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Community perception and stewardship of public coastal infrastructure in Cedar Key, Florida

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This study contributes to empirical evidence about how local communities may perceive and steward nature-based coastal infrastructure developed in the public realm to enhance coastal resilience. Coastal communities increasingly face flood risks driven by chronic erosion, habitat degradation, and climate change. Nature-based coastal infrastructure-such as living shorelines-offers promise for hazard mitigation, resilience, and co-benefits. However, public awareness and acceptance remain barriers to broader adoption, and little is known about perception of community-level coastal infrastructure beyond private settings. This study used an intercept survey (N = 155) in Cedar Key, Florida, U.S., to investigate public perceptions of various coastal infrastructure options across the green-gray spectrum, community stewardship of coastal infrastructure in terms of funding and maintenance, and potential factors that predict more positive perceptions of nature-based options and stronger lay stewardship. Among the five types of coastal infrastructure that we examined (i.e., vegetation-only, sills, beach nourishment, revetment, and sea wall), participants rated nature-based options (vegetation-only and sills) significantly higher for beauty. However, contrary to existing literature, we found no significant differences in perceived protection between nature-based and hardened options. Instead, beauty and protection ratings were strongly correlated for all options except sea walls. More favorable views of nature-based options were associated recognizing shoreline's role in pollutant capture and having more pro-environmental attitudes. Findings also suggest that sills were seen as more effective than vegetation-only for erosion control and protection. Additionally, over 45% of self identified residents reported feeling responsible for maintaining coastal infrastructure significantly more than non-residents-while over 40% of tourists indicated responsibility for funding-significantly more than non-visitors. Shore-based anglers also emerged as promising stewards, expressing support for both funding and maintenance. These findings contribute to understanding public perception and potential stewardship of nature-based coastal infrastructure at the local level and inform designs that can gain stronger community preference and support.

KEYWORDS

living shorelines, nature-based solutions, coastal resilience, community engagement, participatory design

1 Introduction

Storms of higher frequency and intensity, erosion, habitat degradation, and rising sea levels are driving increasing flood risks in many coastal communities around the world, posing complex challenges to infrastructure, economies, ecosystems, and public health (Hossain et al., 2022; Kopp et al., 2017; Neumann et al., 2015; Woodruff et al., 2013). Conventionally, hardened structures like sea walls have been the primary method to stabilize shorelines and defend coastal communities against storms (Dugan et al., 2011; Gittman et al., 2014). However, gray infrastructure is becoming less appealing due to negative impacts on ecosystems and erosion, limited built-in lifetime, high maintenance demands, and inability to adapt to climate change (Cohn et al., 2022; Saleh and Weinstein, 2016; Smith et al., 2020). In the U.S., the cumulative cost of coastal infrastructure damage from sea level rise and storm surge could reach hundreds of billions of dollars by the end of the century (NOAA, 2024).

Increasingly, agencies, academics, and practitioners are considering how coastal infrastructure can integrate natural elements to enhance resilience and deliver co-benefits, informed by the broader concept of nature-based solutions (Cohn et al., 2022; Hobbie and Grimm, 2020; Nesshöver et al., 2017). For example, major US agencies including the National Oceanic and Atmospheric Administration and the Army Corps of Engineers have developed guidelines around "natural and nature-based features" and "living shorelines", promoting coastal management practices that conserve and restore natural habitats or strategically place plants, stone, sand fill, and other organic materials (Gaskin et al., 2025; NOAA, 2015; NOAA Fisheries, 2022).

Accumulating evidence shows that natural, soft, and hybrid measures can mitigate the impacts of chronic flooding and extreme weather events by absorbing wave energy, reducing erosion, and self-adapting with rising sea levels, especially in environments with low-medium wave energy (Arkema et al., 2017a; Huynh et al., 2024; Smith et al., 2020; Sutton-Grier et al., 2015). In addition, nature-based coastal infrastructure may provide additional ecological and social benefits, contributing to habitat restoration, water filtration, nutrient cycling, carbon storage, sense of place, and aesthetic and recreational experiences (Arkema et al., 2017b; Jacob et al., 2021; Narayan et al., 2016).

Despite the great potential, adoption of nature-based infrastructure remains highly limited. Key barriers include uncertainties regarding costs and benefits, lack of funding, complicated permitting processes, and inadequate public awareness and acceptance (Dario et al., 2024; Sutton-Grier et al., 2015). To address the last dimension, many studies have surveyed or interviewed waterfront residents to understand perceptions of various shoreline options on private properties (Barry et al., 2024; Gray et al., 2017; Guthrie et al., 2023; O'Donnell et al., 2022; Scyphers et al., 2019, 2020; Smith et al., 2017). These studies consistently show that residents tend to perceive armored shorelines as more effective for protection against erosion and storms than natural and living shorelines, and this perception can greatly drive decisions on coastal management practices (Barry et al., 2024; Guthrie et al., 2023; Smith et al., 2017). At the same time, satisfaction with natural and living shorelines is often higher due to their perceived aesthetic value, connection with place-based identity, and environmental benefits for water quality and habitat (Barry et al., 2024; Gray et al., 2017; Palinkas et al., 2022; Scyphers et al., 2020). In addition, residents' perceptions of shoreline and infrastructure types may relate to their concerns about coastal hazards (Scyphers et al., 2019) and risk perception (Guthrie et al., 2023).

However, most existing studies focus on nature-based shorelines in private settings. This study expands the current research by examining community-level, publicly accessible nature-based coastal infrastructure. Compared to implementations on private properties, public nature-based shorelines arguably offer broader community benefits. They can also serve as visible demonstrations of innovative coastal design, providing residents with firsthand experiences of nature-based solutions and potentially encouraging broader private adoption (Dario et al., 2024). To foster community buy-in and ensure successful implementation, it is therefore critical to understand how different stakeholder groups perceive and value public nature-based coastal infrastructure (Frantzeskaki, 2019).

This study also explores community stewardship, a key factor in sustaining the intended functions and benefits of nature-based solutions (NBS). Stewardship is broadly defined as "the wise and responsible use of natural resources" (West et al., 2018) and encompasses a range of actions individuals or groups take to protect and care for natural environment (Bennett et al., 2018; Dean et al., 2024; West et al., 2018). Compared to their gray infrastructure counterparts, NBS may be more susceptible to neglect or mistreatment and often depend on local community stewardship to maintain performance and reduce municipal maintenance burdens (Lamond and Everett, 2023). While most stewardship studies have focused on non-coastal contexts such as green stormwater infrastructure and urban green spaces, they offer valuable insights. For example, Lamond and Everett, 2019, 2023) found that individuals who used green infrastructure sites (e.g., retention ponds, rain gardens) for recreation were more likely to engage in stewardship behaviors such as avoiding littering and volunteering for maintenance. Factors such as strong beliefs in green infrastructure, heightened concern about climate change and flooding, previous flood experiences, and longer residential tenure also contributed to stewardship. Similarly, Shandas (2015) observed that residents were more willing to participate in stormwater management when they perceived green infrastructure as improving their neighborhood or had prior involvement in environmental projects. In addition, place attachment, memory, and meaning can motivate voluntary stewardship, particularly when programs offer opportunities to deepen a sense of belonging (Ferreira et al., 2020; McCarthy and Russo, 2023). Drawing on Lamond and Everett (2023)'s framework of stewardship modes, we conceptualize stewardship of coastal infrastructure in this study as comprising both maintenance (active care) and funding contributions (ownership).

Responding to the need for more research on community perception and stewardship of public coastal infrastructure, we draw on a community intercept survey conducted in Cedar Key, Florida, U.S., to investigate the following questions:

1. How do community members perceive different types of coastal infrastructure along the green-gray spectrum?
2. Which stakeholder groups see themselves as responsible for funding and maintaining coastal infrastructure?
3. What factors contribute to positive perceptions of nature-based infrastructure and to community stewardship of coastal infrastructure?

By examining community engagement with nature-based solutions in the public realm, this study advances understanding of how coastal resilience efforts can be more inclusive and effective.

2 Materials and methods

2.1 Study city

Cedar Key is a small municipality (covers less than four square miles and has a population of fewer than 700) in Florida's Gulf Coast, a region that is disproportionately affected by some of the most significant coastal flood risks in the U.S (Horton et al., 2015; Mondal et al., 2025; Park and Sweet, 2015; U.S. Global Change Research Program, 2023) (Figure 1). The Cedar Key community faces severe flood risks and shoreline erosion due to its low-lying topography, exposure to open waters, intensifying storms, and accelerating sea level rise. In 2020, Cedar Key recorded the fourth-highest rate of sea level rise acceleration in the U.S., with local sea levels rising nearly six inches since 1992 (Malmquist, 2021; VIMS, 2022). Chronic shoreline erosion has led to the loss of many vegetated buffers, marshes, and oyster habitats, as well as recreational beaches. This has adversely affected water quality, critical infrastructure, tourism, aquatic recreation, and seafood production.

Despite the small size, it is a regional hub of cultural, economic, and scientific significance and provides emergency and fire department services beyond the city boundary. Before European contact, the Timucua and other native people lived and traded there (McCarthy, 2007). By the 1800s, it hosted a military base and hospital, an international shipping port, and the western terminus of the Florida Railroad. In the late 19th century, two major hurricanes forced much of the community inland and reshaped the city. Today, conservation efforts and low population density have contributed to a major hard clam aquaculture industry that accounts for roughly 80% of Florida's production (Botta et al., 2021). Cedar Key also houses research labs and offices for five state and federal agencies that focus on the management of regional natural resources.

Addressing coastal flooding and erosion has been a central concern for Cedar Key officials and residents. Previous state-led efforts have proposed new jetties and beach nourishment (Olsen Associates, 2007). But none of these solutions was pursued due to high costs and a lack of community input, especially from stakeholder groups such as aquaculture workers, lower-income visitors, and shore-based anglers who rely on the shoreline for livelihoods, recreation, and flood protection. This study was embedded within an action research project Cedar Key ShOREs (Shoreline Options for Resilience and Equity) that focused on co-design and capacity-building with diverse stakeholders for nature-based solutions around key public infrastructure in Cedar Key. It also carries on a wider community engagement effort during recent years' pilot living shorelines projects led by the University of Florida.

2.2 Survey design

To understand how diverse stakeholders use the Cedar Key shoreline, perceive the local environment, and view different types of infrastructure to inform nature-based solutions design in the project, an interdisciplinary team of researchers developed a community intercept survey. The survey included 22 questions that addressed five topics: critical shoreline issues, coastal infrastructure options, stakeholder participation, environmental views, and demographics.

The first section asked about participants' views on important coastal issues, key needs for addressing coastal issues, and

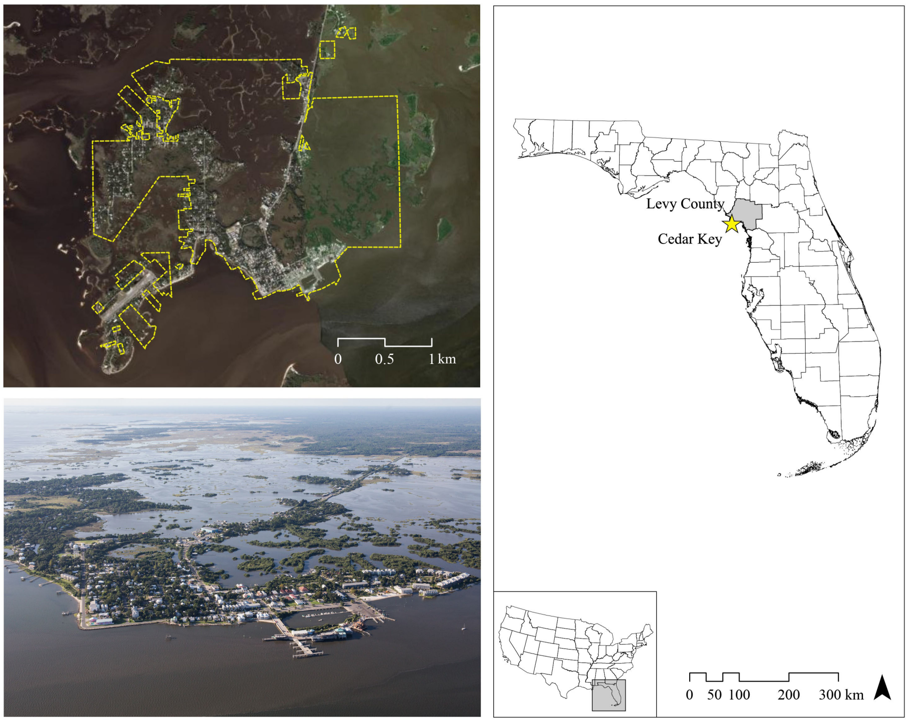

FIGURE 1
Map of Cedar Key, Levy County, Florida, U.S. Photo credit: Cat Wofford, UF/IFAS File Photo.

important shoreline functions. For each question, participants were asked to select the top three from a list of options, and there was an option for typing in answers that were not listed. In the second section, the participants were presented with visualizations of ten coastal infrastructure options using the typology developed by the Systems Approach to Geomorphic Engineering (SAGE, 2015) and were asked to rate the coastal protection and beauty of each option on a 5-point Likert scale from "Best" to "Worst". Subsequently, participants were asked about their priorities in choosing coastal infrastructure and their preferred approaches to managing stormwater. The third section included five questions about stakeholder participation, including one question asking which stakeholder groups should contribute funding to Cedar Key's coastal infrastructure and another asking which stakeholder groups should contribute to management and maintenance. Again, participants were asked to select the top three from a list of options for each question. The fourth section employed the New Ecological Paradigm (NEP) Scale, a widely used tool in environmental psychology and sociology, to gauge participants' general environmental attitudes (Madeira et al., 2025). Participants were asked to indicate their level of agreement with ten standardized statements on a 5-point Likert scale (Amburgey and Thoman, 2011; Izadpanahi and Tucker, 2018). Lastly, the demographics sections asked about participants' age, location of residence, time of residence in Cedar Key, self-identified stakeholder group(s), gender, and race/ethnicity. The full survey questionnaire is provided in Appendix A. The survey instrument was pilot-tested and revised for clarity before distribution.

2.3 Survey data collection

The community intercept survey was conducted from December 2, 2022, to March 16, 2023, and was administered by eight trained undergraduate research assistants. Survey participants were recruited along all main streets adjacent to the shoreline (G Street, Airport Rd., 1St Street, Dock Street, and 2nd Street) where major destinations such as docks, shops, restaurants, and art galleries are located, as well as at key community gathering places, including the food pantry, local cafés, city offices, City Park, the public boat ramp, and aquaculture facilities. Over a total of 17 days (8 weekdays and 9 weekend days), research assistants approached individuals at these locations, explained the purpose of the survey, and invited adults (18 years and older) to participate. Consenting participants completed the survey on electronic tablets via Qualtrics (https://www.qualtrics.com/), with research assistants available to provide guidance if needed. The survey was written in plain English and took approximately 15-20 minutes to complete. To encourage participation, the first 200 respondents received a $10 Amazon e-gift card as compensation for their time. The overall refusal rate was 56.45%, although some people accepted flyers with survey information and self-administered the survey later. Ethical approval for this research was obtained from the University of Florida Institutional Review Board (IRB) (reference number IRB202200544).

2.4 Data analysis

2.4.1 Measures

Drawing on the existing literature, we focused on eight questions in the survey and re-coded the data to create the study's dependent and predictor variables (Supplementary Table S1, Appendix B). Dependent variables included 1) perceived shoreline protection of coastal infrastructure (measured by a 5-point scale), 2) perceived beauty of coastal infrastructure (measured by a 5-point scale), 3) likelihood of identifying one's own stakeholder group as responsible for coastal infrastructure funding (binary, 1=Yes, 0=No), and 4) likelihood of identifying one's own stakeholder group as responsible for coastal infrastructure maintenance and management (=Yes, 0=No). Predictor variables included the type of coastal infrastructure, participants' views of important coastal issues, important shoreline functions, and infrastructure priorities; NEP score; self-identified stakeholder groups; and demographics including gender and age.

Specifically, the study focused on five distinct types of coastal infrastructure that represent varying levels of "naturalness" but have a consistent linear form parallel to the shoreline. These options, from "green" to "gray" are: 1) vegetation-only, 2) sills (combining vegetation and rocks), 3) beach nourishment, 4) revetment, and 5) sea wall (Figure 2). Our conceptualization of maintenance and funding as two distinctive forms of stewardship was informed by the categorization of active care and ownership in Lamond and Everett (2023).

2.4.2 Statistical analysis

Data processing and analyses were completed in R 4.4.2 (R Core Team, 2024). After data preparation, we first computed descriptive statistics for the study variables. Second, we conducted Friedman's ANOVA, a non-parametric test for repeated measures, to assess whether the five types of coastal infrastructure differed in perceived coastal protection and beauty. This test accounts for the non-independence of perception ratings, as each participant evaluated multiple types. Because the analysis employed a balanced within-subjects design, participants who did not provide ratings for all five types of coastal infrastructure were excluded to ensure a complete dataset across conditions. *Post-hoc* tests were conducted for pairwise comparisons using R package 'pgirmess' (Giraudoux et al., 2024). Third, we conducted multiple linear regression analyses to investigate how perceptions of vegetation-only and sills—two types of nature-based coastal infrastructure—may relate to priorities for coastal infrastructure, valued shoreline functions, identified critical coastal issues, and general environmental attitude. We also included age and gender in the regression models, given their potential effects on perceptions of other types of nature-based solutions (e.g., Anderson and Renaud, 2021; Flotemersch and Aho, 2021; Li et al., 2022). Last, we performed a logistic regression using the R base package 'stats' to examine how people's self-identified stakeholder group, valued shoreline functions, identified critical coastal issues, general environmental attitude, and demographic characteristics may relate to their potential contribution to coastal infrastructure funding and maintenance.

Both multiple linear regression and logistic regression adopted a hierarchical model-fitting approach (Field et al., 2012), which started with a full model that included all relevant predictors based on prior research and then excluded statistically redundant variables (Supplementary Table S3). Final multiple regression and logistic regression results were checked through diagnostic tests, including the Durbin-Watson test for independent errors, the VIF and tolerance statistics for multicollinearity, and examinations of the residuals (Field et al., 2012). All statistical tests used a significance level of $p < 0.05$.

3 Results

3.1 Participants' demographics, stakeholder identities, and environmental views

The final study sample (N=155) aligned with Cedar Key demographics overall, though included more females and people

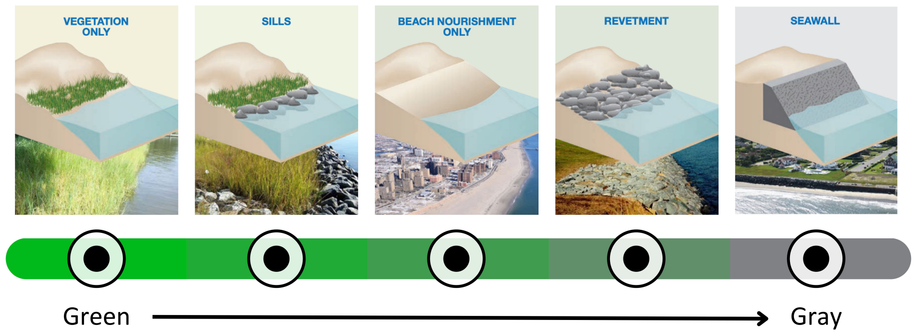

FIGURE 2
Five types of coastal infrastructure along the green-gray spectrum based on the SAGE typology.

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TABLE 1 Survey participant profile. Percentage is calculated based on valid responses, not the study sample.

Participant characteristics	Study sample (N=155)		2022 ACS 5-year estimates (U.S. Census Bureau, 2023)
	n	%	%
Age			
Median age	59 years old		55 years old
Age Group			
18-29	13	9.6	21.3
30-39	19	14.1	3.3
40-49	10	7.4	7.1
50-59	26	19.3	10.1
60-69	39	28.9	15.4
70 and Older	28	20.7	31.1
Gender			
Female	83	56.1	52.3
Male	65	43.9	47.7
Race/Ethnicity			
White	133	87.5	85.9
Hispanic or Latino	9	5.9	2.3
Black or African American	6	3.9	9.1
American Indian or Alaska Native	6	3.9	0
Asian	2	1.3	0
Place of Residence			
Cedar Key	70	46.05	
Levy County	17	11.18	
Florida	43	28.29	N/A
Outside Florida, U.S.	21	13.82	
Outside U.S.	1	0.66	

whose age is between 30 and 39 or 50 and 70 years old (Table 1). In addition, most participants were Cedar Key residents. More participants came from other Florida counties than from Levy County or from outside the state (13.8%).

Regarding stakeholder identity, most participants identified themselves as shore-based anglers (50.32%), followed by Cedar Key residents (47.10%), boat-based anglers (43.23%), tourists (27.10%), and local business owners (20.65%) (Supplementary Table S2, Appendix B). Participants on average selected more than two groups. Over half (51.61%) identified with two to five groups, among whom nearly all identified with shore or boat-based anglers. Cedar Key residents (n = 20) and tourists (n = 17) dominated the 36.77% of participants (n = 57) who selected only one stakeholder group.

The above-average NEP score (M = 3.66, SD = 0.40; measured on a 5-point scale) among participants suggested prevailing pro-environmental attitudes. Participants' views toward the local environment also demonstrated a strong ecological awareness (Supplementary Figure S1, Appendix B). The top three selections for coastal infrastructure priorities were impacts on the ecosystem (81.82%), best scientific solution (59.1%), and functionality (50%). The top three selections for critical coastal issues in Cedar Key were shore erosion (52.9%), loss of habitat (41.29%), and marine debris (32.9%), followed closely by drinking water quality (32.26%), hurricane protection (31.61%), and wastewater system exposure (30.97%). The top three selections for important shoreline functions were shellfish production (65.16%), pollutant capture (52.26%), and residential living (44.52%).

3.2 Perceptions of coastal infrastructure

3.2.1 Perceived protection and beauty by coastal infrastructure type

Among the five types of coastal infrastructure that we examined, sills had the highest protection function score while beach nourishment had the lowest; and vegetation-only had the highest beauty score while sea wall had the lowest (Table 2). In addition, the mean perceived beauty scores for the five types of coastal infrastructure consistently decreased along the green-gray spectrum. Such a tendency was not observed for the mean perceived protection scores. Notably, the correlations between perceived protection and beauty were statistically significant for all options except sea wall (Table 2).

Following Friedman's ANOVA results showed that the perception mean scores were statistically significant between the five infrastructure types (perceived protection: $\lambda^2(4) = 54.138$, p-value < 0.001; perceived beauty: $\lambda^2(4) = 94.333$, p-value < 0.001). Following *post-hoc* analysis revealed that, for perceived protection function, beach nourishment was the only statistically different type, showing a lower ranking than all other types (Figure 3). For perceived beauty, sea wall had a significantly lower ranking than all other types. Vegetation-only and sills had similar levels of perceived beauty, which were significantly higher than all other types. There was no statistical difference between beach nourishment and revetment.

3.2.2 Predictors for positive perceptions of nature-based coastal infrastructure

We further employed multiple regression to investigate what factors relate to more positive perceptions of vegetation-only and sills, two types of nature-based coastal infrastructure. The dependent variables were the aggregated scores for protection and beauty. The overall perceptions for vegetation-only (M = 7.22, SD = 2.07; measured by a 5-point scale) and sills (M = 6.97, SD = 2.11; measured by a 5-point scale) showed statistically significant positive correlations with a medium-sized effect in Kendall's test ($\tau = 0.31$, z = 4.7144, p-value < 0.001). Therefore, the overall perceptions of them were modeled separately, using a hierarchical model-fitting approach (Supplementary Table S3, Appendix B).

Regarding perception of vegetation-only, it showed significant positive associations with identifying pollutant capture as one of the three most important shoreline functions, NEP mean score, and age (Table 3). Perception of sills showed significant positive associations with identifying pollutant capture as one of the three most important shoreline functions, identifying shoreline erosion as one of the three most important shoreline issues, and NEP mean score.

TABLE 2 Mean perception scores by coastal infrastructure type and correlations between perceived protection and perceived beauty.

Coastal infrastructure type (green to gray)	Mean perceived protection score (SD)	Mean perceived beauty Score (SD)	Spearman's correlation of protection and beauty [a]	
			r	*p-value*
Vegetation-only	3.40 (1.30)	3.79 (1.33)	0.30	**0.0004*****
Sills (vegetation + rocks)	3.53 (1.22)	3.37 (1.23)	0.50	**<.0001*****
Beach nourishment	2.43 (1.41)	2.91 (1.42)	0.19	**0.0216***
Revetment	3.31 (1.16)	2.90 (1.23)	0.51	**<.0001*****
Sea wall	3.09 (1.45)	2.24 (1.40)	0.14	0.1005

[a]Effect size of Spearman's Correlation Pearson correlation coefficients: $r < 0.1$, very weak; $0.1 < r < 0.3$, weak; $0.3 < r < 0.5$, medium; $0.5 < r < 0.7$, strong; $r > 0.7$, very strong.
*p-value <.05, **p-value <.01, ***p-value <.001).
Statistically significant results are in bold.

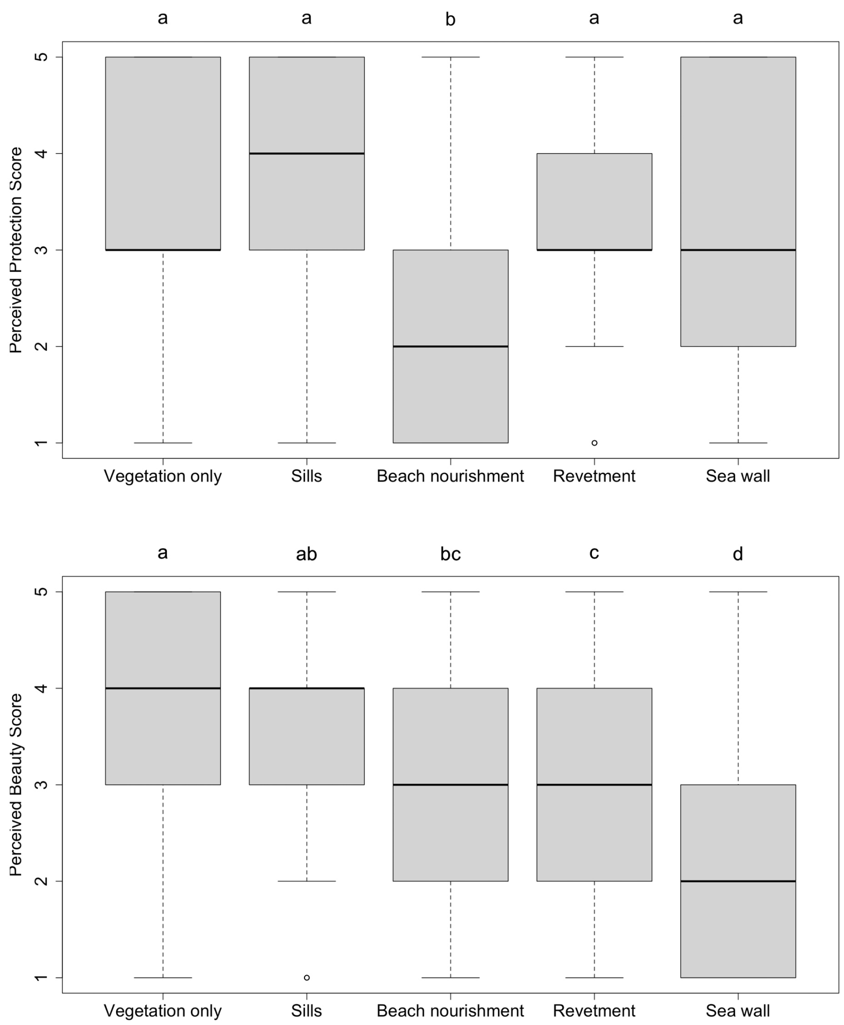

FIGURE 3
Perception ratings across five types of coastal infrastructure and type pairwise comparisons from the Friedman's ANOVA *post-hoc* analysis. Significant differences are indicated with letters (a, b, ab, bc, c, d) above each group. Significance is considered at p<0.05.

3.3 Stewardship of coastal infrastructure

3.3.1 Stakeholder groups and coastal infrastructure stewards

Participants identified different stakeholder groups with coastal infrastructure funding vs. maintenance and management responsibilities (Supplementary Table S4, Appendix B). For funding, the top three stakeholder groups that participants identified were state government (60.13%), city government (49.67%), and shore anglers (44.44%). For maintenance, the top three stakeholder groups were city government (66.01%), state government (48.37%), and Cedar Key residents (46.41%). Additionally, while participants generally showed a consensus on state and city government's major role in funding and maintaining coastal infrastructure, many participants viewed non-governmental stakeholder groups as solely responsible for funding (24.52%) and maintenance (21.29%). In comparison, among the 15 participants who identified with the city government, four (26.7%) believed that neither the city or the state is responsible for funding coastal infrastructure, and three (20%) believed that neither the city nor the state is responsible for maintaining coastal infrastructure.

Notably, over half participants thought their stakeholder groups should contribute to infrastructure funding (56.29%) or maintenance (52.32%) (Supplementary Figure S2, Appendix B). Among them, for funding, most participants were identified with shore anglers (46.15%), followed by tourists (40.48%) and local business (28.13%). For maintenance, most participants were identified with Cedar Key residents (45.21%), followed by aquaculture workforce (39.13%) and local business (31.25%).

3.3.2 Predictors for coastal infrastructure stewardship

We further employed logistic regression to examine the likelihood of participants selecting their stakeholder groups as a

TABLE 3 Multiple regression results for the aggregated perception ratings for vegetation-only and sills.

Predictor variables	Perception ratings for vegetation-only			Perception ratings for sills		
	Estimates	Std. β	*p*	Estimates	Std. β	*p*
(Intercept)	1.37	0.00	0.349	1.73	-0.00	0.247
Coastal infrastructure priority						
Look	0.54	0.11	0.223	0.02	0.00	0.959
Access to water	0.78	0.16	0.077	0.57	0.11	0.207
Important shoreline functions						
Pollutant capture	1.09	0.26	**0.005****	1.12	0.25	**0.005****
Resident living	0.63	0.15	0.121	-0.22	-0.05	0.597
Important coastal issues						
Hurricane protection	0.80	0.17	0.058	-0.03	-0.01	0.943
Shoreline erosion	-0.25	-0.06	0.509	1.17	0.27	**0.003****
General environmental attitude						
NEP mean score	0.87	0.22	**0.015***	1.09	0.27	**0.003****
Stakeholders group						
Boat Anglers	0.42	0.10	0.273	0.76	0.17	0.051
Demographics status						
Age	0.02	0.20	**0.028***	-0.00	-0.02	0.812
Female	-0.56	-0.13	0.147	-0.51	-0.12	0.195
Observations	121			121		
R^2/R^2 adjusted	0.236/0.167			0.259/0.192		
AIC	515.561			520.491		

(*p-value <.05, **p-value <.01, ***p-value <.001).
Statistically significant results are in bold.

responsible party for coastal infrastructure funding or maintenance, using a hierarchical model-fitting approach (Supplementary Table S4, Appendix B). Among the examined predictor variables including stakeholder groups (i.e., shore-based anglers, Cedar Key residents, tourists, and local business), identified important coastal issues, perception of beach nourishment (a non-structural measure), NEP score, and age, only stakeholder group variables showed significant effects (Supplementary Table S5, Appendix B).

Specifically, participants identified with shore anglers or visitors were significantly more likely to contribute to coastal infrastructure funding, while participants identified with Cedar Key residents or shore anglers were significantly more likely to contribute to coastal infrastructure maintenance. Specifically, shore-based anglers were 6.20 times more likely to select their own stakeholder group as a responsible party for funding (OR = 6.20, 95% CI [2.62, 15.86], $p < 0.001$), and visitors were 3.48 times more likely to select their own stakeholder group as a responsible party for funding than non-visitors (OR = 3.48, 95% CI [1.30, 10.14], $p < 0.05$).

Cedar Key residents were 5.63 times more likely to select their own stakeholder group as a responsible party for maintenance than non-residents (OR = 5.63, 95% CI [2.13, 16.05], $p < 0.01$), and shore-based anglers were 2.89 times more likely to select their own stakeholder group as a responsible party for maintenance (OR = 2.89, 95% CI [1.23, 7.13], $p < 0.05$).

4 Discussion

This study focuses on community perception and stewardship of coastal infrastructure in the public realm, providing important insights into how residents view various types of shorelines outside private settings. Additionally, we investigated potential predictors for positive perceptions of nature-based coastal infrastructure, as well as lay stewardship for coastal infrastructure regarding both funding and maintenance.

Previous studies focusing on private shorelines in the Southeastern U.S., including Florida, consistently reported that residents view natural and nature-based shorelines as more aesthetically pleasing but less protective than armored ones (Barry et al., 2024; Gray et al., 2017; Guthrie et al., 2023; Palinkas et al., 2022; Smith et al., 2017). In contrast, our study results based in Cedar Key, Florida showed that, among five types of coastal infrastructure on the green-gray spectrum (vegetation-only, sills, beach nourishment, revetment, and sea wall), the first two nature-based options were perceived as significantly more beautiful than revetment and sea walls and similarly protective (Figure 3). Indeed, we observed significant correlations between perceived coastal protection and beauty for all five types of coastal infrastructure except sea wall, and there was little perceived trade-off between protection function and aesthetic appeal for sills and vegetation-only (Table 2).

This result may be attributed to the strong environmental awareness and advocacy for nature-based coastal infrastructure that are present in the Cedar Key community. The study participants reported a relatively high pro-environmental attitude as reflected by the average NEP score (3.66 ± 0.40 out of 5) (Izadpanahi and Tucker, 2018). They also most frequently selected "Impact on ecosystems" as their top priority for coastal infrastructure choices. In addition, Cedar Key's history of ecological restoration, multi-year efforts to construct three public living shoreline projects (Barry et al., 2025), and ordinance that promotes living shorelines and restricts the construction of bulkheads and sea walls (City of Cedar Key, 2018, §§ 4-8.10, 10.04.00) may have fostered a stronger awareness and more positive perception of nature-based coastal infrastructure.

Another potential explanation is that people's perceptions of public coastal infrastructure at the community level can differ greatly from their perceptions of private implementation on their own properties. For example, O'Donnell et al. (2022) found that residents in Lower Florida Keys perceived mangroves offering more storm protection for their neighborhood than at the parcel scale of their homes. This discrepancy in perceptions of nature-based shorelines between the public and private realms might be linked to weaker social pressures to conform to neighborhood norms when managing one's own property (Barry et al., 2024). Additionally, the larger scale of public nature-based coastal infrastructure may be viewed as providing more defense than the smaller-sized practices, thereby enhancing its perceived protection function.

The study results also highlight several factors that may enhance perceptions of nature-based coastal infrastructure. First, understandings about shoreline functions and concerns about existing issues may affect their perceptions of coastal infrastructure. Nature-based options may be preferred for their co-benefits such as erosion control and water purification—participants who viewed pollutant capture as an important shoreline function had significantly higher ratings for both vegetation-only and sills, and participants who viewed erosion as a critical shoreline issue had significantly higher ratings for sills. Second, general pro-environmental attitudes may contribute to a more positive perception of nature-based coastal infrastructure. Consistent with previous studies on acceptance of nature-based solutions (Anderson et al., 2021), perceptions of both vegetation-only and sills were positively associated with NEP scores. Additionally, age may influence perceptions of nature-based coastal infrastructure—we found that older participants rated vegetation-only significantly higher. This might be explained by the stronger environmental awareness often present among senior residents, as well as the greater knowledge and more experiences of the local environment and its change over time (Rodenburg and MacDonald, 2021). However, as fewer than 10% of participants were under 30 years old, and younger generations are increasingly engaged in environmental activism and advocacy, future studies should investigate potential generational differences in perceptions of coastal infrastructure, especially in the younger generations (Halkos and Matsiori, 2017; Sudbury-Riley et al., 2014). While previous studies on private shorelines have collected demographic and socioeconomic data (e.g., age, gender, race, household income, length of residence), none have investigated how these factors may influence shoreline perceptions (Barry et al., 2024; O'Donnell et al., 2022; Scyphers et al., 2019; Smith et al., 2017). Understanding how variables like age, income, and length of residence shape perceptions of shoreline types can provide valuable insights for tailoring coastal infrastructure development in local communities and remains an important topic for future research.

Regarding community stewardship, participants widely agreed that other stakeholders besides governmental agencies should take responsibilities for coastal infrastructure funding and maintenance. Importantly, we found that contributions to funding versus maintenance emerged as distinct stewardship roles associated with different stakeholder groups. Many Cedar Key residents believed that their group should contribute to coastal infrastructure maintenance, while many tourists identified their group as responsible for funding. Residents, viewing the shoreline as integral to their everyday living environment, may be willing to assist with upkeep but hesitant to contribute financially. Tourists, conversely, may not see themselves as responsible for routine maintenance but are willing to support infrastructure financially to enhance their sightseeing and recreation experiences. Shore-based anglers were the only stakeholder group that was significantly more likely to contribute to both funding and maintenance. Recreational activities have been associated with stronger stewardship of natural coastlines (Dean et al., 2024). Interestingly, we found that, unlike shore-based anglers, boat-based anglers did not show high willingness to engage in stewardship, despite that they generally have higher socioeconomic status than the shore-based group. Therefore, the physical location of recreation might have a stronger influence on stewardship behaviors than the type of recreational activity. In addition, local government officials might be burdened by the costs and maintenance need of nature-based coastal infrastructure— despite their positive perceptions of nature-based shoreline options, over 20% of the 15 participants from the city government group believed that neither the city or the state should be responsible for costal infrastructure funding or maintenance. These findings point to both an opportunity and a necessity to seek funding and maintenance support from the private sector. For example, innovative funding mechanisms that leverage tourism and shoreline-based recreation may be particularly effective in coastal communities like Cedar Key, which hold historical and cultural significance (Nguyen et al., 2024).

4.1 Design implications for nature-based coastal infrastructure

The study results have several implications for nature-based coastal infrastructure design. First, including coastal plants like marsh grasses may help enhance the aesthetic appeal of nature-based options. Strong associations between greenness and preference have been found for nature-based stormwater infrastructure in terrestrial settings (Suppakittpaisarn et al., 2020). Our study also found that vegetation-only and sills, both of which include plants in the design, were perceived as significantly more beautiful than all other options without vegetation. Second, incorporating visible, hard, structural materials—such as rocks—into nature-based designs may enhance their perceived protective function. Our study showed that, sills had the highest protection scores, as well as the strongest correlation between protection and beauty, among the five types of coastal infrastructure we examined. Furthermore, they may be perceived as offering more erosion control than the vegetation-only option. Plants are often considered as a "soft" material in landscape design. For example, some studies on nature-based stormwater infrastructure have reported higher preference and perceived safety for designs that included bollards (Nassauer et al., 2021). Hybrid coastal infrastructure can more effectively protect shorelines than purely engineered or natural designs (Huynh et al., 2024). Our findings further suggest that hybrid designs may also hold an advantage in terms of public perception. Lastly, strong community engagement can inform the design of tailored nature-based coastal infrastructure and help identify potential sources of support for funding and maintenance. Through orchestrated efforts to reach diverse stakeholders—especially shoreline users such as residents, visitors, and shore-based anglers who had not participated in earlier coastal infrastructure proposals—the community intercept survey provided valuable insights into preferences for nature-based solutions that guided subsequent design decisions.

4.2 Limitations

Several limitations of this study should be considered when interpreting the generalizability of the results. This study has some limitations that call for caution when generalizing the results. First, despite that our study sample reflected the local demographic profile (Table 1), Cedar Key's small population and relatively remote location naturally limit the sample size. Findings may not be applicable to larger or more urbanized communities with hardened shorelines. Additionally, more environmentally conscious individuals may have been more likely to participate in the study and be included in the sample. Second, the survey was conducted during a specific time, during which no major storm or other extreme weather events occurred. This might have influence on how participants perceived various shoreline options and considered their capacity to be stewards for public coastal infrastructure. Third, the survey employed the widely used SAGE's typology for Natural and Structural Measures for Shoreline Stabilization (Figure 2) to depict coastal infrastructure options. These diagram-style visualizations lacked details of the local environment and site-specific design characteristics, potentially affecting participants' perceptions of shoreline options. Furthermore, although ten shoreline options were presented in the survey, our analysis focused on five of them. While we accounted for non-independent ratings in our data analysis methods, exposure to the other options may have influenced responses in ways not fully captured.

5 Conclusion

This study explores community perception and stewardship of public coastal infrastructure, expanding research focus beyond private settings and providing important insights to support broader adoption of nature-based solutions. Our findings challenge the binary framing of green vs. gray infrastructure often prevalent in research, policy, and management efforts in coastal resilience. Hybrid and soft costal defense measures can cost-effectively reduce hazards and mitigate climate change impacts (Huynh et al., 2024; Mondal et al., 2025). This study further highlights the great potential of hybrid and nature-based coastal infrastructure from the perspective of public perception and acceptance. Specifically, combining vegetation and hardened materials may enhance both perceived beauty and perceived protection. We argue that nature-based coastal infrastructure must not be treated as a homogenous solution and its development needs to pay more attention to fine-scale design features characteristics that contribute to aesthetic appeal and sense of security. In addition, community members may associate nature-based coastal infrastructure with social and environmental co-benefits such as aesthetic value and water purification, which can be leveraged in communication and outreach strategies to enhance public acceptance and support. Furthermore, our findings stress the necessity of developing community-level nature-based coastal infrastructure through deep community engagement. Although private shorelines dominate Florida and many other coastal regions in the U.S., publicly accessible demonstration projects at the community level can play a pivotal role in increasing acceptance and fostering lay stewardship among diverse stakeholders. Given the persistent funding challenges for nature-based coastal infrastructure (Sutton-Grier et al., 2018), exploring private-sector contributions—especially from residents, recreational users, and tourists—may be an effective strategy.

Future research should devote more attention to hybrid nature-based coastal infrastructure in the public realm—not only in terms of its potential to protect against coastal disasters and support natural habitats, but also in relation to community preferences, benefits, and engagement. Studies with larger sample sizes, drawn from communities with diverse landscape and socioeconomic contexts, are needed to enhance understanding of perception and stewardship. In addition, qualitative or mixed-method approaches—such as interviews with stakeholder groups, case studies, and policy analyses—can provide deeper insights to inform design principles and stewardship programs that support the adoption and long-term performance of nature-based coastal infrastructure.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by University of Florida Institutional Review Board (IRB) (reference number IRB202200544). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JL: Conceptualization, Formal analysis, Methodology, Supervision, Visualization, Writing – original draft, Writing – review & editing. AA: Conceptualization, Formal analysis, Methodology, Writing – review & editing. EB: Writing – review & editing. CB: Investigation, Methodology, Writing – review & editing. MC: Writing – review & editing. JV: Investigation, Methodology, Writing – review & editing. AO: Data curation, Visualization, Writing – review & editing. SB: Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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