Public participation and willingness to participate in marine debris management in Batam City: A preliminary assessment using an open-ended contingent valuation approach

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Abstract. Marine debris has become a growing environmental challenge in Batam City, driven by rapid coastal development, increasing tourism, and cross-border waste transport within the Singapore Strait. Understanding community engagement is critical for designing effective waste reduction strategies, yet empirical evidence on local participation remains limited. This preliminary study assesses public willingness to participate (WtP) in marine debris management using an open-ended contingent valuation method (CVM). A total of 70 respondents from five coastal zones Nongsa, Marina, Tanjung Pinggir, Barelang, and Batu Ampar were surveyed in September 2025 through face-to-face interviews. WtP was measured in terms of hours per month that individuals were willing to contribute to beach clean-ups, environmental monitoring, educational campaigns, and related activities. The results show an average willingness to participate of 5.68 hours/month/person, with a median and mode of 2 hours, indicating a highly skewed distribution driven by a small group of highly motivated individuals. Chi-Square analysis reveals that age is the only demographic factor significantly associated with participation levels ($p = 0.008$), while gender, occupation, and income show no significant relationship. The participation curve follows an exponential decline, and the marginal willingness to participate evaluated at the mean is approximately 0.80 persons per additional hour, suggesting that higher time commitments sharply reduce overall community engagement.

1 Introduction

Marine debris has emerged as an increasingly pressing environmental issue in numerous coastal regions globally [1], with Batam City exemplifying this challenge. Situated within the heavily trafficked Singapore Strait, Batam, as a rapidly developing island, experiences significant maritime traffic, industrial activities, tourism, and inter-island mobility. These factors render Batam particularly susceptible to the leakage of land-based waste, littering from port areas, tourism hotspots, and transboundary marine debris from adjacent coastal jurisdictions. The accumulation of debris jeopardizes coastal ecosystems, diminishes tourism potential, disrupts fisheries, escalates local government expenditures on clean-up operations, and adversely affects the health and well-being of coastal residents [2]. Addressing these multifaceted issues necessitates not only the implementation of appropriate infrastructure and regulatory frameworks but also a comprehensive understanding of community engagement, as public participation is often the most effective mechanism for promoting long-term coastal stewardship. Despite Batam's strategic significance, empirical research concerning marine debris management in the region remains limited, particularly with respect to its social dimensions. Existing studies on coastal waste issues in Indonesia predominantly focus on biophysical assessments, the sources and composition of plastic waste, ecological impacts, and technical waste management solutions [3]. While these studies underscore the scale of the problem, they frequently overlook community perceptions of marine debris challenges and the willingness of residents to engage in mitigation efforts. This deficit in social and behavioral insights creates a gap in the formulation of participatory coastal governance strategies. Absent an understanding of community members' readiness to invest time, effort, and labor, government-led initiatives may lack the sustained impact necessary for effective change.

Another notable gap in literature pertains to valuation approaches. Most valuation studies in environmental management primarily utilize monetary willingness to pay (WTP) as the chief indicator of community support [4–6]. However, monetary contributions do not consistently reflect the actual level of environmental stewardship in communities where time availability, social norms, and a culture of volunteerism significantly influence environmental behavior more than financial resources [7]. In numerous coastal communities, particularly those characterized by diverse socio-economic backgrounds, non-monetary contributions [8,9], including volunteer hours, may offer a more accurate representation of local commitment to environmental initiatives. Limited research within Indonesia has employed time-based willingness to participate (WtP) metrics, and an even smaller number of studies have utilized WtP as the principal valuation instrument for marine debris management. This underscores a methodological deficiency that the current study aims to address.

The originality of this research lies in its implementation of an open-ended contingent valuation method (CVM) to evaluate willingness to participate in terms of hours volunteered per month, rather than focusing on monetary contributions. By prioritizing time, the study captures an alternative dimension of community value that is more closely aligned with the labor-intensive nature of marine debris mitigation activities, which include beach clean-ups, environmental monitoring, and community education. The open-ended format enables respondents to express the amount of time they are willing to contribute freely, thereby capturing nuanced variations in participation that are often obscured in closed-response formats. At the same time, this approach serves as an exploratory valuation tool, acknowledging that open-ended CVM responses may exhibit considerable variance and skewness. In this context, integrating CVM with a time-based WtP framework provides a coherent methodological justification, as it enables the study to directly connect individual

participation behavior with broader dimensions of adaptive capacity that shape community preparedness and responses to environmental challenges.

A further innovative element is the incorporation of adaptive capacity indicators into the survey's design and interpretation. Rather than treating participation as an isolated behavioral variable, the study contextualizes it within Batam's larger governance framework, encompassing the availability of coastal waste bins, green port initiatives, risk communication, educational outreach, enforcement mechanisms, and community-based programs. These indicators elucidate how community willingness to participate interacts with governance performance, infrastructure deficiencies, and institutional readiness. Although this preliminary study does not conduct a comprehensive adaptive capacity index or structural modeling, it establishes a conceptual foundation for a more extensive valuation framework in subsequent research phases.

2 Method

This study adopts a preliminary quantitative approach to examine public participation and willingness to participate (WtP) in marine debris management in Batam City. Willingness to participate is defined as the number of hours per month that community members are willing to allocate to activities such as beach clean-ups, environmental monitoring, educational campaigns, or community-based waste initiatives. This measure of non-monetary contribution provides an early understanding of community engagement potential, which is often a stronger predictor of long-term environmental stewardship than financial willingness alone. The analytical foundation of this study is rooted in the adaptive capacity framework, in which public participation is influenced by key dimensions such as assets, flexibility, learning, organization, and agency. The status quo and recommended improvements for each of these dimensions were evaluated using a set of indicators previously compiled through field observations and expert judgment, as shown in Table 1.

Table 1. Adaptive capacity dimensions, status quo conditions, and proposed improvement scenarios for marine debris management in Batam City.

Attribute	Attribute Description (Adaptive Capacity Dimension)	Status Quo (Current Condition in Batam)	Alternative
Asset Availability	Asset availability reflects the community's access to physical resources needed for marine debris management. These include waste disposal facilities, cleaning tools, and operational infrastructure such as coastal waste stations and marine waste collection systems. Higher asset availability enhances a community's ability to take action and reduces constraints that prevent participation.	Coastal areas such as Nongsa, Barelang, and Batu Ampar lack designated coastal waste bins and disposal points, resulting in scattered trash along the shoreline. Residents and volunteers do not receive waste bags, gloves, or cleaning tools, and there is no regular system of marine waste collection using boats to retrieve debris from nearby islands.	The improved scenario provides organized coastal waste disposal infrastructure, including segregated waste bins and accessible 3R coastal stations. Residents and volunteers are supplied with suitable cleaning tools such as reusable bags, gloves, and protective equipment distributed through CSR programs. A scheduled marine waste-collection boat service operates routinely to remove debris from surrounding islets before it accumulates or disperses into the open sea.

Flexibility (Time Availability)	Flexibility reflects the community's ability to adjust schedules and allocate time for environmental activities despite work and household commitments. Strong flexibility enables residents to participate because activities align with their available time and are supported by social and workplace structures.	Most residents work full-time and lack the free time necessary to join environmental programs. Clean-up events are irregular and not aligned with times when residents are available, and employers generally do not grant time allowances or recognize environmental volunteerism.	The improved scenario introduces regular beach-cleaning activities held during weekends and national holidays when residents are more available. Community environmental activities become incorporated into neighborhood agendas, and employers support environmental participation by granting volunteer leave or adjusting work schedules to accommodate involvement in marine debris management.
Learning (Knowledge & Awareness)	Learning reflects the community's access to environmental knowledge, training, and awareness about marine debris. Strong learning capacity enables residents to understand environmental risks, adopt proper waste practices, and engage in informed participation.	Residents have limited awareness of the sources, impacts, and solutions related to marine debris. There is minimal dissemination of educational content through digital media, and no regular workshops are conducted by universities, NGOs, or government agencies. As a result, knowledge of environmentally responsible behavior remains low.	The improved scenario provides widespread digital learning materials such as videos, infographics, online modules, and interactive content explaining marine debris issues in simple and accessible formats. Universities, NGOs, and government institutions conduct workshops, school programs, and community outreach activities. Residents also indicate the number of hours they are willing to devote each month to marine debris management, reflecting increased environmental awareness and willingness to learn.
Organization (Collective Action & Governance)	Organization reflects the presence of structured community groups, leadership systems, and collaborative networks that allow coordinated, sustained environmental action. Strong organizational capacity helps communities maintain long-term programs, mobilize volunteers, and build partnerships.	There is no formal community structure for coastal environmental management. Activities remain dependent on government-led initiatives, and there are no dedicated committees, planned schedules, or collaborative partnerships with industrial areas, tourism operators, or NGOs. As a result, participation is inconsistent and short-lived.	The improved scenario includes the formation of community environmental committees responsible for organizing clean-up programs and monitoring coastal conditions. These groups maintain structured schedules, hold regular meetings, and coordinate volunteers. Collaboration is established with industrial zones, port authorities, tourism operators, and NGOs, resulting in long-term

			support, funding, and shared responsibilities.
Agency (Responsibility & Initiative)	Agency represents the community's sense of responsibility, motivation, and willingness to take independent action. Strong agency reflects empowerment, initiative, and the belief that individual and collective actions can improve environmental outcomes.	Many residents believe marine debris management is solely the responsibility of the government, resulting in low personal motivation and limited community-driven initiatives. Youth engagement and local leadership are also minimal.	In the improved scenario, residents show a greater sense of responsibility and actively participate in clean-up activities and environmental programs. Youth and community leaders initiate and organize events, share educational content, and mobilize participation through social media and local networks. Residents voluntarily monitor coastal conditions, report illegal dumping, and contribute to ongoing environmental efforts without relying solely on government directives.

Data collection was conducted in September 2025 across five major coastal zones in Batam City, namely Nongsa, Marina, Tanjung Pinggir, Barelang, and Batu Ampar. These areas were selected due to their high exposure to marine debris accumulation and their representation of diverse socio-economic and functional coastal settings, including tourism corridors, fishing settlements, port and industrial zones, and mixed residential areas. Previous studies have documented significant coastal degradation and waste accumulation in several parts of Batam, particularly in Tanjung Uma, where a once-flourishing marine ecosystem has deteriorated due to persistent pollution and unmanaged waste. Similar challenges have been reported in densely populated small islands such as Pulau Lengkang in Belakang Padang, where urban waste pressure has intensified coastal environmental degradation [10]. Additional studies from Penawar Rindu and surrounding small islands in Batam further highlight weaknesses in solid waste management systems and their implications for marine environments [11].

A total of 70 respondents were interviewed using accidental sampling. This technique was appropriate for a preliminary study whose primary aim was to capture initial perceptions from coastal users who experience marine debris firsthand in their daily routines. The respondents represented a broad cross-section of the coastal population, including fishermen, traders, housewives, students, manual laborers, and office workers. The survey instrument consisted of three components. The first section gathered demographic information, including gender, age, occupation, and monthly income. The second section introduced respondents to the current challenges of marine debris in Batam, referring to the previously defined governance indicators coastal waste bin availability, green port initiatives, environmental education programs, cross-border data sharing, community clean-up activities, incentive mechanisms, risk communication, and law enforcement. These indicators reflect the operationalization of adaptive capacity in the marine debris context and were presented with short descriptions, photographs, and simple explanations to ensure respondents clearly understood the local environmental problems.

The third section focused on measuring willingness to participate. Respondents were asked an open-ended question in which they stated the number of hours per month they were willing to dedicate to marine debris management activities. The open-ended approach, reflected in the format illustrated in Figure 1, allowed for unrestricted responses and captured subtle variations that fixed-category questions might overlook. This format is particularly valuable for preliminary studies because it reveals the full distribution of participation levels including very low and very high values providing a detailed picture of community commitment.

Attribute	Status Quo (Current Condition)		Alternative (Solution)
Asset Availability	 • No designated waste bins along the coast. • Litter is scattered without proper disposal sites.	**How much time are you willing to spend participating in marine debris management in Batam City?** ____ hours/month.	 1. Households receive waste bags, gloves, and basic cleaning tools (CSR support). 2. Coastal waste bins, marine waste stations (TPS 3R), and scheduled waste-collection boats are available.
Flexibility (Time Availability)	 • Residents work full-time and do not have available time for environmental activities.		 1. Residents can join weekly beach-cleaning events during weekends or public holidays. 2. Environmental activities are recognized by the neighborhood association (RT/RW) and eligible for special leave permission from employers.
Learning (Environmental Knowledge)	 • Residents lack information about marine debris, its impacts, and ways to manage it.		 1. Online learning modules, videos, and infographics about marine debris are accessible. 2. Community learning groups and social media campaigns support environmental education.
Organization (Collective Action)	 • No community structure or organized program for coastal environmental management.		 1. Community members form committees for beach-cleaning programs. 2. Regular schedules, organizational structures, and external partnerships are established for coastal management activities.
Agency (Sense of Responsibility)	 • Residents feel that marine debris is the government's responsibility and show little individual initiative.		 1. Residents are willing to participate in clean-up events or environmental programs without relying on government instruction. 2. Individuals take active roles in organizing groups, monitoring coastal conditions, and supporting marine debris actions.

Fig. 1. Conceptual illustration of adaptive capacity dimensions and WtP scenarios for marine debris management in Batam City.

Data collection was carried out through face-to-face interviews in public coastal areas, fishing docks, small business areas, and residential shoreline zones. Enumerators followed a standardized script to avoid interviewer bias and ensure consistent explanation of "participation hours," particularly regarding the types of activities included. All respondents were informed that the study was exploratory, participation was voluntary, and no personal identifying information would be recorded. Ethical protocols were followed throughout the process. The dataset was analyzed using descriptive statistics and simple regression. Descriptive measures such as mean, median, mode, standard deviation, minimum and maximum values, and quartiles were used to summarize the distribution of participation hours. This analysis provided an overview of general trends in community participation,

revealing whether willingness levels clustered around low, moderate, or high contributions and identifying outliers that may indicate strong leadership potential or exceptional willingness.

To explore the socio-economic determinants of participation, a simple regression model was applied, using willingness to participate (hours per month) as the dependent variable. The independent variables included age, income, occupation type, and gender. The regression was intentionally kept basic to match the exploratory nature of the study, aiming to detect early associations rather than build a complex predictive model. These initial patterns can help researchers refine hypotheses and inform the design of more advanced statistical models in future studies. The methodological design emphasizes clarity, practicality, and suitability for a preliminary assessment. Unlike valuation studies requiring economic bids or complex utility modeling, willingness to participate measures community commitment directly and can be easily understood by respondents. The insights generated from this preliminary research will support the development of more comprehensive frameworks for community-based marine debris management in Batam, including the integration of behavioral drivers, motivation factors, and long-term monitoring in subsequent phases of the research.

3 Results and discussion

Table 2 summarizes the descriptive statistics for the community's willingness to participate (WtP) in marine debris management activities in Batam City, expressed in hours per month. The results show that, on average, respondents are willing to contribute 5.68 hours per month, although participation levels vary widely across the sample. The median and mode values are both 2 hours, indicating that most respondents tend to offer only a few hours each month, while a smaller number of highly motivated individuals contribute substantially more time. This variation is reflected in the relatively large standard deviation of 9.6 hours, with participation ranging from 0 hours at the minimum to 60 hours at the maximum. The percentile distribution further clarifies the spread of responses: 25% of respondents are willing to participate for 1 hour, 50% for 2 hours, and 75% for 6 hours per month. These descriptive patterns provide an important baseline for understanding community engagement potential and the diversity of participation levels among coastal residents in Batam.

Table 2. Descriptive statistics of community WtP in marine debris management activities

Statistic	Value
Mean	5.68 hours/month
Standard Error of Mean	1.16
Median	2 hours
Mode	2 hours
Standard Deviation	9.6
Minimum	0 hours
Maximum	60 hours
25th Percentile (P25)	1 hour
50th Percentile (P50)	2 hours
75th Percentile (P75)	6 hours

Figure 2 illustrates the distribution of respondents' WtP in marine debris management activities, expressed in hours per month. The histogram shows that participation levels are heavily concentrated at the lower end of the scale, with most respondents contributing only

a small number of hours. The highest frequencies occur around 1–2 hours per month, consistent with the median and mode values reported earlier (both 2 hours). This confirms that while many residents are willing to participate, their available time for environmental activities is limited. The distribution is positively skewed, with a long tail extending toward higher participation levels. A small number of respondents reported substantially higher contributions, ranging from 12 hours up to 60 hours per month, indicating the presence of highly motivated individuals or active community leaders who consistently engage in coastal clean-up or environmental activities. An exponential trendline was fitted to the data, represented by the function $y = 12.306e^{-0.186}x$, which closely follows the decreasing pattern of the histogram. The coefficient of determination ($R^2 = 0.4608$) indicates a moderate level of explanatory fit, suggesting that an exponential decay pattern reasonably captures the overall decline in participation frequency as hours increase. This pattern is common in early-stage participation studies, where the majority of the population contributes minimally, and only a small proportion offers substantial time commitments.

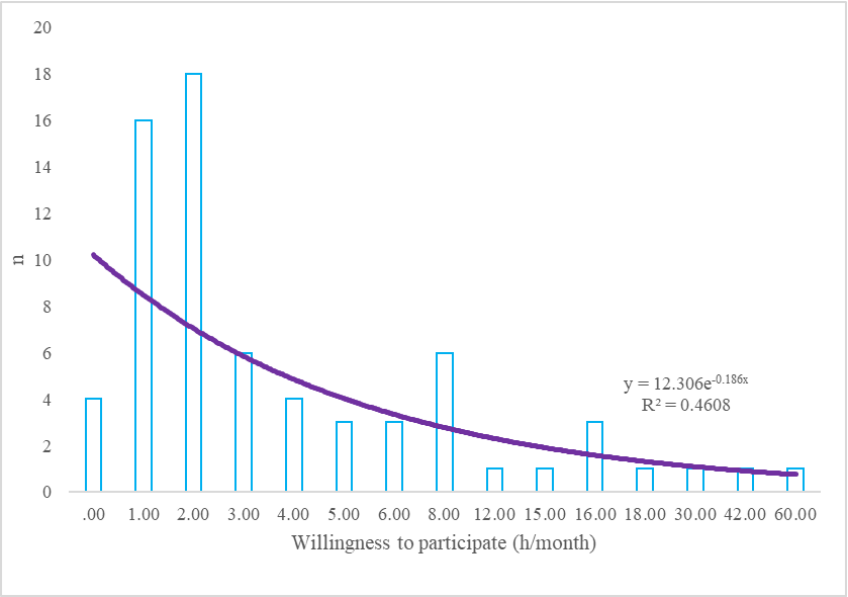

Fig. 2. Distribution of community WtP in marine debris management activities with fitted exponential decay curve.

To further interpret the distribution of participation hours, the marginal willingness to participate (MWtP) was derived from the exponential decay function fitted to the histogram in Figure 2. The relationship between participation frequency and participation hours was expressed as (Equation 1):

$$y = 12.306\, e^{-0.186x} \quad (1)$$

where y represents the number of respondents and x denotes willingness to participate in hours per month. The marginal rate of change was obtained by differentiating the function with respect to x (Equation 2):

$$\frac{dy}{dx} = -0.186 \times 12.306\, e^{-0.186x}, \quad (2)$$

which simplifies to (Equation 3):

$$\frac{dy}{dx} = -2.290\, e^{-0.186x}. \quad (3)$$

Because the derivative is always negative, the number of people willing to participate decreases as the required level of participation (hours per month) increases. This reflects the expected decline in engagement when time commitments become more demanding. To estimate the marginal willingness to participate at the average participation level, the derivative was evaluated at the mean of 5.68 hours/month/person. Substituting this value yields (Equation 4):

$$\frac{dy}{dx}\,|_{x=5.68} = -0.796 \quad (4)$$

This value indicates that for each additional hour of expected participation at the mean, the number of individuals willing to contribute decreases by approximately 0.8 hour/month/person. In other words, requiring one more hour of participation reduces the pool of willing participants by nearly one person. This highlights the strong sensitivity of community engagement to time availability and suggests that marine debris programs should prioritize low-time-burden activities to sustain broad participation.

Table 3 presents the results of the Chi-square tests examining whether demographic characteristics are associated with differences in community willingness to participate in marine debris management activities in Batam City. The variables analyzed include gender, age group, occupation, and income, providing a preliminary assessment of the socio-economic factors that may influence participation behavior. The results indicate that most demographic variables do not exhibit statistically significant associations with participation levels. Gender ($\chi^2 = 13.773$, $p = 0.467$), occupation ($\chi^2 = 32.495$, $p = 0.995$), and income ($\chi^2 = 51.371$, $p = 0.650$) all yield p-values greater than 0.05, suggesting no meaningful relationship with willingness to participate. In contrast, age group shows a statistically significant association with participation behavior ($\chi^2 = 67.277$, $p = 0.008$), indicating that willingness to participate varies across age categories. This finding suggests that age is the only demographic factor that meaningfully influences participation in this preliminary study. Understanding age-related differences is important for designing targeted community engagement strategies, as different age groups may exhibit varying capacities, motivations, and time availability for involvement in marine debris reduction initiatives.

Table 3. Results of Chi-square tests examining associations between demographic characteristics and willingness to participate in marine debris management.

Variable	Pearson Chi-Square (χ^2)	df	p-value (Asymptotic Sig.)	Interpretation
Gender	13.773	14	0.467	Not significant
Age Group	67.277	42	0.008	Significant association
Occupation	32.495	56	0.995	Not significant
Income	51.371	56	0.65	Not significant

The findings of this preliminary study provide early insights into how communities in Batam City perceive their role in marine debris management and how demographic characteristics, participation patterns, and governance gaps shape their adaptive capacity. Although the study is exploratory, several implications emerge for strengthening policy design and developing a more comprehensive adaptive capacity valuation model tailored to coastal urban settings.

The WtP data indicate that community engagement is present but highly uneven. With an average participation of 5.68 hours/month/person and a median of 2 hours, the distribution suggests that a core group of highly committed individuals is compensating for a broader population that contributes minimally. This skewed distribution is common in early-stage environmental stewardship studies, where participation is often concentrated among those with stronger awareness or proximity to environmental risks [12]. The declining marginal willingness to participate further confirms that additional time requirements sharply reduce overall engagement, indicating that future programs should prioritize low-burden, flexible participation options.

In terms of socio-demographic influences, the Chi-Square analysis reveals that age is the only significant predictor of willingness to participate. Younger groups (18–29 years) show higher levels of engagement, likely due to increased environmental awareness, digital exposure, and participation in school or university activities. In contrast, gender, income, and occupation did not significantly influence participation levels. This finding suggests that marine debris management in Batam can be designed as an inclusive program across social groups provided that activities remain accessible, time-efficient, and supported by clear benefits to community well-being. From an adaptive capacity perspective, the results align with the notion that capacity emerges from the interaction of assets, learning, organizational structures, flexibility, and agency [13–15].

Policy implications from this study center on strengthening governance arrangements that both enhance institutional performance and leverage community willingness. First, because younger respondents demonstrate the highest levels of engagement, outreach and participation programs should be anchored in schools, universities, and youth communities, employing gamified and technology-based engagement strategies to sustain interest and long-term involvement. Second, given the high perceived importance but low performance of several governance indicators, municipal agencies and port authorities should prioritize investments in coastal waste management infrastructure, particularly in zones with high exposure to marine debris such as Nongsa and Barelang. Third, the non-significant influence of income suggests that participation is not primarily constrained by financial capacity, reinforcing the relevance of non-monetary engagement pathways, including time contributions, voluntary monitoring, and citizen science initiatives. Finally, this preliminary study establishes a foundation for developing an adaptive capacity valuation model that integrates time-based WtP, demographic characteristics, and governance gaps. Future research can build on this foundation by expanding sample size, incorporating behavioral predictors, evaluating program effectiveness, and examining longitudinal changes over time. Such an approach can ultimately support policymakers in designing participatory, equitable, and resilient marine debris management systems in Batam.

4 Conclusion

This preliminary study provides an initial assessment of public participation and time-based willingness to participate (WtP) in marine debris management in Batam City using an open-ended contingent valuation approach. The findings indicate that the community demonstrates a foundational level of engagement, with an average willingness to contribute 5.68 hours/month/person. However, the highly skewed distribution reflected in a median mode of only 2 hours suggests that meaningful participation is concentrated among a relatively small group of motivated individuals. From a policy perspective, this pattern implies that marine debris programs in Batam should be designed to minimize individual time burdens while maximizing collective impact. Practical programmatic responses include organizing short,

regular clean-up activities, integrating participation into weekend or community events, and embedding marine debris actions into existing neighborhood or school-based programs to sustain broad engagement without requiring excessive time commitments. The significant influence of age on participation further highlights the need for age-responsive engagement strategies. In practice, this finding supports prioritizing youth-centered programs through schools, universities, and digital platforms, where environmental awareness and time flexibility tend to be higher. At the same time, the absence of significant associations for gender, occupation, and income indicates that participation is not structurally limited by socio-economic status. This reinforces the relevance of non-monetary policy instruments, such as volunteer-based monitoring, citizen science initiatives, and community reporting mechanisms, as inclusive tools for marine debris management across diverse population groups.

The results point to the early-stage nature of Batam's adaptive capacity. While community members recognize the urgency of marine debris problems, their willingness to contribute time remains constrained by uneven access to knowledge, limited coastal waste infrastructure, and weak organizational and institutional support. Translating WtP into effective action therefore requires governance interventions that reduce participation costs and enhance enabling conditions, including improved coastal waste facilities, clearer coordination between municipal agencies and port authorities, and sustained environmental education efforts. In this regard, the study provides a valuable empirical baseline for designing structured participation programs that align community time availability with institutional capacity.

Several limitations must be acknowledged. First, the relatively small sample size of 70 respondents, while appropriate for exploratory analysis, limits the generalizability of the findings. Second, the use of accidental sampling constrains representativeness, as respondents were selected based on availability rather than probabilistic methods. Third, although the open-ended CVM format effectively captures the full range of participation hours, it is sensitive to extreme values and may generate skewed distributions, as observed in this study. Finally, the analysis relies on descriptive statistics and simple regression and does not account for contextual dynamics such as seasonal variation, tourism intensity, or cross-border waste flows, despite Batam's exposure to transboundary marine debris in the Singapore Strait. Building on this initial assessment, future research should employ larger and more diverse samples to improve statistical power and representativeness and extend data collection across seasons and additional coastal zones. The next phase of this research will apply a choice experiment (CE) approach to estimate preference structures and trade-offs among marine debris management attributes, including waste infrastructure, environmental education, green port initiatives, community incentives, and enforcement mechanisms. Integrating CE with time-based WtP will allow for more robust policy simulations and the estimation of marginal values for both monetary and non-monetary contributions. Future studies should also incorporate psychological and behavioral factors, such as environmental attitudes, risk perception, and social norms, which may influence participation more strongly than demographic characteristics alone.

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Author Contributions

I. W. K. Suryawan contributed to the conceptualization of the study, research design, methodological development, data interpretation, and manuscript drafting and revision. N. Ulhasanah contributed to the development of the conceptual framework, data validation, and interpretation of results. M. M. Sari contributed to data collection, preliminary analysis, and manuscript preparation. E. S. Sofiyah contributed to survey design, field coordination, and data verification. A. Rahman contributed to methodology design, statistical analysis, supervision of data processing, and critical review and editing of the manuscript. All authors have read and approved the final version of the manuscript.

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 related to respondent confidentiality.

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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.

References

1. F. Ayala, K. Castillo-Morales, and S. Cárdenas-Alayza, Mar. Pollut. Bull. **174**, 113281 (2022)
2. G. G. N. Thushari and J. D. M. Senevirathna, Heliyon **6**, e04709 (2020)
3. M. R. Cordova, T. Purbonegoro, R. Puspitasari, R. Subandi, M. T. Kaisupy, S. P. A. Wibowo, Nurjamin, Suparmo, and S. Sapulete, J. Ecol. Eng. **22**, 131 (2021)
4. Y. Kuang and B. Lin, Sustain. Cities Soc. **67**, 102741 (2021)
5. T. R. Walker, E. McGuinty, S. Charlebois, and J. Music, Humanit. Soc. Sci. Commun. **8**, 80 (2021)
6. B. Maskey and M. Singh, Environments **4**, (2017)
7. R. L. Ryan, R. Kaplan, and R. E. Grese, J. Environ. Plan. Manag. **44**, 629 (2001)
8. R. K. Turner, J. Mar. Syst. **25**, 447 (2000)
9. J. D. Lau, C. C. Hicks, G. G. Gurney, and J. E. Cinner, Ecosyst. Serv. **35**, 219 (2019)
10. G. Prajati and S. Widiantoro, in *2019 2nd Int. Conf. Appl. Eng.* (IEEE, 2019), pp. 1–6
11. D. P. Safitri, Y. Adicita, N. Ulfah, and A. S. Purba, in *Int. Conf. Soc. Marit. Bord. Area (SHIMBA 2023)* (Atlantis Press, 2023), pp. 21–27
12. W. N. Adger, in *Clim. Chang. Adapt. Capacit. Dev.* (PUBLISHED BY IMPERIAL COLLEGE PRESS AND DISTRIBUTED BY WORLD SCIENTIFIC PUBLISHING CO., 2003), pp. 29–49
13. N. L. Engle, Glob. Environ. Chang. **21**, 647 (2011)
14. P. J. Cohen, S. Lawless, M. Dyer, M. Morgan, E. Saeni, H. Teioli, and P. Kantor, Ambio **45**, 309 (2016)
15. L. W. Robinson and F. Berkes, Glob. Environ. Chang. **21**, 1185 (2011)