# Evaluating community priorities for marine debris reduction in Batam City using importance–performance analysis: A preliminary study

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**Abstract.** Marine debris has become an escalating environmental challenge in Batam City, driven by rapid coastal development, port activities, tourism pressure, and waste leakage from surrounding settlements. As part of an early scoping effort, this preliminary study examines community priorities for improving marine debris management using the Importance–Performance Analysis (IPA) framework. Eight key indicators of coastal waste governance: coastal waste bin provision, green port and marine waste transport, marine debris education, cross-border data sharing, community beach clean-ups, participation incentive schemes, marine debris risk information, and enforcement of anti-littering were evaluated by 70 respondents across major coastal areas of Batam in September 2025. Descriptive statistics were used to summarize respondent characteristics, while IPA mapped perceived importance against perceived performance for each indicator. The results reveal several priority gaps, with some indicators rated as highly important yet insufficiently implemented, highlighting areas that require immediate policy attention. Infrastructure availability, environmental education, and regulatory enforcement emerged as relative strengths, whereas risk communication, institutional collaboration, and community engagement showed notable performance challenges. The findings provide an initial evidence base to guide more targeted interventions and support the development of adaptive, community-centered marine debris reduction strategies in Batam City.

# 1 Introduction

Marine debris has emerged as one of the most persistent and complex environmental challenges confronting coastal cities across Southeast Asia [1]. Batam City, located in the Riau Islands and situated at a critical maritime intersection between Indonesia and Singapore, faces increasing pressures stemming from population growth, tourism expansion, intensive maritime traffic, industrial development, and rapid coastal urbanization. These dynamics contribute to significant volumes of unmanaged waste entering the marine environment, adversely affecting not only ecological systems but also public health, economic activities, and coastal livelihoods [2]. Prior research in Indonesia has indicated that inadequate waste infrastructure, limited public awareness, and weak institutional coordination are core factors driving the accumulation of marine debris in many coastal regions [3]. As an emerging coastal hub, Batam reflects these national challenges while also possessing unique socio-ecological conditions that necessitate localized assessment. The urgency of addressing marine debris in Batam is heightened by its geographical position within an international maritime corridor. Floating waste in Batam's waters frequently originates from both domestic sources and transboundary flows from surrounding regions. The presence of shipyards, ports, fishing zones, and tourism sites means that various stakeholders engage daily with the coastal environment, each contributing to or being affected by marine debris in distinct manners. This complexity underscores the necessity for governance approaches that are not only technically sound but also socially inclusive and responsive to community perceptions.

Despite the growing concern regarding marine debris, empirical studies examining community-level perspectives on marine debris governance in Batam remain scarce. Much of the existing literature focuses on ecological impacts, waste composition, marine spatial planning, or large-scale waste management strategies. However, few studies investigate how local residents perceive key governance indicators such as infrastructure availability, green port initiatives, environmental education, institutional cooperation, or enforcement mechanisms. Understanding these perceptions is critical, as community support and involvement can significantly influence the efficacy of coastal waste management interventions [4]. Without the incorporation of local views, programs may fail to align with public expectations or may not achieve long-term sustainability [5]. A notable gap in the current body of research is the absence of structured tools to identify which aspects of marine debris management are deemed most important by residents and how well these aspects are currently being implemented. Prior research has not systematically mapped the relationship between perceived importance and perceived performance of marine debris governance indicators in Batam. Consequently, policymakers lack a practical evidence base to prioritize interventions and allocate resources more effectively. This gap indicates the necessity for diagnostic tools that can swiftly elucidate areas of strategic weakness, community dissatisfaction, or governance mismatch.

The novelty of the present study resides in its application of the Importance–Performance Analysis (IPA) framework, which has been extensively utilized in tourism, public services, and environmental management, yet has rarely been employed to assess marine debris governance in Indonesian coastal cities. By applying IPA, this study introduces a structured and visually intuitive method for identifying priority indicators that require immediate improvement, as well as indicators that should be maintained, minimized, or redesigned [6,7]. Furthermore, unlike many ecological assessments, this study prioritizes community perceptions, acknowledging that successful coastal management depends not solely on infrastructure and policy but also on local engagement and social acceptance. Another innovative aspect is the inclusion of eight governance indicators specifically tailored to the Batam context: coastal waste bin provision, green port and marine waste transport, marine

debris education, cross-border data sharing, community beach clean-ups, participation incentive schemes, marine debris risk information, and enforcement of anti-littering regulations. These indicators reflect a comprehensive socio-institutional approach that transcends traditional "clean-up only" perspectives. They encapsulate the multi-dimensional nature of marine debris governance, encompassing infrastructure, education, incentives, regulation, and international cooperation.

## 2 Method

This study employed a preliminary quantitative survey design to understand community perceptions of marine debris management in Batam City, Indonesia. The overall purpose of the study was to identify how residents evaluate a set of governance-related indicators that are essential for improving coastal cleanliness, strengthening community-based environmental management, and supporting adaptive capacity in coastal areas. Marine debris has become a persistent challenge in Batam due to high maritime traffic, tourism activity, inter-island mobility, and waste leakage from residential and industrial zones. To capture early insights into community responses, the research adopted the Importance–Performance Analysis (IPA) approach, which enables the identification of priority indicators that require immediate intervention [8-12].

The context for this study includes eight indicators selected through literature review, field observation, and local policy relevance (Table 1). These indicators were coastal waste bin provision, green port and marine waste transport, marine debris education, cross-border data sharing, community beach clean-ups, participation incentive schemes, marine debris risk information, and enforcement of anti-littering regulations. The selection of these indicators reflects multi-dimensional considerations of marine debris governance, including infrastructure readiness, institutional initiatives, community engagement, regional cooperation, communication strategies, and regulatory enforcement. The descriptions and operational definitions of all indicators used in this study were adapted directly from the indicator table provided in Table 1. Because this was a preliminary assessment, the study aimed to generate baseline understanding rather than test complex theoretical models.

Data collection took place in September 2025, covering several coastal zones in Batam, namely Nongsa, Marina, Tanjung Pinggir, Barelang, and Batu Ampar. These sites were selected because they represent diverse coastal typologies touristic beaches, local residential shorelines, fishing areas, and economic zones connected to port activities. Each site faces different forms of marine debris pressures, making them suitable for capturing a wide range of perceptions. The field team used accidental sampling, approaching individuals present in coastal public spaces, fishing docks, small business strips, and local community clusters. Although non-probability sampling, accidental sampling was considered appropriate for an exploratory study focusing on rapid data acquisition and early-stage indicator validation.

A total of 70 respondents participated in the survey. Respondents included community residents, fishermen, informal sector workers, formal employees, traders, students, and housewives. The diversity of participants ensured that the data reflected the perspectives of individuals with different levels of coastal interaction and environmental exposure. Prior to data collection, the questionnaire was reviewed by subject-matter experts to ensure clarity, relevance, and comprehension, especially for respondents with varying educational backgrounds.

**Table 1.** Description of marine debris management indicators used in the study

| No. | Indicators | Description |
|---|---|---|
| 1 | Coastal waste bin provision | Measures the availability and adequacy of coastal waste bins, garbage sacks, and collection points installed across Batam's major beaches (Nongsa, |

| | | |
|---|---|---|
| | | Barelang, Batu Ampar). This indicator captures infrastructure readiness by the Sanitation Department to reduce shoreline littering and improve on-site waste handling. |
| 2 | Green port & marine waste transport | Refers to the establishment of Batu Ampar Port as Indonesia's first green port and the provision of dedicated marine waste-collection vessels serving surrounding small islands. This indicator reflects institutional investment in pollution control technologies and port-based waste retrieval operations. |
| 3 | Marine debris education | Assesses educational initiatives delivered by environmental educators, universities, local NGOs, and coastal community groups through social media campaigns, school programs, community workshops, and outreach activities to increase public understanding of marine debris management. |
| 4 | Cross-border data sharing | Measures the use of international marine debris databases (e.g., UNEP, IOC) and collaborative research between Indonesia and Singapore for data exchange, monitoring, hotspot identification, and regional knowledge dissemination regarding transboundary marine litter flows. |
| 5 | Community beach clean-up | Represents routine weekend-based coastal clean-up programs organized in areas such as Nongsa, Marina, and Tanjung Pinggir, where local communities, youth groups, and volunteers engage in shoreline waste removal linked with eco-tourism and environmental awareness events. |
| 6 | Participation incentive scheme | Evaluates CSR-supported incentive schemes (rewards, vouchers, cashback) provided by industrial zones (e.g., Batamindo) and port operators to encourage residents and fishermen to participate in beach clean-ups and marine litter reduction programs. |
| 7 | Marine debris risk information | Measures the extent of information dissemination concerning the health risks, tourism losses, and cross-border diplomatic tensions caused by marine debris. This indicator focuses on public communication materials, campaigns, and hazard warnings. |
| 8 | Enforcement of anti-littering | Captures the consistency and strictness of law enforcement toward illegal dumping at sea by communities, fishermen, coastal industries, and tourism operators. Includes monitoring, penalties, and coastal patrol activities. |

The questionnaire was structured into three sections. The first section covered demographic characteristics such as gender, age group, occupation, and income. This information was essential for determining whether demographic factors influenced perception patterns within the community. The second section contained importance ratings for each indicator. Respondents were asked to evaluate how important each marine debris governance indicator was for improving coastal environmental conditions. The third section asked respondents to assess the current performance of the same indicators in Batam. Both importance and performance were measured using a five-point Likert scale ranging from 1 (very low) to 5 (very high). This symmetry of measurement allowed for direct comparison between perceived importance and perceived implementation. Face-to-face data collection ensured that respondents fully understood each item being evaluated. This was especially important because several indicators, such as cross-border data sharing or green port initiatives, may be unfamiliar to some community members. Enumerators provided brief explanations when necessary but avoided influencing responses. Participation was voluntary, and respondents were informed that their answers would remain anonymous. No personal identifying information was collected.

After completing data collection, responses were coded and entered into a statistical software package for analysis. Descriptive statistics, including means, standard errors, and standard deviations, were computed to summarize respondent evaluations and demographic distributions. IPA was then applied by plotting each indicator onto a two-dimensional grid. Indicators with high importance and low performance were considered priority areas requiring immediate attention, while those with high importance and high performance were regarded as strengths that should be maintained [8]. Indicators falling into low-importance

quadrants were interpreted accordingly but with caution due to the exploratory nature of the study.

Chi-square tests were conducted to examine whether demographic variables were associated with significant differences in importance and performance ratings. This analysis provided insight into the potential variation in perceptions among different groups, such as younger versus older respondents or fishermen compared with office workers. These statistical procedures ensured that the findings were based on systematic analysis rather than anecdotal impressions. Throughout the study, ethical considerations were strictly followed. All respondents participated willingly after receiving a clear explanation of the study's purpose. No financial incentives were provided, and confidentiality was fully guaranteed. The study was conducted as an initial step to support more comprehensive research on adaptive marine debris governance in Batam and to provide evidence for designing future community-based interventions.

## 3 Results and discussion

The demographic composition of the respondents reflects a diverse segment of Batam's coastal community, with characteristics that help contextualize the perception patterns captured in this study (Table 2). A total of 70 individuals participated in the survey, consisting of 65.7% male (n = 46) and 34.3% female (n = 24), indicating that men were more frequently encountered in accessible coastal and public activity areas during the September 2025 data collection period. In terms of age, the majority of respondents were relatively young, with 55.7% falling within the 18–29 year range (n = 39), followed by 17.1% aged 40–49 years (n = 12), 14.3% aged 50 years or older (n = 10), and 12.9% aged 30–39 years (n = 9). The occupational structure further illustrates the heterogeneity of coastal users in Batam. Formal-sector employees constituted the largest group at 24.3% (n = 17), while other categories such as housewives (12.9%), students (11.4%), manual laborers (8.6%), traders (5.7%), fishermen (2.9%), and farmers/laborers (2.9%) were also represented. A substantial portion, 37% (n = 26), categorized themselves under "others," indicating a mix of informal workers, small business owners, and residents with varied economic engagements. This demographic distribution provides important contextual grounding for interpreting perceptions of marine debris initiatives across age, gender, and occupational groups.

**Table 2.** Demographic Characteristics of Respondents (n = 70)

| Category | Sub-category | n | % |
|---|---|---|---|
| **Gender** | Male | 46 | 65.7 |
| | Female | 24 | 34.3 |
| **Age Group** | 18–29 years | 39 | 55.7 |
| | 30–39 years | 9 | 12.9 |
| | 40–49 years | 12 | 17.1 |
| | ≥ 50 years | 10 | 14.3 |
| **Occupation** | Others | 26 | 37 |
| | Employee/Office worker | 17 | 24.3 |
| | Housewife | 9 | 12.9 |
| | Student | 8 | 11.4 |
| | Manual labour (Buruh) | 6 | 8.6 |
| | Trader | 4 | 5.7 |
| | Fisherman | 2 | 2.9 |
| | Farmer/Labourer | 2 | 2.9 |

The assessment of marine debris management indicators elucidates distinct priorities as perceived by the surveyed community (Table 3). Respondents ascribed the highest importance score to green port and marine waste transport, with a mean rating of 4.500 (SE = 0.099; SD = 0.830), underscoring the public's strong recognition of the critical role that port operations and waste-collection vessels play in mitigating marine debris. This was closely followed by coastal waste bin provision, which attained an important score of 4.457 (SE = 0.113; SD = 0.943), and marine debris education, yielding an importance mean of 4.429. These metrics suggest that accessible infrastructure and public awareness are regarded as fundamental components of coastal waste governance.

However, performance ratings indicate significant gaps in implementation. Marine debris risk information was perceived as the best-performing indicator, with a mean score of 3.229 (SE = 0.157; SD = 1.310), implying that communication efforts regarding environmental risks are relatively prominent within the community. Conversely, indicators such as green port and marine waste transport, as well as cross-border data sharing, received considerably lower performance scores of 2.857, reflecting community concerns that these institutional or cross-jurisdictional initiatives remain limited or inadequately recognized at the local level. Coastal waste bin provision exhibited moderate performance at 3.214, indicating partial implementation while still leaving substantial room for enhancement. Other indicators, including community beach clean-ups (3.071) and enforcement of anti-littering regulations (3.057), were assessed as fair but fell below optimal standards. Collectively, the disparity between high importance ratings and lower performance values highlights a pressing need for more coordinated, resource-supported, and community-integrated initiatives to enhance marine debris management in Batam.

**Table 3.** Importance–performance scores for marine debris management indicators in Batam City

| Indicator | Importance (Mean; SE; SD) | Imp. Rank | Performance (Mean; SE; SD) | Perf. Rank |
|---|---|---|---|---|
| Coastal waste bin provision | 4.457 (0.113; 0.943) | 2 | 3.214 (0.169; 1.413) | 2 |
| Green port & marine waste transport | 4.500 (0.099; 0.830) | 1 | 2.857 (0.162; 1.354) | 7 |
| Marine debris education | 4.429 (0.107; 0.894) | 3 | 3.100 (0.167; 1.395) | 3 |
| Cross-border data sharing | 4.300 (0.121; 1.012) | 7 | 2.857 (0.168; 1.407) | 7 |
| Community beach clean-up | 4.357 (0.112; 0.933) | 5 | 3.071 (0.161; 1.344) | 4 |
| Participation incentive scheme | 4.214 (0.139; 1.166) | 8 | 2.900 (0.163; 1.364) | 6 |
| Marine debris risk information | 4.314 (0.125; 1.043) | 6 | 3.229 (0.157; 1.310) | 1 |
| Enforcement of anti-littering | 4.414 (0.114; 0.955) | 4 | 3.057 (0.153; 1.284) | 5 |

Figure 1 illustrates the results of the IPA for eight governance indicators pertinent to marine debris management in Batam City, derived from standardized (z-score) values of importance and performance. By centering both axes at the grand means, the IPA framework facilitates a relative comparison of community expectations against perceived implementation outcomes [9,10]. This methodology emphasizes structural imbalances in governance performance rather than assessing absolute effectiveness, rendering it particularly adept at identifying priority intervention areas in preliminary assessments. The IPA results demonstrate a distinct differentiation between indicators that yield visible, community-oriented outcomes and those that are institutionally focused yet less perceptible at the local level. Indicators situated in the *Keep Up the Good Work* quadrant specifically, coastal waste bin provision, marine debris education, and enforcement of anti-littering regulations represent governance actions that residents highly value and perceive as functioning effectively. These indicators share a crucial characteristic: they produce tangible and immediately observable benefits, including cleaner beaches, clearer behavioral guidance, and a visible regulatory presence. Their positioning suggests that investments in physical infrastructure, awareness-raising, and enforcement have achieved a level of maturity sufficient to meet baseline community expectations. Nonetheless, the maintenance of these gains necessitates sustained institutional commitment; any decline in service quality or enforcement visibility could rapidly undermine public confidence and participation.

Conversely, the *Concentrate Here* quadrant underscores the most significant governance gaps, encompassing green port initiatives and marine waste transport systems. These indicators are regarded as highly important due to Batam's strategic role as a major port city and its vulnerability to transboundary marine debris flows in the Singapore Strait. The low performance scores associated with these indicators imply that, although institutional programs may exist, their outcomes are not sufficiently visible or effective from the community's perspective. This discrepancy suggests a disconnection between upstream, port-based interventions and the downstream coastal conditions experienced by residents. Analytically, this points to a coordination challenge rather than a deficiency in policy intent. Enhancing inter-agency collaboration, improving operational efficiency, and increasing transparency regarding port-related waste management outcomes could facilitate the translation of institutional investments into tangible coastal improvements and restore public confidence in these initiatives.

The *Low Priority* quadrant includes community beach clean-ups, participation incentive schemes, and cross-border data sharing. Despite the frequent emphasis on these measures in policy discourse, their placement indicates that the public currently perceives them as peripheral to effective marine debris management. While community clean-ups hold symbolic significance, they may be perceived as reactive and inadequate in addressing systemic waste inflows. Participation incentive schemes appear to exert limited motivational influence, suggesting that extrinsic rewards are less effective than intrinsic motivations such as environmental concern and civic responsibility. Cross-border data sharing, although pertinent to transboundary pollution, is likely regarded as remote and technical, operating beyond the immediate awareness of local communities. This reflects a visibility and communication gap rather than an absence of importance at the institutional level, indicating that these initiatives may require reframing to underscore their relevance to local environmental outcomes. The *Possible Overkill* quadrant encompasses marine debris risk information, characterized by relatively strong performance yet comparatively lower perceived importance. This suggests that risk communication efforts, such as informational signage, warnings, or public campaigns, are present and functioning, but may not fully align with community priorities. From an analytical perspective, this does not imply that risk information is unnecessary; rather, it indicates diminishing returns from standalone communication strategies. Enhancing the effectiveness of risk information may necessitate closer integration with actionable measures, such as linking health risks to specific waste sources or coupling informational campaigns with infrastructure improvements and enforcement actions.

The IPA results reveal a governance structure in which community-facing interventions are generally more successful than institutionally complex or transboundary measures. The analysis emphasizes the necessity of rebalancing governance efforts by fortifying high-importance but underperforming domains, particularly in relation to port-related waste management and marine transport systems, while sustaining effective practices in infrastructure provision, education, and enforcement. By elucidating both performance gaps and perceptual mismatches, Figure 1 provides a coherent analytical foundation for prioritizing policy interventions and enhancing Batam's adaptive capacity in managing marine debris.

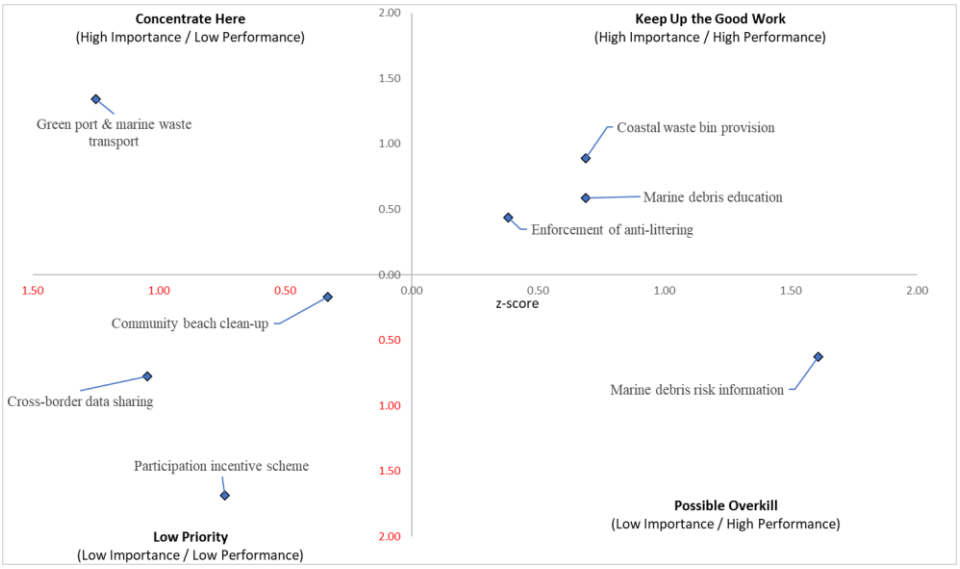


**Fig. 1.** IPA quadrant grid based on standardized (Z-Score) importance and performance values

The "Low Priority" quadrant, characterized by low importance and low performance, includes community beach clean-ups, participation incentive schemes, and cross-border data sharing. Community beach clean-up programs, with an important score of 4.357 but performance score of 3.071, lies close to the quadrant boundary, suggesting that while respondents recognize their value, these activities are not viewed as urgent compared to infrastructure- or enforcement-based approaches. Participation incentive schemes (importance 4.214, performance 2.900) appear further from the center, suggesting that the public does not prioritize financial or reward-based motivation as strongly as other strategies. This aligns with findings from coastal community studies showing that intrinsic motivations such as environmental concern, stewardship, and community identity often outweigh extrinsic incentives [13,14]. The placement of cross-border data sharing (importance 4.300, performance 2.857) indicates moderate recognition of its relevance; however, its technical nature may make it less visible to the general public. Since transboundary waste dynamics between Indonesia and Singapore are complex and often managed at institutional levels, respondents may not fully understand or directly perceive these processes. The "Possible Overkill" quadrant reflects low importance but high performance. Here, green port and marine waste transport, with an important score of 4.500 but a performance score of 2.857, appears unexpectedly in this region due to the relative placement of the grand means. Although respondents considered this indicator to be important, its performance is perceived lower relative to others, causing its position to appear within or near the quadrant boundary. This placement suggests a mismatch: institutional initiatives such as port greening and marine waste-collection boats are visible but may not directly translate into improvements that residents experience on the coastline. It is possible that the community perceives port-based waste management as an institutional matter that does not immediately address household-level or beach-level waste concerns. This type of mismatch has been observed in other coastal governance studies where institutional investments fail to generate direct public satisfaction [15].

The IPA results highlight the need for targeted improvement, particularly in areas that the community deems important but insufficiently implemented. Strengthening risk communication, expanding infrastructure provisioning, enhancing educational programs, and ensuring consistent enforcement represent high-priority strategies. Meanwhile, less urgent indicators such as incentive schemes and technical cross-border cooperation may be improved gradually or supported indirectly through increased public awareness. The preliminary findings underscore the necessity of multi-level collaboration between government, port authorities, NGOs, and communities to develop an adaptive, inclusive, and sustainable marine debris management system for Batam.

## 4 Conclusion, limitation, and future research

This preliminary study provides early insights into community perceptions of marine debris management in Batam City by evaluating eight key governance indicators through Importance–Performance Analysis (IPA). The results highlight that residents generally view infrastructure, education, and enforcement as highly important components of effective coastal waste governance. While several indicators such as coastal waste bins, anti-littering enforcement, and public education are perceived to perform reasonably well, others show clear gaps between importance and implementation. Risk communication, community programs, and several institutional initiatives require greater attention to meet community expectations. Overall, the findings emphasize the need for stronger coordination between government agencies, port authorities, industries, NGOs, and local communities to develop a more adaptive and community-centered marine debris management system in Batam.

This study has several limitations that should be acknowledged. First, the sample size was relatively small (n = 70) and collected using accidental sampling, which limits the generalizability of the results beyond the surveyed communities. Second, the indicators used in the IPA were adapted for preliminary assessment and may not fully capture the complexity of Batam's marine debris governance landscape. Third, responses relied on self-reported perceptions, which may be influenced by respondent awareness, personal experiences, or seasonal variations in marine debris conditions. Lastly, the study did not include direct environmental measurements or observational data, which could provide stronger triangulation with community perceptions.

Future studies should expand the sample size and adopt probability-based sampling methods to improve representativeness across Batam's coastal districts. Additional indicators may be incorporated to reflect broader governance dimensions such as funding mechanisms, stakeholder coordination, and behavior change interventions. Mixed-method approaches, including in-depth interviews, focus groups, and field observations could offer deeper insight into the drivers of community perceptions and institutional performance. Longitudinal research would also be valuable for monitoring changes over time, particularly as Batam implements new policies related to port environmental management and transboundary waste issues. Finally, comparative studies involving nearby islands or cross-border cooperation with Singapore could further enrich understanding of regional marine debris dynamics.

**Author Contributions**

A.R. contributed to the study conceptualization, methodological design, statistical analysis, and interpretation of results, and provided critical revisions to the manuscript. N.U. contributed to the development of the conceptual framework, data validation, and interpretation of findings. M.M.S. contributed to data collection, preliminary data processing, and manuscript preparation. E.S.S. contributed to survey instrument development, field coordination, and data verification. I.W.K.S. contributed to the overall study design, supervised data collection and analysis, led manuscript drafting and revision, and served as the corresponding author. All authors have read and approved the final version of the manuscript.

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**Data Availability Statement**

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to ethical considerations and the need to protect respondent confidentiality.

**Ethics Approval and Consent to Participate**

This study involved human participants and was conducted in accordance with ethical research standards. Participation was voluntary, informed consent was obtained from all respondents prior to data collection, and no personally identifiable information was recorded.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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