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Fragile Shores: Coastal Ecosystem Vulnerability in Barangay Bacong, Babatngon, Leyte, Philippines

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ABSTRACT

Introduction: The Philippines, as an archipelagic nation, hosts a vast and dynamic coastal ecosystem that plays a critical role in the socio-economic activities of coastal communities. However, increasing development pressures, such as industrialization and population growth, contribute to the gradual degradation of these environments. This study investigates the vulnerability of the coastal ecosystem in Barangay Bacong, Babatngon, Leyte, a developing coastal barangay experiencing environmental stress amid growing industrial activities. **Methods:** The study employed the Coastal Vulnerability Index (CVI) to assess coastal geomorphology and vulnerability. Primary data were collected through a validated survey instrument adapted from Gan et al. (2022), which measured residents' perceptions of coastal resilience. Secondary spatial data were obtained from the Municipal Planning and Development Office (MPDO) and the Mines and Geosciences Bureau (MGB) in shapefile format. The spatial analysis was conducted using Quantum Geographic Information System (QGIS) version 3.28.8. The CVI was classified into three vulnerability levels—low (1–2), moderate (3–4), and high (5)—based on the scale used by Husaini et al. (2021), which reflects the observed degree of environmental damage. **Results:** The assessment revealed that Barangay Bacong's coastal areas exhibit a moderate level of vulnerability, indicating a pressing need for integrated management strategies. Interestingly, statistical analysis showed no significant correlation between demographic variables and ecological vulnerability, which may be attributed to the relatively low population density in the area. **Discussion:** The findings suggest that, despite exposure to coastal hazards, the area demonstrates a moderate level of adaptive capacity. The absence of significant demographic influence on perceived vulnerability underscores the need for ecosystem-based rather than solely population-focused approaches to coastal management. **Conclusion:** This study provides baseline data critical for future initiatives in Disaster Risk Reduction and Management (DRRM) and Climate Change Adaptation (CCA) in coastal areas. It advocates for the adoption of community-based and data-informed coastal management strategies to strengthen ecosystem resilience in the face of environmental change.

Keywords: Vulnerability Assessment, Coastal Vulnerability Index, Adaptive Capacity, Coastal Ecosystem

1. INTRODUCTION

The study on vulnerability has a significant role in gaining a better understanding on the risk of natural disasters and man-made activities. Vulnerability is defined as the extent to which a population or system is likely to suffer harm due to exposure to certain potential hazards (Prasetyo et al., 2020). Based on a recent study by Estoque et al. (2022), the Intergovernmental Panel on Climate Change (IPCC) vulnerability framework, presented in its Third and Fourth Assessment Reports, is frequently used in climate-related vulnerability assessments. Vulnerability results from exposure, sensitivity, and adaptive capacity. Following definitions given by most vulnerability studies, such as those by Robielos et al. (2020), and Jones et al. (2020), the determination of the risk source, including its magnitude, frequency of occurrence, and spatial impact, is part of the exposure assessment process. Sensitivity describes the degree to which a population or system is harmed due to exposure to natural hazards.

These studies also examine how human communities are dealing with these impacts and explore potential solutions for ecological and human adaptation (Cooley et al., 2022). The coastal zone is a delicate area that requires particular care to protect ecosystems and human activities. Coastal areas are under threat due to the effects of climate change and anthropogenic activities. As a result, analyzing their vulnerabilities and the potential for natural habitats to help preserve coastal areas and communities is critical for long-term planning, sustainability, and resilient coastal management (Ruheili & Boluwade, 2023).

This research was driven by a clear need to address a gap in studies focused on vulnerability assessments for small, rural coastal communities like Barangay Bacong in Babatngon, Leyte. While earlier research has mostly focused on coastal risks in larger cities, few studies examine how these risks impact smaller, resource-dependent areas where communities rely on fishing and have limited disaster-preparedness infrastructure. This study addresses this gap by looking at the unique challenges faced by Barangay Bacong's coastal ecosystem, where environmental changes directly affect local livelihoods and community resilience. By evaluating factors such as sea-level rise, coastal landscape, and local development, the research tackles the core problem: understanding the adaptive capacity and resilience of a rural coastal area that depends heavily on natural resources. The study contributes baseline data to support conservation and sustainable development planning for similar rural coastal areas, offering a valuable framework for future vulnerability assessments and informed coastal management strategies.

2. METHODOLOGY

2.1 Research Design

The coastal vulnerability assessment of Barangay Bacong, Babatngon Leyte, utilized a mixed-method approach, incorporating qualitative and quantitative data collection and analysis techniques. Thus, a validated survey questionnaire was provided for the local residents and the data were obtained from MPDO and MGB in the form of shape files and mainly utilized the tool Quantum Geographic Information System (QGIS) version 3.28.8 to determine the spatial data needed. The typical categories of the coastal vulnerability index were established from the research conducted by Husaini et al. (2021) and classified as low (!-2), moderate (3-4), and high (5),

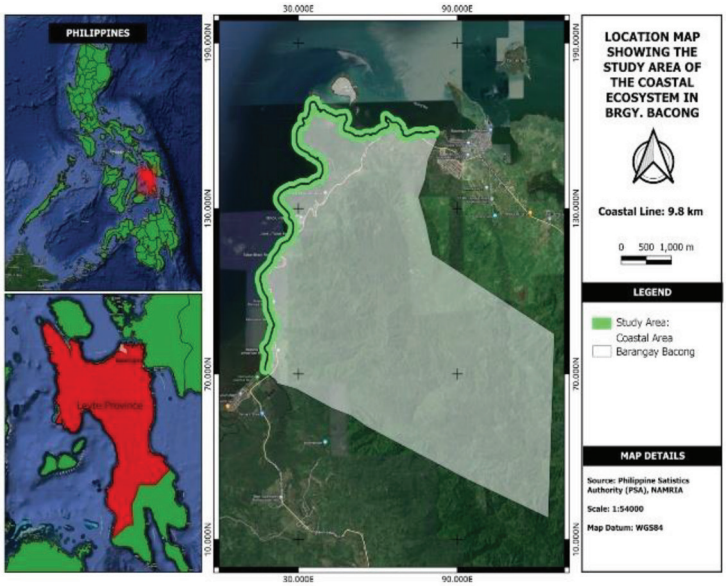

Figure 1. Location of the Study.

according to the extent of damage observed, especially in coastal regions.

2.2 Respondents of the Study

The study employed a simple random sampling method to gather data from 228 residents of Barangay Bacong, Babatngon, Leyte, out of a total population of 529. this method was chosen to ensure a representative sample, minimizing bias and allowing for generalizable findings. The Krejcie & Morgan was used as recommended by Bukhari (2021) to determine the sample size, ensuring desired level of accuracy for the study. By selecting participants randomly, the study aimed to capture the diverse characteristics of the community, making the results statistically significant and applicable to the entire barangay.

2.3 Method of Scoring and Interpretation

The following equivalents were used to record the data gathered from the questionnaire adapted from the study of Gan et al., (2022). The respondents' level of education was categorized and put into several categories. Each of the following codes designates a different level of education: 1 denotes never having attended school; 2 denotes having completed elementary school; 3 denotes having graduated from elementary School; 4 having completed High School; 5 having graduated from High School; 6 having completed some coursework; and 7 denotes having earned a postgraduate degree.

A 5-point Likert scale was used for respondents' comments in order to rate their attitudes according to what they said. The use of Likert scales in research allowed researchers to quantify community attitudes towards coastal sustainability. This was achieved through questionnaires that presented statements related to coastal sustainability, and respondents indicated their level of agreement or disagreement using a scale. This quantifiable data provided valuable insights into community perceptions and preferences, informing interventions and policies aimed at promoting sustainable practices.

The coastal vulnerability assessment of Barangay Bacong, Babatngon Leyte, utilized a mixed-method approach, incorporating qualitative and quantitative data collection and analysis techniques. Thus, the data were obtained from both primary and secondary sources.

Each parameter assigned a ranking score between 1, 2 and 3. To assess vulnerability quantitatively (Yaddav et al., 2022), the individual measurements were compared and assigned a ranking from low (1- 2), moderate (3-4), to high (5). The quantification was generally based on the definition of semi- quantitative scores according to a 1-3 scale, where 1 indicated a low contribution to coastal vulnerability of a specific key variable for the studied area, while 2 indicated a moderate level and 3 indicated a high contribution. The ranking was assigned to these values and summed for each area to provide a relative score of Coastal Vulnerability Index (CVI) based on Borruf (2005).

The degree of vulnerability which can be seen on Table C, was then evaluated using a rating methodology.

In a similar context, the standard levels of the coastal vulnerability index were derived from Husaini et al., study (2021) and categorized as low vulnerability, moderate, and high, based on the impact of the damage observed, particularly in coastal areas. Each cell then received a vulnerability ranking in the corresponding parameter.

The data obtained from the assessment underwent various statistical treatment to address the research problem. Therefore, the study utilized the following formula of Borruf (2005):

$$CVI = \sqrt{(a * b * c * d * e)/n}$$

Where:

n = number of vulnerability variables, a = coastal geomorphology, b = type of coastal development, c = coastal slope, d = presence or absence of coastal habitats, e = sea level rise.

3. RESULTS AND DISCUSSION

3.1 Profile of the Respondents

The study considered various attributes of the participants, including their age range, educational background, occupation, and number of household members. These attributes are described in the following discussion.

3.1.1 Age

Majority of the people who answered the survey were at the middle aged which can be seen on Table

Table 1. Interpretation on the Attitude-based Actions of the Local Community

Scale	Mean Range	Interpretation
1	1.00- 1.80	Strongly Disagree
2	1.81-2.60	Disagree
3	2.61-3.40	Neutral
4	3.41-4.20	Agree
5	4.21-5.00	Strongly Agree

Source: *Authors, 2024.*

Table 2. Coastal Vulnerability Levels

(CVI)	VULNERABILITY
1-2	Low
3-4	Moderate
5	High

Source: *Authors, 2024.*

1. Followed by ages from 18-24 categorized as adults at twenty-seven-point twenty percent (27.20%). Furthermore, twenty-one-point ninety percent (21.90%) are young adults that are ages 25- 34, whereas thirteen-point ten percent (13.10%) are old adults. The least respondents were older adults that ages 55 and above having comprised of five- point eighty percent (5.80%). The finding of the study is consistent with the research conducted by Lau et al. (2019) which highlighted the importance of middle-aged individuals in coastal resource management.

3.1.2 Educational Attainment

Of the total number of respondents, twenty-three- point two percent (23.20%) have an educational attainment at a high school level as seen on table 2, whereas nineteen-point twenty percent (19.20%) have graduated in high school. Followed by eighteen-point forty percent (18.40%) were college level and seventeen-point thirty percent (17.30%) having elementary level of education. Twelve-point twenty percent (12.20%) of which graduated from elementary and eight-point thirty percent (8.30%) graduated in college, with zero-point forty percent (0.40%) being post graduate. People that have a certain degree of education are sometimes connected to being aware of environmental issues, helping them to make decisions that provides an outcome that benefits the majority. Conversely, lower levels of education can contribute to behaviors that may negatively impact coastal ecosystems, such as overfishing and pollution, due to a lack of awareness regarding their significance and vulnerability (Wang et al., 2022). The findings of this study are consistent with the research conducted by the La Support (2022), which emphasizes that education's effectiveness and significance are widely established. Engaging people in education and raising their level of awareness about the environment as a whole is an effective strategy of motivating them to take action to protect it.

3.1.3 Occupation

The data indicates which can be seen in Table 5 revealed that the most common occupation is fishing (100 respondents) making up 44.00% of the total surveyed population. Additionally, occupation listed are vendors (44 respondents) with nineteen-point twenty percent (19.20%) of those surveyed population. Followed by employees (14 respondents) with six-point ten percent (6.10%) of the total, and drivers (7 respondents) making up three-point ten percent (3.10%) of the population.

Another construction worker (3 respondents) and caretakers (3 respondents) have the same number of results with one-point thirty percent (1.30%) of the sum total. There were (2 respondents) that have pension with the percentage of zero-point ninety percent (0.90%). Farmer represents the smallest portion of the population

Table 3. Age

Age Range	Frequency	Percentage
18-24	62	27.20%
25-34	50	21.90%
35-44	73	32.00%
45-54	30	13.10%
55 above	13	5.80%
Total	**228**	**100%**

Source: *Authors, 2024.*

Table 4. Educational Attainment

Educational Attainment	Frequency	Percentage
Post Graduate	1	0.40%
College Graduate	19	8.30%
College Level	42	18.40%
High School Graduate	44	19.20%
High School Level	53	23.20%
Elementary Graduate	28	12.20%
Elementary Level	41	17.30%
Total	**228**	**100%**

Source: *Authors, 2024.*

Table 5. Occupation

Occupation	Frequency	Percentage
Caretaker	3	1.30%
Construction Worker	3	1.30%
Driver	7	3.10%
Fisherman	100	44.00%
Employee	14	6.10%
Farmer	1	0.40%
Vendor	44	19.20%
Seasonal Worker	54	23.70%
Pension	2	0.90%
Total	**228**	**100%**

Source: *Authors, 2024.*

Table 6. Number of Household Members

Number of Household Members	Frequency	Percentage
1-3	99	43.50%
4-6	111	48.70%
7-9	12	5.20%
10-12	6	2.60%
Total	**228**	**100%**

Source: *Authors, 2024.*

Table 7. Attitude-based action of the local community towards sustainability of the coastal area

Statement	Mean	Interpretation
a. I think any plastics are harmful to marine ecosystems.	4.28	Strongly Agree
b. I think marine environment pollution is currently a serious problem.	4.26	Strongly Agree
c. I think marine environment pollution negatively affects our tourism sector.	4.22	Strongly Agree
d. To reduce the amount of solid waste in the marine environment, we should reduce plastic production.	4.17	Agree
e. I think daily-life needs generate and ultimately will cause marine pollution.	4.14	Agree
f. I should be aware about the damage caused by various marine environment pollutants.	4.18	Agree
g. I should be aware about reports of marine about the reports of marine-related pollution.	4.18	Agree
h. I should support activities related to the marine environmental pollution.	4.19	Agree
i. I agree that the government should build sanitary sewers and sewage treatment plants.	4.21	Strongly Agree
j. I intend to do my part to prevent the ocean pollution.	4.13	Agree
k. I will inform the relevant Local Government institutions when I notice pollution near the coast.	4.11	Agree
l. I do not support manufacturers or companies that do not have proper waste disposal.	4.14	Agree
m. I will reduce my consumption of coastal marine species such as shrimp, crabs, fishes, etc.	3.05	Agree
n. I will reduce the use of cleaning products such as detergents that pollute the sea.	3.60	Agree
o. I will reduce my participation in leisure activities that will affect the coastal ecosystem.	4.03	Agree
p. I will discuss topics related to the sustainability of the coastal ecosystem with the community, family, and friends.	4.13	Agree
q. I will partake in beach clean-up activities.	4.08	Agree
r. When I go to the seaside, I will take my own garbage with me.	4.16	Agree
Total Mean	**4.07**	**Agree**

Source: *Authors, 2024.*

with (1 respondent) making up zero- point forty percent (0.40%) of the entire surveyed population. However, a significant number of respondents (54 respondents) which makes up twenty-three-point seven percent (23.7%) of the whole surveyed population considered as seasonal worker. In general, the data suggests that most of the respondents depend on natural resources or common work for their income. A huge part of population leans on fishing or various marine resources exploitation for their livelihood; this could be one of the contributing factors in terms of coastal vulnerability.

3.1.4 Number of Household Members

The results of the distribution revealed that majority of the respondents which can be seen in Table 7, had 4-6- or forty-eight-point seventy percent (48.70%) members in their family. Of the total respondents, ninety-nine (99) or forty-three-point fifty percent (43.50%) had 1-3 members in their family, whereas twelve (12) of them had 7-9 household members or five-point twenty percent (5.20%). And the lowest of which, 10-12 household members in their family or two-point sixty percent (2.60%). While house hold size is one of the demographic factors, it is not directly relating to the vulnerability of the coastal ecosystem in Barangay Bacong, implications including an increased population density have a higher chance of generating more waste and having more impact with regards to susceptibility.

3.1.5 Attitude-based Actions of the Local Community

Majority of the respondents' rates indicate their level of agreement with the statement concerning the sustainability of the coastal area in the barangay. This aligns with the studies of Jones & Patel (2022) which highlight the significance of community attitudes and actions in waste management and pollution control, which are the crucial aspects for maintaining the health and resilience of coastal ecosystems. In addition, the knowledge of the coastal community proves significant in mitigation and conservation efforts in promoting the sustainability of coastal environments (Hasriyanti et. al., 2024). This shows individuals of improper disposal of plastic garbage has a harmful impact to human and

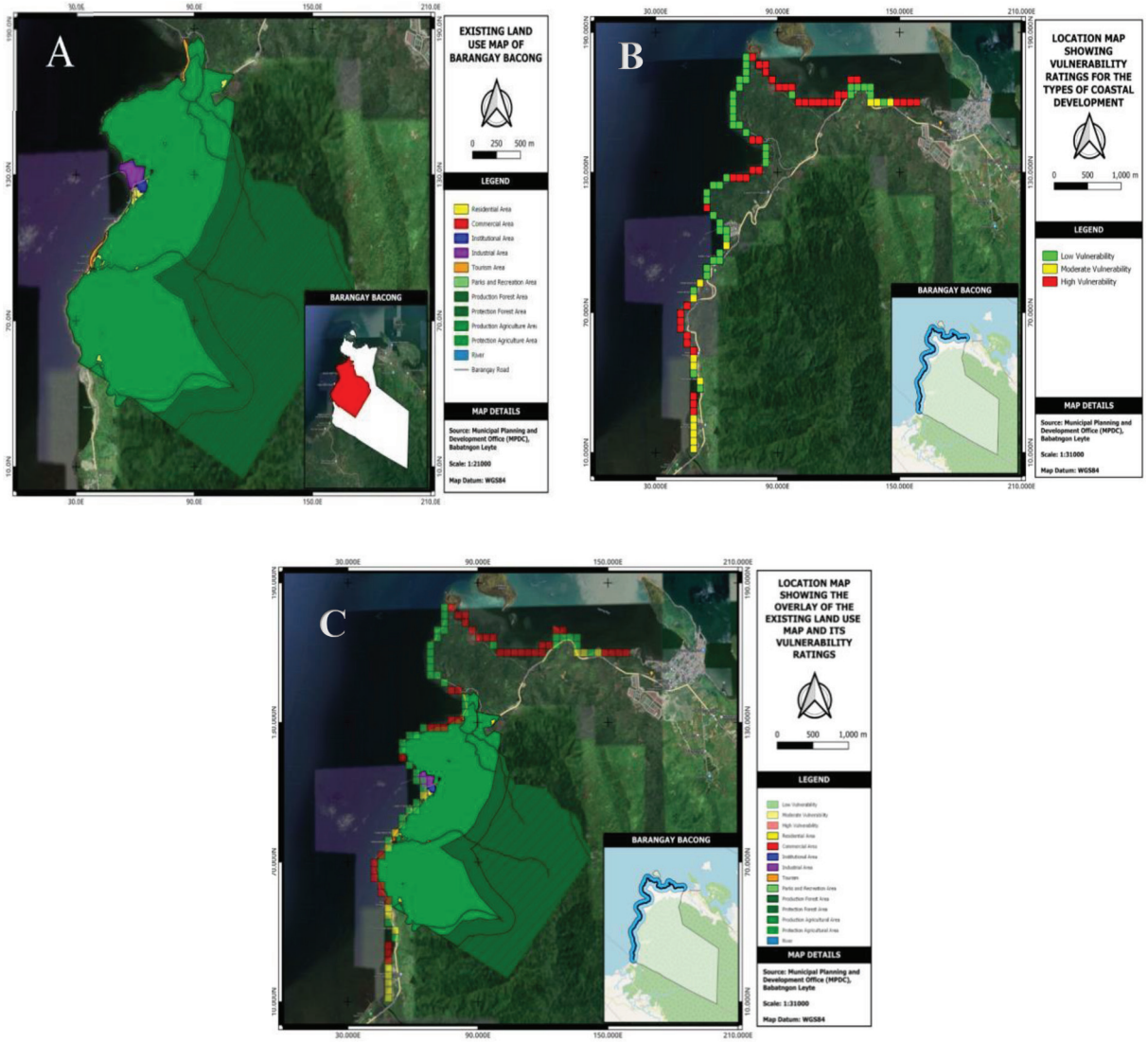

Figure 2. (A) Existing land use map (B) Vulnerability ratings for the type of coastal development (C) Location map showing the overlay of the existing land use map and its vulnerability ratings.

environmental health. The majority of respondents 51-57% agreed that properly disposing of personal waste helps to reduce beach pollution. In beaches, it is typical seen management gather PET, scale and other (Inocente et al., 2023). Additionally, Fava (2022), stated that, the most effective plan of actions, according to a number of experts, to stop plastic debris by starting from our home. They can begin implementing better policies for everybody by deepening their understanding and knowledge about the effects of marine pollution.

3.2 Type of Coastal Development

The existing map which can be seen on Figure 2 indicate that along the coast: tourism, industrial residential, and agricultural areas are commonly found. The existing land use map serves as the basis for the ratings in determining the level of vulnerability of each cell which can be seen on Figure 2B. The result of the vulnerability ratings is further visualized which is seen in Figure 2C. The type of coastal development shows that out of ninety-seven (97) cells, forty-two cells (42) of the coastal are is given the classification of low (1) mostly due to the land use type being tourism, commercial, and industrial area. Fourteen (14) of the cells are categorized as moderate (2) because of the area possessing in comparison to the low vulnerability zones, these residential infrastructure locations are more vulnerable to coastal disasters. Additionally, the classification of high (3) indicates that forty-one (41) cells of the coastline region are used for agriculture indicating that agricultural areas, especially those situated in the coastal zone, are more vulnerable to coastal dangers. The analysis of Rocha et al., (2021) stated in terms of assessing coastal vulnerability, distance is a crucial factor. The coastal area is susceptible to coastal pressures. As the distance to coastline increases, erosion and coastal vulnerability decreases. In contrast, the closer the distance of the residents near the coastline the more vulnerable the are in coastal damages.

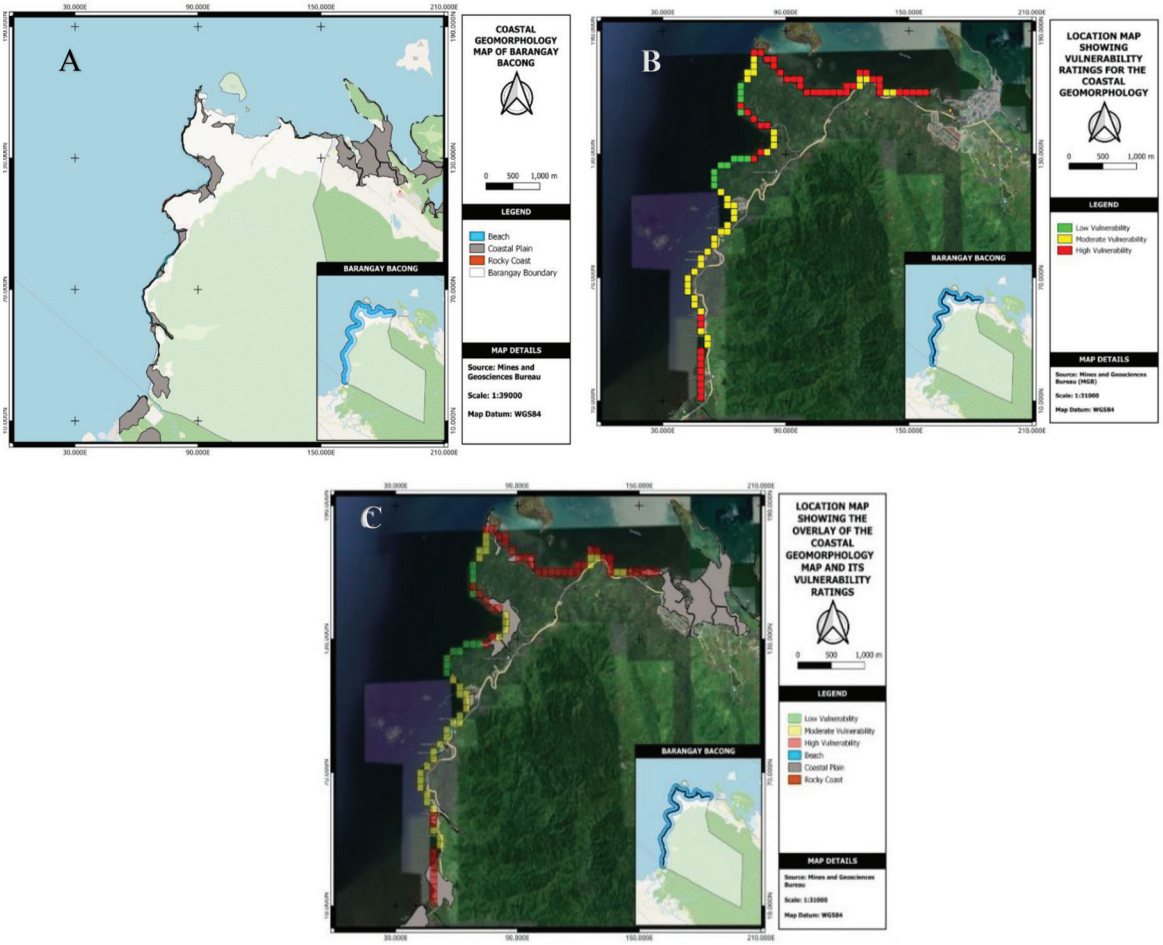

Figure 3. (A) Coastal geomorphology map (B) Vulnerability ratings for coastal geomorphology (C) Location map showing the overlay of the coastal map and its vulnerability ratings.

3.3 Coastal Geomorphology

The coastal geomorphology map which is seen in figure 3A indicate that along the coast; coastal plain, rocky coast and beach are commonly found. The coastal geomorphology map serves as the basis for the ratings in determining the level of vulnerability of each cell which can be seen on Figure 3B. The result of coastal geomorphology shows that out of ninety-seven (97) cells, thirty- eight (38) cells of the area are classified as moderate (2), it is observed that sandy beaches, such as Tulaan Beach Resort and Karisyohan Beach are located along the coast. A total of twelve (12) cells of the area classified as low (1) shows rocky coastlines that tend to be more resistant to erosion compared to sandy beaches, providing a natural protective barrier against coastal hazards, and forty- seven (47) cells are coastal plains that consists of low-lying areas classified as high (3).

The data presented suggest that the area, having varied landscape, experiences moderate levels of vulnerability. This implies that although most of the coast has sandy beaches, coastal plains and rocky coast are also evident which causes to have a high vulnerability. Furthermore, the study of Widura and Mardiatno (2022) explains that marine landforms such as rocky coastal lower erosion that formation disposition has moderate vulnerability, while marine landforms that have low vulnerability are found on the cliff coast. Moreover, the study of Koroglu (2019) indicates how the geomorphology of the coast affects how it responds to rising sea levels which some areas like cliffs, rocky coasts, are naturally more resistant to erosion than sandy beaches.

3.4 Coastal Slope

The coastal slope map as seen on Figure 4A indicate the slope degrees found. Along the coast, the values observed were only less than or equal to zero point-two degrees (≤0.2°). The coastal slope map served as the basis for the ratings in determining the level of vulnerability of each cell which can be seen on Figure 4B. The coastal slope of the coastal area was given a classification of high (3), a value of less than or equal to zero point- two degrees (≤0.2°) were observed which signify high vulnerability in terms of the inclination rate of the coastal area. According to López-Dóriga et al. (2020) human development tends to concentrate in flat coastal areas, further increasing vulnerability by intensifying exposure to coastal hazards and reducing natural buffers.

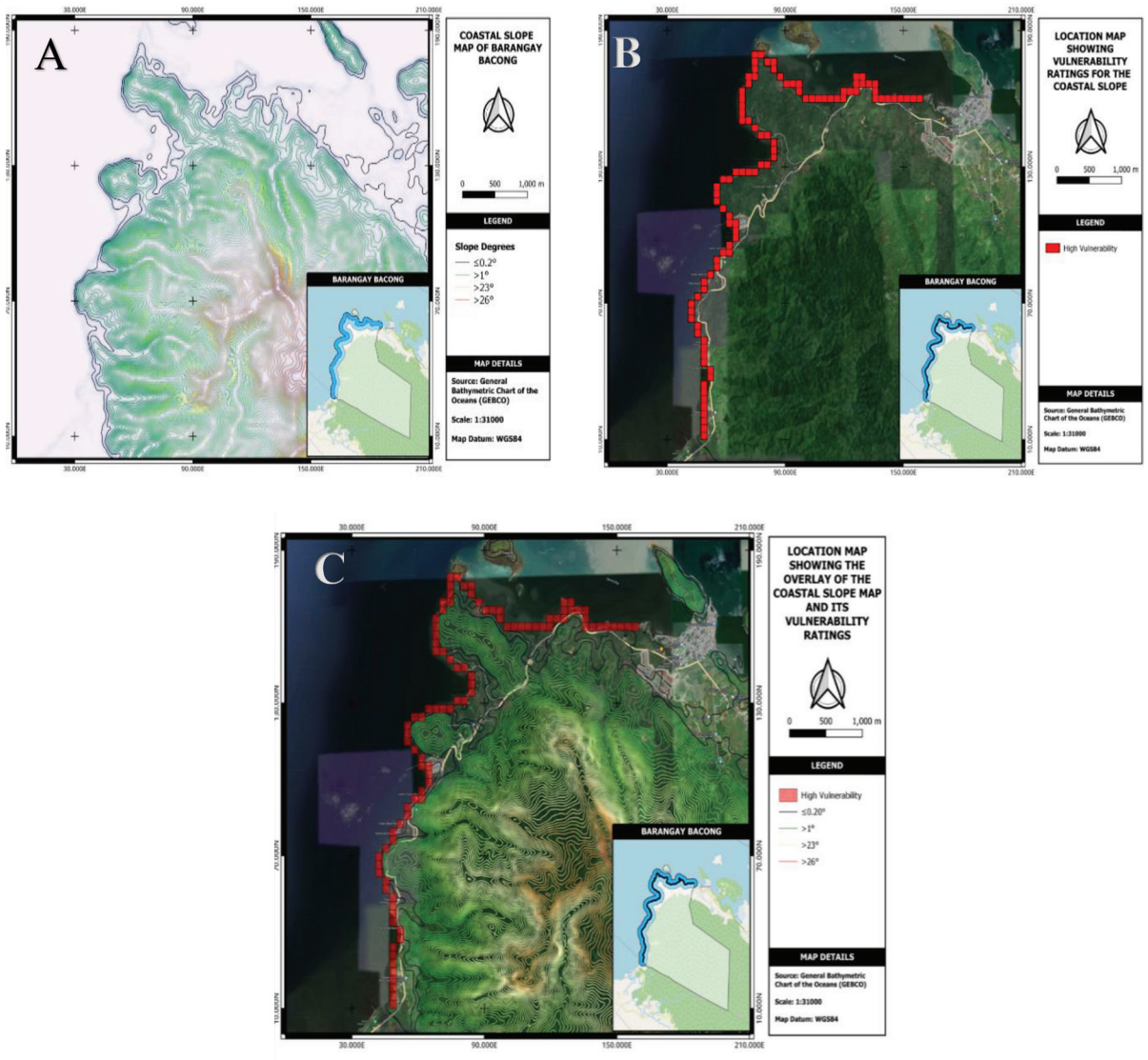

Figure 4. (A) Coastal slope map (B) Vulnerability ratings for coastal slope (C) Location map showing the overlay of the coastal map and its vulnerability ratings.

3.5 Presence or Absence of Coastal Habitats

The coastal habitat map which can be seen on Figure 5A indicate that along the coast the presence of mangroves, sea-grasses and coral reefs are observed. However, there are also some areas do not have coastal habitat present. The coastal habitat map served as the basis for the ratings in determining the level of vulnerability of each cell which can be seen on Figure 5B. The presence or absence of coastal habitat shows that out of ninety-seven (97) cells, thirty (30) cells of the coastal area consist of coral reefs and sea-grasses which is given the classification of moderate (2). A total twenty-nine (29) cells did not have any coastal habitats observed and were classified as high (3), the thirty-eight (38) cells were classified as low (1) due to the coastal area having mangroves as well as coral reefs and sea-grasses. The best ways to mitigate coastal risks ought on by sea level rise and protect coastal towns have been proposed as nature-based solutions. People at risk from these impact risks will significantly rise with the loss of current natural ecosystems (Manes et al., 2023).

3.6 Sea Level Rise

At projected 0.5 meters scenarios, which can be seen on Figure 6A indicate that along the coast that flooding at ankle deep (0.1-0.25) meters and knee deep (0.25-0.7) meters are mostly observed. The projected sea level rise served as the basis for the ratings in determining the level of vulnerability of each cell which can be seen on figure 6B. The projected sea level rise at 0.5 meters shows that the coastal area has the possibility of experiencing flooding at 0.1 meters to 0.7 meters. The projected sea level rise at 0.5 meters' scenarios shows that out of ninety-seven (97) cells, four (4) cells of the area show 0.1 meters to 0.25 meters of flooding, giving the classification of moderate (2) which suggest significant vulnerability. The inundation indicates the potential for adverse impacts such as erosion, coastal habitat loss, and infrastructure

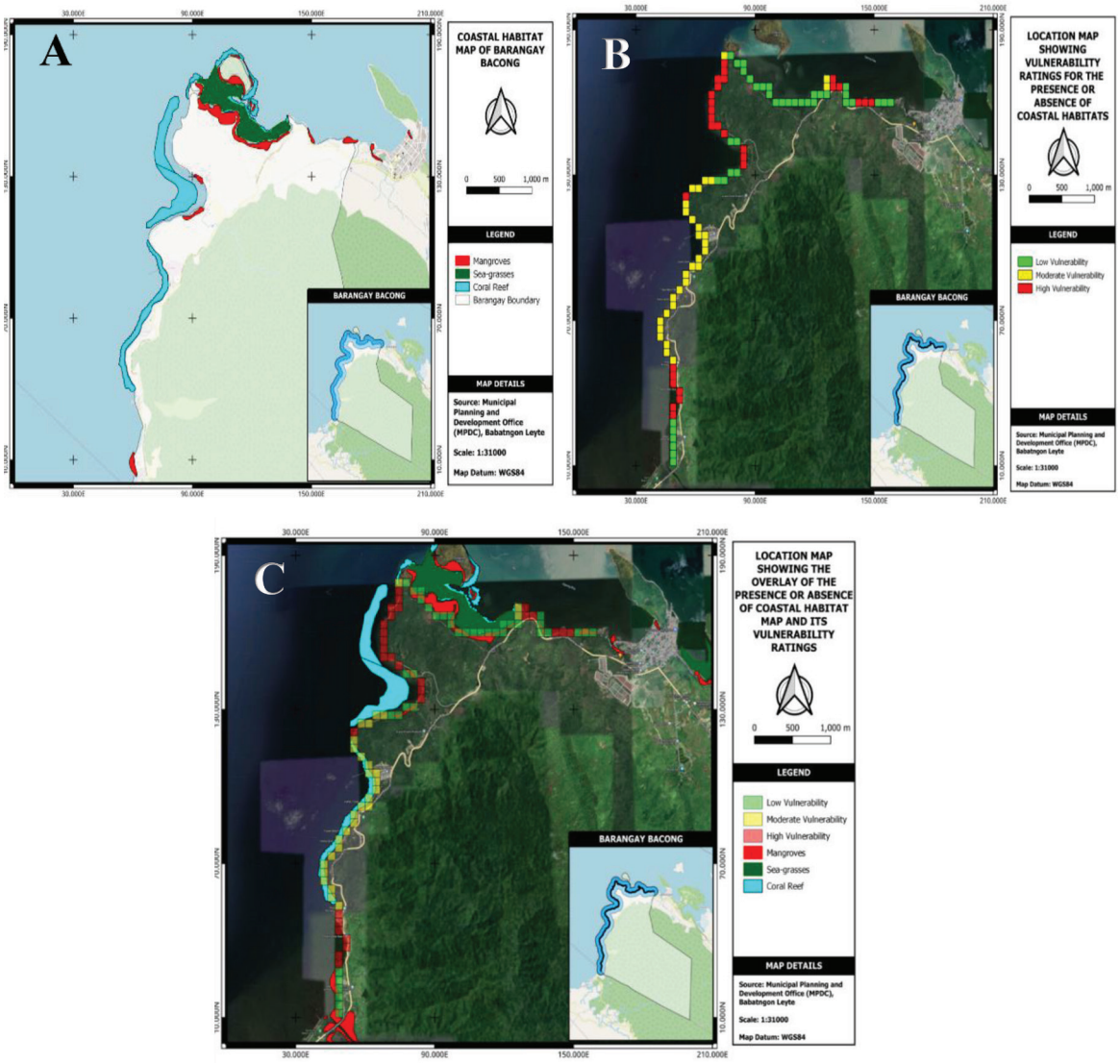

Figure 5. (A) Coastal habitat map (B) Vulnerability ratings for the presence or absence of coastal habitat (C) Location map showing the overlay of the coastal map and its vulnerability ratings.

damage, highlighting the urgent need for adaptation measures to enhance resilience. Additionally, seventeen (17) cells of the area shows that there is no flooding experienced at 0.5 meters sea-level rise scenario due to presence of natural buffers. A large portion of the area also shows that seventy-six (76) cells experienced knee deep flooding between 0.25 to 0.7 meters. Taherkhani et al., (2020) indicates that coastal floods can be disproportionately increased by even little sea level rise. Numerous oceanic phenomena, including tides, extratropical and tropical storms, climatic cycles (such as the El Niño / Southern Oscillation). As a result, there are many different time scales at which coastal flooding occurs and how severe it is. However, there is a significant interplay between the constant trend and accelerated rise in sea level and brief intense occurrences.

3.7 Coastal Vulnerability Index

The findings of this study are consistent with the research conducted by Yadav et al. (2022), who observed that coastal areas classified with moderate vulnerability often sustain their adaptive capacity through natural features like mangroves and coral reefs. Similarly, in Barangay Bacong, moderate vulnerability levels were observed, with some areas benefitting from natural barriers that provide resilience against environmental threats. The study further aligns with López-Dóriga et al. (2020), who noted that low-elevation coastal areas face heightened vulnerability to sea-level rise and erosion, as demonstrated by Barangay Bacong's exposure to significant flood risks. These similarities underscore the importance of coastal elevation and geomorphology in determining resilience.

This research also integrates with Fedele et al. (2021), who emphasized that communities dependent on natural resources for livelihoods, particularly in tropical regions, face amplified risks from environmental degradation. The high reliance on fishing in Barangay Bacong places it in a similarly vulnerable position, indicating a need for diverse livelihood options and conservation measures to bolster

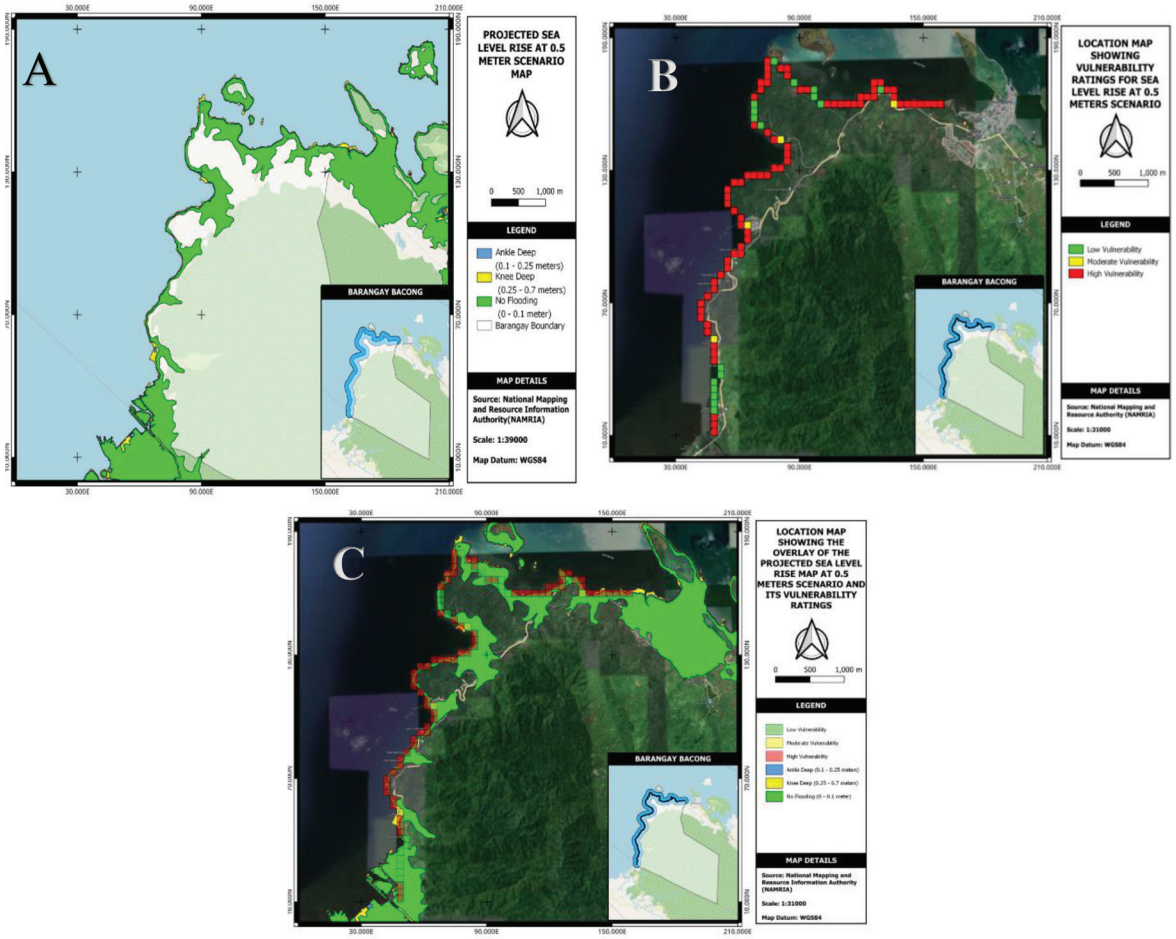

Figure 6. (A) Projected sea level rise at 0.5 meters scenarios (B) Vulnerability ratings for the sea level rise (C) Location map showing the overlay of the coastal map and its vulnerability ratings.

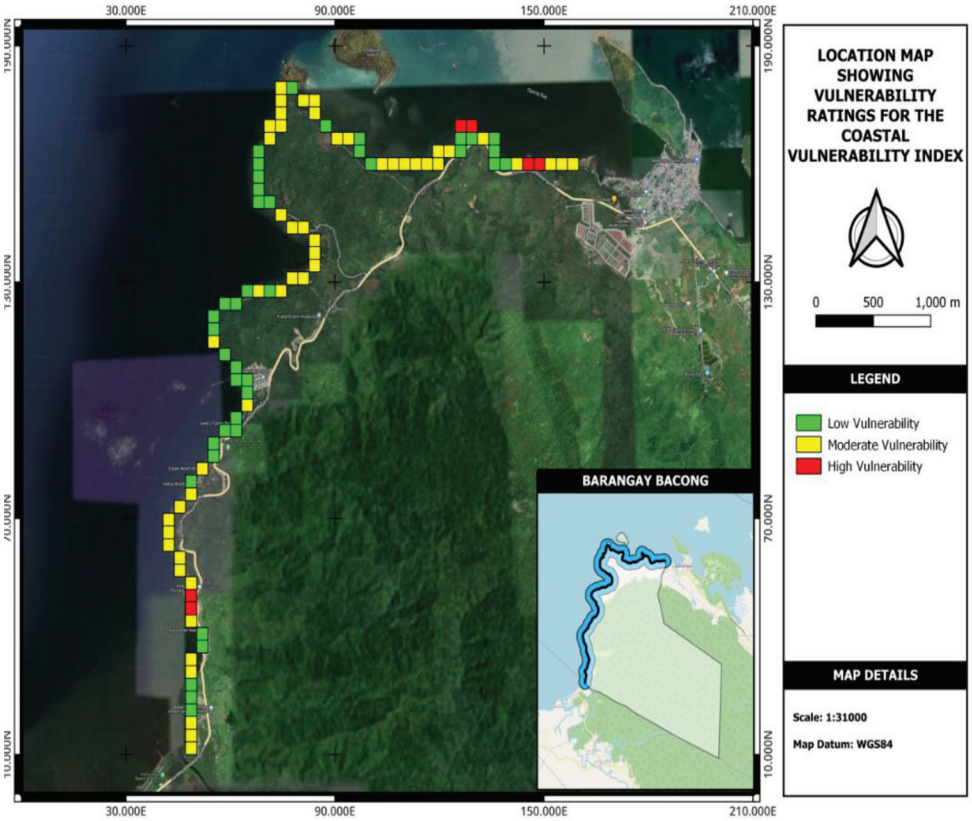

Figure 7. Ratings for the Coastal Vulnerability Index.

resilience. Additionally, the findings echo Meddah et al. (2023), who advocated for community-based adaptive strategies tailored to the unique socio-economic and environmental needs of small coastal communities. Together, these comparisons highlight the importance of integrative, community-focused approaches in managing coastal vulnerability effectively.

4. CONCLUSIONS

The study reveals that the respondents, primarily middle-aged adults (35-44 years old) and young adults (18-24 years old) with a high school education, are mainly engaged in fishing as their occupation. Despite the low population in Barangay Bacong, there is a notable awareness of marine pollution among respondents. They actively take steps to mitigate pollution by refraining from waste disposal into the sea and participating in conservation efforts by releasing immature marine species back into their natural habitat. The area shows a moderate level of vulnerability, emphasizing the need for continuous community engagement, infrastructure development, sustainable practices, and effective disaster risk reduction strategies to enhance adaptive capacity.

The coastal ecosystem exhibits a high level of integrity, with sandy beaches and diverse habitats contributing to its resilience. However, challenges like coastal slope and sea level rise pose significant risks, with a notable vulnerability flooding. This study provides valuable baseline information for future research but ongoing monitoring and management practices are essential to address the complexities of vulnerability assessment in coastal ecosystem.

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The authors declare that they have no competing interests.

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