hazard mitigation projects that are both ecologically and socioeconomically sound and sustainable. We have two suggestions for consideration.

First, while NNBFs can mitigate specific coastal vulnerabilities (e.g., Langridge et al. 2014), the siting and construction of these projects must consider the desires and concerns of coastal residents, particularly marginalized residents. We recommend that NNBF projects broaden public participation in decision-making with a goal of improving equity, which is recognized as a broader challenge (e.g., Nelson et al. 2020). Second, we echo the need articulated by practitioners for more extensive centralized information about NNBFs that builds on existing extension agency programs and collaborations, including case examples and best practices for understanding the socioeconomic and geophysical aspects of NNBFs. As suggested by some practitioners and reflected in other research projects (e.g., Kochnower et al. 2015; Raymond et al. 2017), practitioners need both support for learning about interdisciplinary aspects of NNBF projects that their professional training does not reflect and an understanding that professional learning and collaboration will be required for these projects. That makes extension and interdisciplinary applied research projects ideal for providing a space for collaboration, peer-learning, and developing the required support resources.

We conclude with four specific recommendations for future research. First, we suggest that a more in-depth focus on the social and political aspects of NNBF project planning—particularly focusing on how different types of professionals view these aspects—could more fully illuminate the local, situated contexts in which individual decision-makers operate. Second, future research should focus on how community members other than coastal professionals and decision-makers, including members of marginalized groups, elected officials, and coastal ecosystem-dependent business owners, perceive the benefits, challenges, and barriers to NNBF implementation described in this study. Third, we advise that researchers examine the role of place attachment in public attitudes toward NNBFs, and suggest that the concept of localization might prove helpful in promoting public acceptance of these projects. Fourth, we recommend additional transdisciplinary research that emphasizes the linkages between the local sociopolitical and bio-geophysical contexts in understanding the costs and benefits of future NNBF projects. While challenging to implement due to various barriers, NNBFs have the potential to transform the ways that communities respond to coastal hazards.

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Author contribution DD planned and led the research design and performed data collection, analysis, and writing of the manuscript in close collaboration with SS. RC oversaw broader stakeholder engagement and participant recruitment and collaborated on the interview guide and manuscript development. All authors contributed to the article and approved the submitted version.

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Declarations

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