

# Coastal Vulnerability Assessment of Fishing Communities in the City of Carcar and the Municipality of Sibonga, Cebu, Philippines

Rey F. Trangia<sup>1\*</sup>

PhD FAS Student, Cebu Technological University – Carmen Campus  
City Agriculturist, Carcar City Agriculture Office

Corresponding Author: Rey F. Trangia\*

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**Abstract:** This study assessed the coastal vulnerability of fishing communities in the City of Carcar and the Municipality of Sibonga, Cebu, Philippines, to provide scientific bases for climate adaptation and coastal resource management. Using the ICSEA-C-Change framework, the research combined participatory approaches with quantitative statistical analysis, including chi-square testing, to compare levels of exposure, sensitivity, and adaptive capacity among coastal barangays. Results revealed that both LGUs exhibited moderate overall vulnerability, influenced by coral reef degradation, coastal population density, and limited institutional mechanisms. Key environmental indicators such as sea surface temperature, sea level rise, wave energy, and rainfall trends highlighted increased exposure to climate hazards. Sensitivity was driven by declining fish catch rates and dependence on passive fishing gears, whereas adaptive capacity reflected the heterogeneous condition of coral, seagrass, and mangrove ecosystems. Strengthening community-based resource management, enhancing early warning systems, and improving local adaptive governance are essential for sustaining fisheries and coastal livelihoods under changing climate conditions. This study provides a replicable framework for integrating community-based data with statistical analysis to inform local climate adaptation planning in Philippine coastal zones.

**Keywords:** Coastal Vulnerability, Climate Change, ICSEA-C-Change, Fishing Communities, Adaptive Capacity, Coastal Management, Cebu, Philippines.

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## I. INTRODUCTION

Climate change remains one of the most pressing global challenges of the 21st century [1]. Its impacts on agriculture, coastal zones, forests, and biodiversity are increasingly evident [2], posing serious threats to communities in vulnerable environments such as coastal areas, where poverty and unequal access to resources are widespread [3]. Many coastal communities in developing nations continue to urbanize rapidly because livelihoods depend heavily on marine and coastal resources [4], [5]. However, population growth and infrastructure expansion heighten their exposure to flooding, storm surges, and sea-level rise [6].

Vulnerability—the degree to which a system cannot cope with adverse climate effects—is determined by its exposure, sensitivity, and adaptive capacity [7]. It reflects limited ability to recover from disasters [8], which are defined as events exceeding a community's coping capacity [9]. In

the Philippines, frequent typhoons, floods, and droughts make Central Visayas one of the most at-risk regions [10], [11]. Cebu's coastal municipalities, in particular, face recurring storm surges and erosion. Recent PAGASA reports underscore these risks, citing Typhoon Rai (2021), Tropical Storm Megi (2022a), Tropical Storm Nalgae (2022b), and Severe Tropical Storm Bising (2025) as major climate events [12].

The City of Carcar and Municipality of Sibonga, located along Cebu's southeastern coast, exemplify these challenges. Carcar is a provincial growth center with thriving industries [13], while Sibonga's economy remains largely dependent on farming and fishing [14]. This study, therefore, assesses the vulnerability of their coastal and fishing communities by integrating ecological, socio-economic, and governance dimensions. Strengthening adaptive capacity is vital to sustain livelihoods and protect marine ecosystems amid accelerating climate change [2].

## II. MATERIALS AND METHODS

### A. Research Design

The study adopted a descriptive–analytical research design, integrating participatory qualitative methods and quantitative statistical analysis to evaluate the coastal vulnerability of fishing communities in the City of Carcar and the Municipality of Sibonga. The ICSEA-C-Change framework [15] was applied to assess three dimensions of vulnerability—Sensitivity, Exposure, and Lack of Adaptive Capacity (LAC). Statistical testing using the chi-square ( $\chi^2$ ) method was employed to determine significant differences in vulnerability classifications between barangays of the two local government units (LGUs).

### B. Respondents and Sampling Procedure

The assessment was conducted at two administrative levels—municipal/city and barangay. At the city/municipal level, secondary data were collected from the City/Municipal Agriculture Office, the City/Municipal Environment and Natural Resources Office (CENRO/MENRO), and the City/Municipal Disaster Risk Reduction and Management Office (C/MDRRMO). The study covered six coastal barangays in the City of Carcar and seven in the Municipality of Sibonga.

At the barangay level, participatory assessments were carried out through focus group discussions (FGDs) and key informant interviews (KIIs) with fisherfolk, people's organizations, and barangay officials engaged in fisheries and coastal resource management.

### C. Data-Gathering Procedure

The ICSEA-C-Change participatory tool [15], [16] guided the assessment of sensitivity, exposure, and adaptive capacity. FGDs and KIIs captured local experiences, perceptions of climate hazards, and observed environmental changes. Secondary data—including climate profiles, hazard maps, and records of extreme weather events—were reviewed to validate and support the community-based findings. Preliminary orientations were organized to ensure institutional support and to align the assessment activities with the LGUs' sustainable development and climate adaptation programs.

### D. Data Analysis

Barangay-level data were summarized descriptively to depict the prevailing vulnerability conditions. Inferential analysis using the chi-square ( $\chi^2$ ) test was applied to evaluate whether differences in vulnerability classifications between Carcar and Sibonga were statistically significant.

The null hypothesis ( $H_0$ ) stated that there is no significant difference between the two LGUs in terms of sensitivity, exposure, and adaptive capacity. A computed  $\chi^2$  value greater than the critical value at the 0.05 level of significance indicated a meaningful difference, while a smaller value suggested that observed variations were due to random factors.

## III. RESULTS AND DISCUSSION

### A. Historical Trends and Climate Exposure

Low-lying coastal areas are increasingly exposed to sea-level rise, higher sea-surface temperatures, and intensified extreme weather events such as rainfall and storm surges [17]. Global warming from elevated greenhouse gases ( $\text{CO}_2$  and  $\text{SO}_2$ ) continues to drive thermal expansion, polar ice melt, and stronger wind patterns [18], [19]. Within the ICSEA-C-Change framework [20], exposure was assessed using parameters such as sea-level rise, sea-surface temperature (SST), rainfall, and wave energy, complemented by local observations gathered through FGDs and KIIs [21], [2].

In both LGUs, community narratives provided firsthand validation of these climate impacts. Residents observed rising sea temperatures affecting fishing and farming patterns, consistent with global SST trends [22]. Philippine SSTs have risen 0.2–0.3°C per decade, accelerating coral reef decline and seagrass loss [23], [24]. Similarly, sea-level data from Cebu (PSMSL, 1935–2023) show a 1.86 mm/year rise, amplifying flooding, saltwater intrusion, and erosion risks [25]–[28] (see figure 1). Typhoon Rai (Odette, 2021) vividly illustrated storm surge destruction and community vulnerability [29], [30]. Rainfall data (PAGASA, 1993–2023) reveal a 233 mm increase over three decades, aligning with global projections of intensified precipitation and flooding [31], [32] (see figure 2).

### B. Sensitivity of Coastal Systems

Sensitivity was largely determined by ecosystem health and fisheries dependence [33]. In the City of Carcar, coral cover ranged from 11–34%, indicating mostly moderate to high sensitivity [34] (see figure 3). In the Municipality of Sibonga, coral conditions were generally better, with several barangays rated as moderately sensitive [35] (see figure 4). Seagrass meadows in both LGUs displayed good ecological conditions, averaging 74% cover in Carcar and 72% in Sibonga—an indicator of moderate sensitivity and stable habitat function [36].

Mangrove forests contributed significantly to coastal stability, though many areas showed moderate sensitivity due to limited diversity and fragmented stands [37]. Fisheries data reflected high ecological dependency: over 60% of fishers relied on demersal and reef-associated species, reinforcing vulnerability to coral decline [38], [39]. High coastal population densities (>500 persons/km<sup>2</sup>) further intensified environmental stress [40], though relatively low fisherfolk ratios (<35%) mitigated direct sensitivity [41].

### C. Adaptive Capacity Indicators

Adaptive capacity—defined by IPCC as a system's ability to adjust or cope [19]—was evaluated through ecosystem health, resource management, and governance indicators. Coral reefs in the City of Carcar were moderately adaptive, while in the Municipality of Sibonga, it displayed higher adaptive potential due to healthier coral cover and greater structural diversity [42]. Seagrass and mangrove systems across both LGUs exhibited moderate to high

adaptive capacity, reflecting balanced species diversity and regeneration [43].

However, water quality issues—particularly turbidity, waste accumulation, and sedimentation—reduced ecological resilience [44], [45]. Limited Marine Protected Area (MPA) coverage—less than 15% of municipal waters—also constrained adaptive potential [46]. In terms of fisheries governance, the absence of formal management plans and moderate fish dependency indicated low to moderate adaptive capacity [47], [48]. Land-use deviations and unregulated coastal development further diminished resilience [49].

#### D. Vulnerability Ratings and Statistical Analysis

Using the ICSEA-C-Change framework [33], [15], both LGU Carcar and Sibonga registered Moderate ratings across all components—Exposure (3.5–4.0), Sensitivity (3.0–3.8), and Lack of Adaptive Capacity (3.1–3.7) (see Tables 1 & 2 and Figure 5). Chi-square test results ( $\chi^2 = 0.00$ –2.71,  $p > 0.05$ ) confirmed no statistically significant difference in vulnerability classifications between the two LGUs, supporting the null hypothesis of comparable coastal vulnerability conditions (see Table 3). These findings highlight shared ecological and socio-economic characteristics shaped by similar climatic pressures and governance frameworks [50].

#### E. Summary Interpretation

Both the City of Carcar and the Municipality of Sibonga exhibit moderate vulnerability, characterized by ecological degradation, limited adaptive capacity, and exposure to climate hazards. Although slight biophysical variations exist among barangays—especially in coral and mangrove health—shared regional drivers such as warming seas, intensified rainfall, and rapid land-use change unify their vulnerability profiles. Strengthening adaptive capacity through MPA expansion, improved water quality, sustainable land use, and diversified livelihoods remains essential to enhance long-term coastal resilience [51], [52].

### IV. CONCLUSION

The ICSEA-C-Change assessment revealed a consistent *Moderate* vulnerability across all coastal barangays in both the City of Carcar and the Municipality of Sibonga, reflecting shared exposure to sea-level rise, rising sea-surface temperatures, intensified typhoons, and extreme rainfall events. Mean scores for Exposure (3.5–4.0), Sensitivity ( $\approx 3.0$ –3.8), and Lack of Adaptive Capacity ( $\approx 3.1$ –3.7) indicate biophysical pressures and socio-institutional constraints that are common to both LGUs [53].

Although no barangay was classified as “High” in overall vulnerability, the interaction among exposure, ecological sensitivity, and limited adaptive capacity could escalate risks if unaddressed [54]. Strengthening natural and built coastal defenses—such as mangrove rehabilitation, coral reef restoration, and shoreline protection—remains a priority. Other key measures include improving access to climate information and early-warning systems, diversifying

coastal livelihoods to lessen resource dependency, and investing in local governance and institutional capacity [55].

These strategies, when implemented in an integrated and proactive manner, can substantially enhance the socio-ecological resilience of coastal communities in Carcar and Sibonga, serving as a model for adaptive coastal management in Central Visayas and other similar regions of the Philippines.

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Table 1. ICSEA-C-Change Vulnerability Rating Summary in the City of Carcar.

| Name of Barangay | Parameters |             |                           |                      |
|------------------|------------|-------------|---------------------------|----------------------|
|                  | Exposure   | Sensitivity | Lack of Adaptive Capacity | Vulnerability Rating |
| Perrelos         | 3.50 (M)   | 3.81 (M)    | 3.47 (M)                  | Moderate             |
| Tuyom            | 3.75 (M)   | 3.20 (M)    | 3.39 (M)                  | Moderate             |
| Valladolid       | 4.00 (M)   | 3.70 (M)    | 3.49 (M)                  | Moderate             |
| Poblacion 3      | 3.75 (M)   | 3.67 (M)    | 3.47 (M)                  | Moderate             |
| Bolinawan        | 3.50 (M)   | 3.64 (M)    | 3.73 (M)                  | Moderate             |
| Ocaña            | 3.50 (M)   | 3.42 (M)    | 3.73 (M)                  | Moderate             |

Source: Prepared by the researcher based on the ICSEA-C-Change Rubric Assessment, field validation (2024), and secondary data from local government offices (CBMS, M/CAO, M/CENRO, and M/CPDO, 2022–2024).

Table 2. ICSEA-C-Change Vulnerability Rating Summary in the Municipality of Sibonga.

| Name of Barangay | Parameters |             |                           |                      |
|------------------|------------|-------------|---------------------------|----------------------|
|                  | Exposure   | Sensitivity | Lack of Adaptive Capacity | Vulnerability Rating |
| Simala           | 4.00 (M)   | 3.62 (M)    | 3.50 (M)                  | Moderate             |
| Bahay            | 3.50 (M)   | 3.59 (M)    | 3.60 (M)                  | Moderate             |
| Candaguit        | 3.50 (M)   | 3.03 (M)    | 3.20 (M)                  | Moderate             |
| Abogon           | 3.50 (M)   | 3.03 (M)    | 3.30 (M)                  | Moderate             |
| Poblacion        | 3.75 (M)   | 3.31 (M)    | 3.50 (M)                  | Moderate             |
| Bagacay          | 3.75 (M)   | 3.34 (M)    | 3.60 (M)                  | Moderate             |
| Sabang           | 3.50 (M)   | 3.14 (M)    | 3.10 (M)                  | Moderate             |

Source: Prepared by the researcher based on the ICSEA-C-Change Rubric Assessment (Appendices F&G), field validation (2024), and secondary data from local government offices (CBMS, M/CAO, M/CENRO, and M/CPDO, 2022–2024).

Table 3. Chi-Square ( $\chi^2$ ) Test Results Comparing Coastal Vulnerability Ratings Between the City of Carcar and the Municipality of Sibonga.

| Vulnerability Dimension         | $\chi^2$ Value | Df | p-value | Decision ( $\alpha = 0.05$ ) | Interpretation            |
|---------------------------------|----------------|----|---------|------------------------------|---------------------------|
| Sensitivity                     | 0.00           | 2  | 1.000   | Fail to Reject $H_0$         | No significant difference |
| Exposure                        | 1.54           | 2  | 0.463   | Fail to Reject $H_0$         | No significant difference |
| Lack of Adaptive Capacity (LAC) | 0.82           | 2  | 0.664   | Fail to Reject $H_0$         | No significant difference |
| Overall Vulnerability           | 2.71           | 2  | 0.258   | Fail to Reject $H_0$         | No significant difference |

Source: Computed by the researcher based on field-validated ICSEA-C-Change vulnerability data (2024).

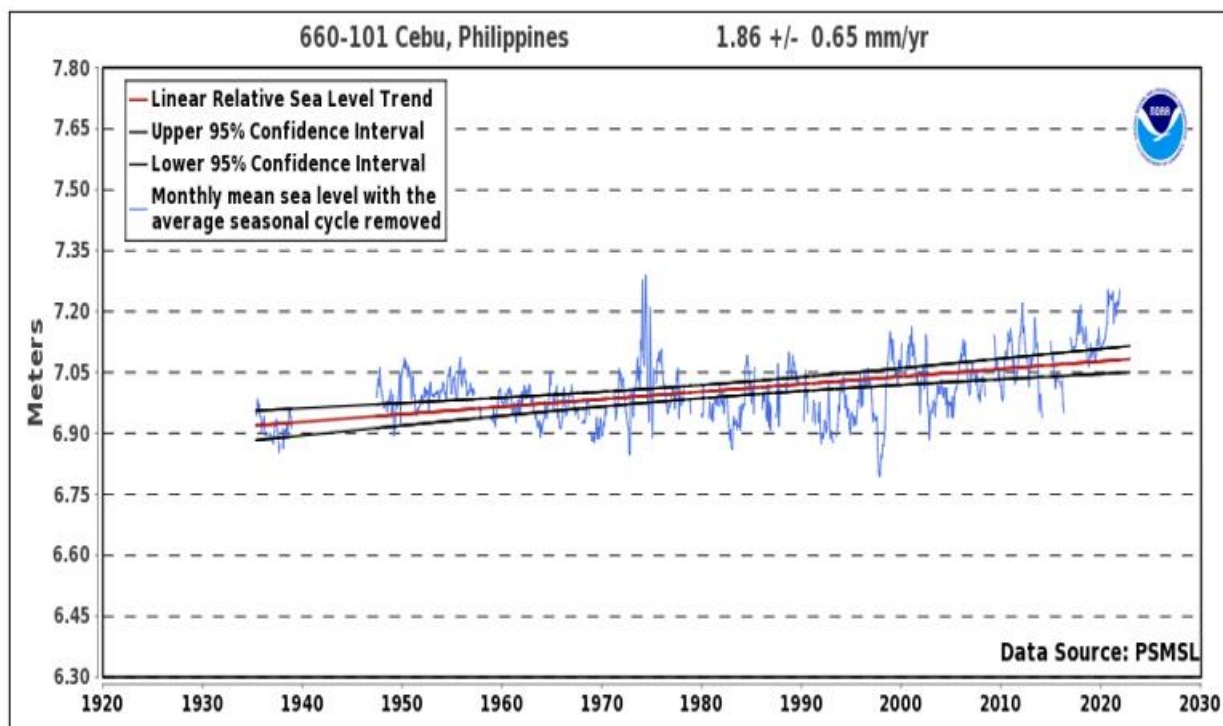


Fig 1. Annual Mean Sea Level Trend for Cebu, Philippines (from Permanent Service for Mean Sea Level (PSMSL)).

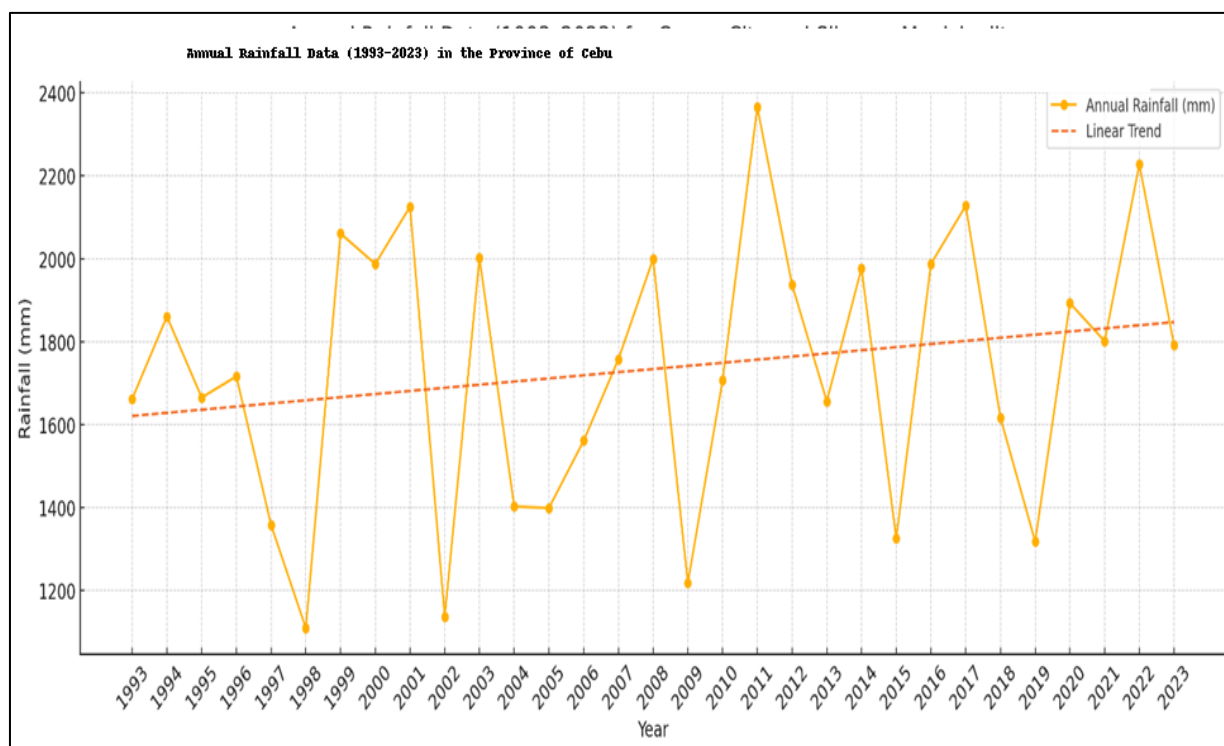


Fig 2. Annual Rainfall Data (1993–2023) in the Province of Cebu (from: Climatology and Agrometeorology Division, PAG-ASA DOST).

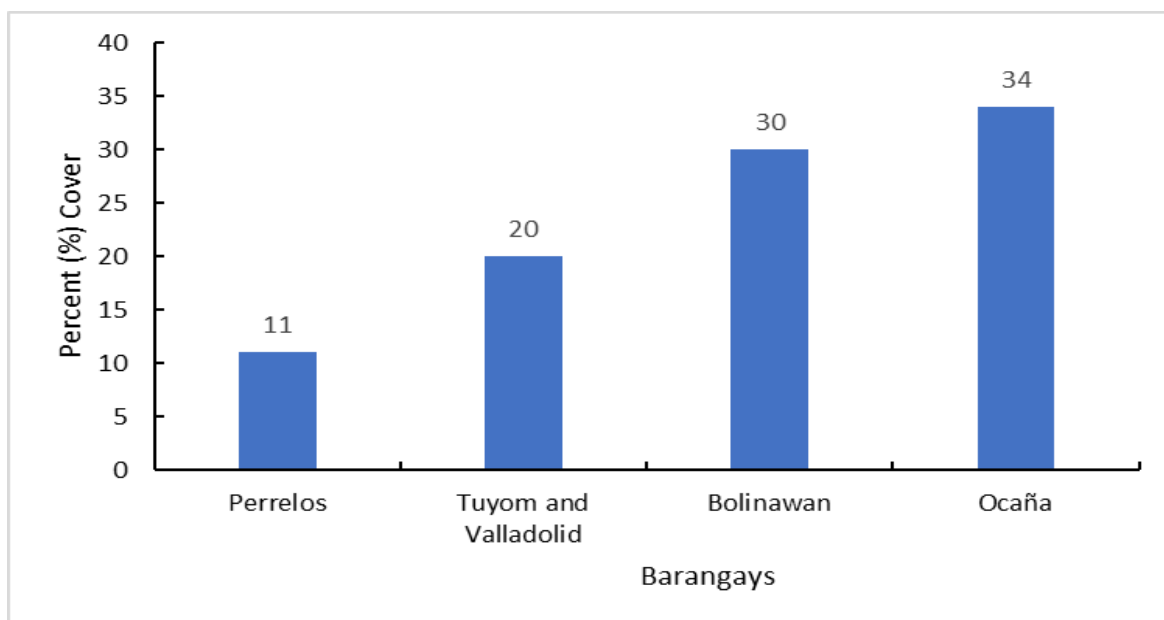


Fig 3. Percent Live Hard Coral Cover (LHCC) in the Five Coastal Barangays of the City of Carcar

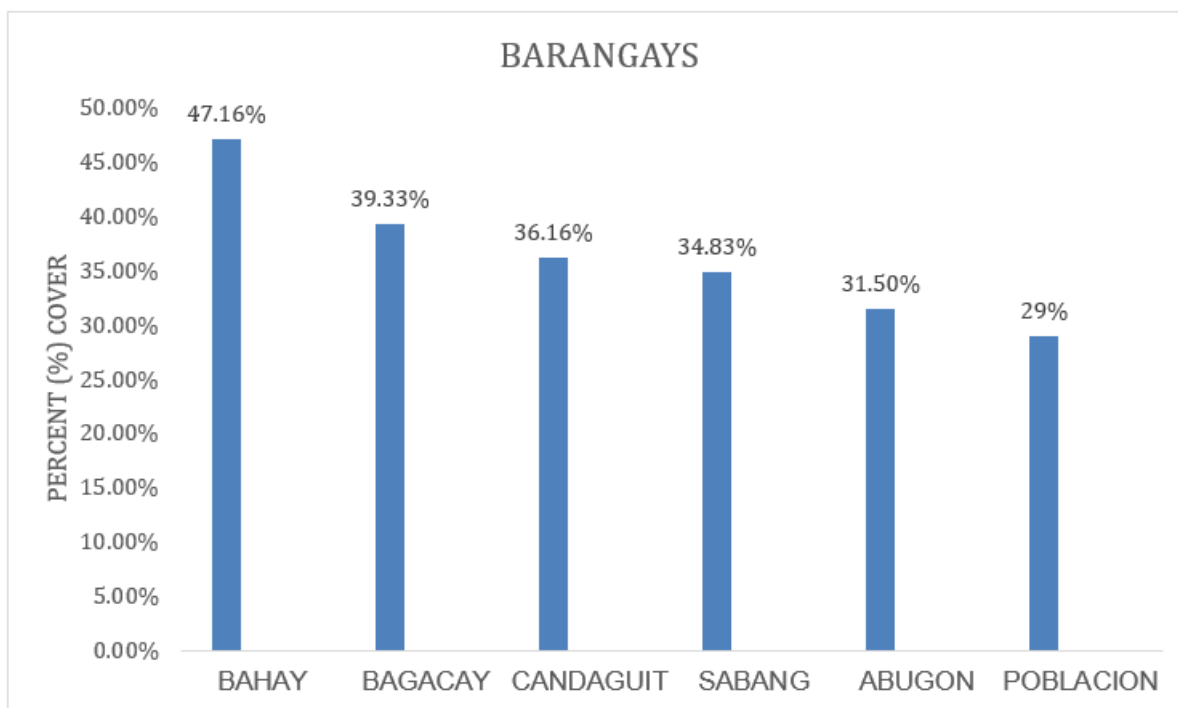


Fig 4. Percent Live Hard Coral Cover in Six Coastal Barangays in the Municipality of Sibonga

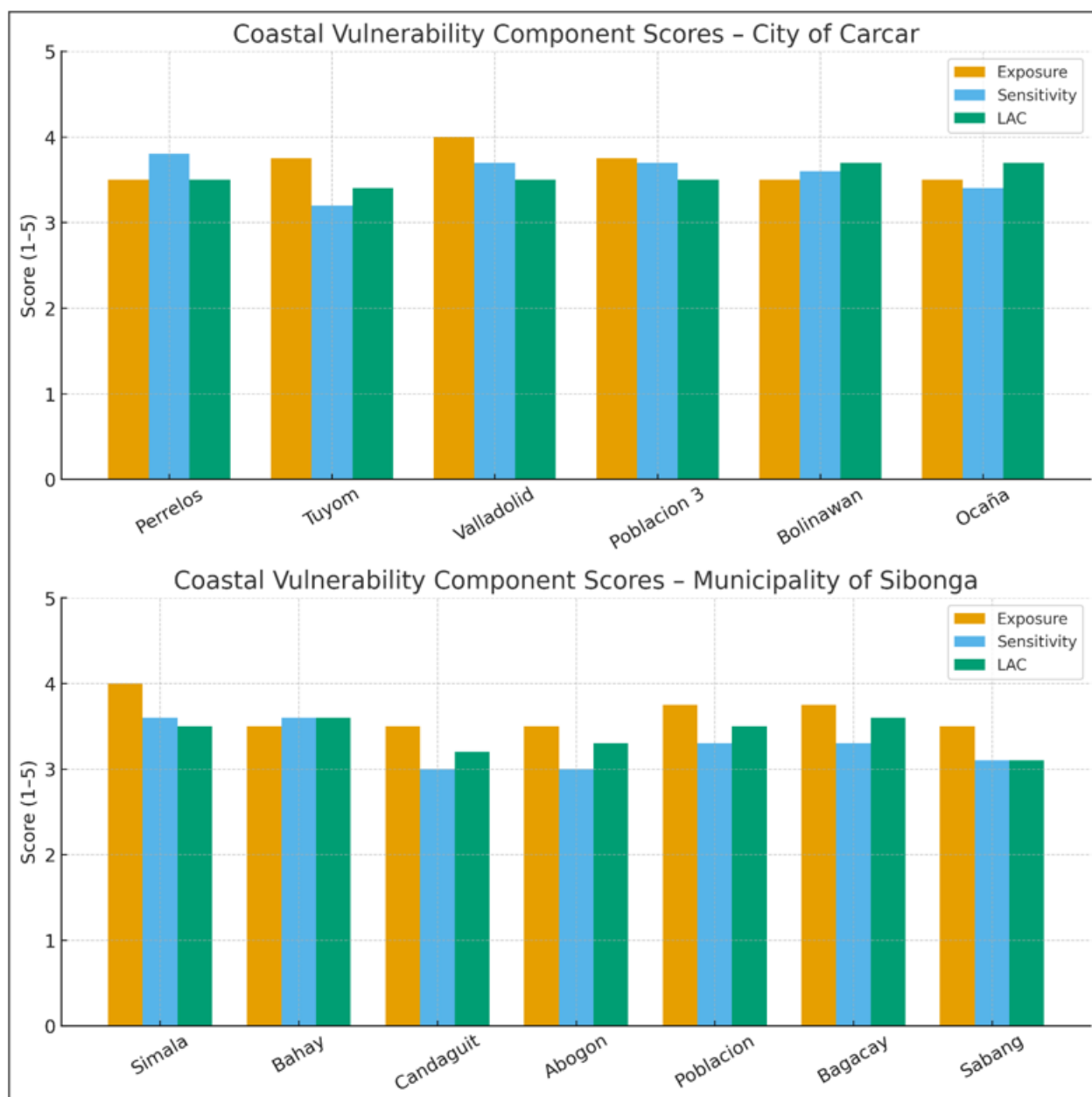


Fig 5. Comparative Vulnerability Component Scores (Exposure, Sensitivity, and Lack of Adaptive Capacity) Among Coastal Barangays in the City of Carcar and the Municipality of Sibonga.