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Effective and Efficient Practices in Predicting High Tide in Selected Barangays in Calumpit and Hagonoy Accurately

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ABSTRACT

This study investigated the effectiveness and efficiency of current high-tide prediction practices in selected barangays in Hagonoy and Calumpit and evaluated their accuracy and influence on community preparedness and disaster response. The study used a mixed-methods descriptive research design. Through stratified sampling, 100 respondents were selected with proportional allocation to provide the required data. The data were collected using questionnaires and open-ended responses, and quantitative data were analyzed using frequency and percentage distributions and weighted mean. In contrast, qualitative data were subjected to thematic analysis. The results revealed that official tide predictions are perceived by the residents as the following: accurate (WM = 4.00), timely (WM = 4.08), and accessible (WM = 4.27). However, knowledge in interpreting tidal charts is moderate (WM = 2.97), which indicates a gap between awareness and analytical understanding. Early evacuation (WM = 3.66) and asset security (WM = 3.56) show that preparedness is highly influenced by accurate tide predictions. In opposition, hesitation in complying with evacuation orders comes from past inaccuracy (WM = 3.51), highlighting the crucial role of trust in disaster communication systems. The study concludes that although current tide predictions are effective, enhancing existing forecasting systems could fortify the resilience in disaster of coastal communities. Combining traditional knowledge with enhanced monitoring systems is recommended to enhance the effectiveness, reliability, and community trust of tide predictions.

Keywords: Calumpit, Hagonoy, High Tide Prediction, Mixed Methods

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INTRODUCTION

A raised concern recently about the gap between available early warning systems and how well those warnings reach the people who need them most, from the World Meteorological Organization (WMO). In the Philippines, the wet season is formed by many factors combining or mixing of weather systems, which are the monsoons, tropical cyclones, thunderstorms, and the Intertropical Convergence Zone (ITCZ). Each one can trigger extensive flooding and disaster (PAGASA, n.d.). In addition, the effectiveness of these early warning systems is not just a function of technology, but rather a function of communication. Lagmay et al. (2018) state that prompt warning systems are only as good as the accuracy of the underlying tidal data. However, Porio (2020) argues that accurate scientific predictions should be transformed into practical action; otherwise, most of it being futile. In Bulacan, the challenge is that it experiences not one but often many weather systems, especially in the municipalities of Hagonoy and Calumpit.

Hagonoy and Calumpit remain highly exposed to tidal flood activity and land sinking that persistently influence each other. In these municipalities, coastal and riverine areas regularly experience flooding due to rain, dam release, and rising tide levels. According to the study, Lagos et al. (2022), awareness of land sinking, sea-level rise, and altered drainage due to infrastructure development is constantly low among affected communities, which reinforces their existing exposure to flood hazards year after year. The objective of this study is to dive in the water to observe the practices of the communities in these barangays that are currently predicting high tides and how effective those methods really are. The researchers investigated the residents and barangay officials to deeply understand their experience in using existing tide prediction tools and how accurate predictions influence their response to rising water levels.

Research Gap(s)

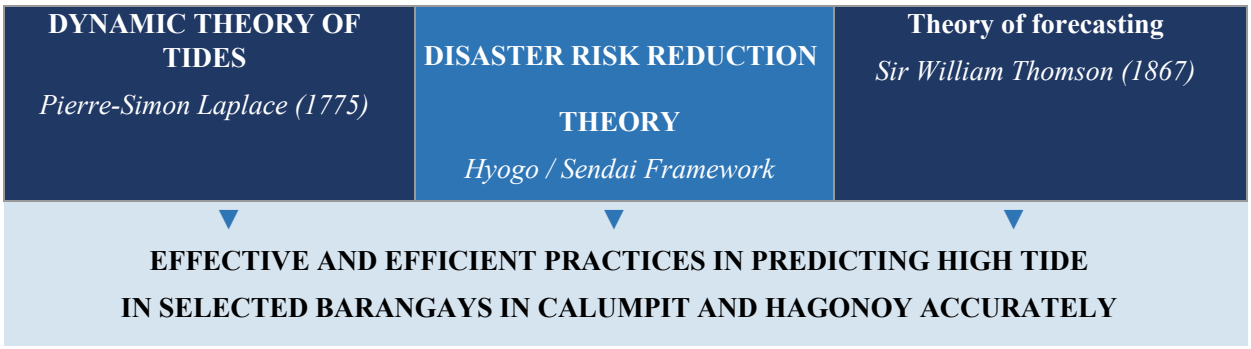
There is a significant gap between information access and data literacy, as many residents struggle to technically interpret tidal charts despite being aware of them. Additionally, traditional methods are becoming insufficient due to progressive land subsidence in the region.

Theoretical Framework

This study is strengthened by three theoretical frameworks: the Dynamic Theory of Tides studied by Laplace (1775), the Disaster Risk Reduction (DRR) Theory by Hyogo and Sendai Frameworks, and the Harmonic Analysis Method of Thomson (1876). These theories provide the physical behavior of tidal movements, accurate prediction, importance, and preparedness in minimizing risk. Together, these theories also provide the information needed as a basis for analyzing tide level prediction in communities in Hagonoy and Calumpit, Bulacan (Figure 1).

Figure 1

Theoretical Framework



Objectives

The main objective of this study is to determine and implement effective and efficient practices for predicting high tides accurately in selected barangays of Calumpit and Hagonoy, Bulacan. Specifically, this study strives to be able to determine the current practices used by residents and barangay officials in predicting high as well as to be able to examine the perceived effectiveness of these prediction practices in terms of accuracy, timeliness, and accessibility. Also, this study aims to determine if the accuracy of high tide prediction influences the effectiveness and efficiency of disaster response practices among the residents and the barangay officials.

METHODOLOGY

Research Design

The researchers utilized a mixed-methods research approach employing a descriptive research design. The mixed-methods method integrates both quantitative and qualitative data, allowing for a more comprehensive understanding of the research problem than either approach could provide alone (Ahmed et al., 2024). Within this framework, a descriptive design was selected to accurately observe and document the existing conditions of high tide prediction practices without manipulating the environment.

This study relied on both primary and secondary data to achieve its objectives. The primary data consisted of firsthand information gathered from residents and barangay officials through surveys and open-ended questions. The secondary data comprised official flood hazard assessments, PDRRMO reports, Project NOAH maps, and local flood marker data, which were used to establish the criteria for site selection and context for the study area.

The quantitative component of this study focused on measuring residents' perceptions regarding the effectiveness and efficiency of current prediction practices through structured Likert-scale questions. Simultaneously, the qualitative component utilized open-ended questions to capture nuanced insights, gathering detailed explanations of the actual methods and lived experiences of both residents and barangay officials.

Participants and Sampling Technique

The population for this study comprises residents from selected barangays in the municipalities of Hagonoy and Calumpit, Bulacan. The researcher selected the barangay based on flood hazard assessments from the Provincial Disaster Risk Reduction and Management Office (PDRRMO) and the National Operational Assessment of Hazards (NOAH). Official flood hazard

maps and local flood marker data were utilized; five barangays were selected according to their flood risk.

A purposive sampling technique was employed to select barangays, including two high flood hazard barangays in Calumpit and three medium flood hazard barangays in Hagonoy. Using Slovin's formula at a 10% margin of error, a total of 100 respondents was determined from a total population of 24,938. Respondents were distributed proportionally across barangays using stratified sampling with proportional allocation.

Instrument

The study used a two-part survey questionnaire administered via Google Forms and onsite distribution. The first part collected respondents' demographic profile, including barangay of residence, type of residency, and length of stay. The second part used a Likert scale to assess the effectiveness of current prediction practices and their impact on household preparedness and residents' everyday routines. Open-ended questions were also included to obtain qualitative data on actual practices used by residents and barangay officials. To establish content validity, the survey instrument was reviewed and validated by a licensed civil engineer.

Data Gathering Procedure

The researchers used Google Forms to acquire the data needed to ensure efficient distribution and systematic recording of responses, supplemented by onsite surveys in the selected barangays to expedite data collection. Respondents' consent was obtained on the first page of the form with a choice to retain anonymity. The gathered data was used exclusively for research purposes with strict confidentiality.

Data Analysis Procedure

Frequency and Percentage Distribution. Frequency counts and percentages were used to describe the demographic profile of respondents and summarize categorical variables. This approach provided an initial overview of the dataset and helped clarify how different groups were represented (Field, 2020).

Formula: Class Percentage = (Class Frequency / Total Frequency) × 100.

Weighted Mean. The weighted mean was used to facilitate the analysis of Likert-scale responses and determine the overall level of agreement among respondents regarding high tide prediction practices. This method is widely used for summarizing ordinal survey data in social and applied research (Sullivan & Artino, 2021).

Formula: Weighted Mean = Σ(weights × quantities) / Σ(weights).

Ethical Consideration

The respondents were fully informed about the purpose of the research and were informed that their participation was voluntary. A data privacy consent form was included on the first page of the Google Form, following the provisions of the Data Privacy Act of 2012 (Republic Act No. 10173) of the Philippines, which mandates that any information collected and used by any means must be protected.

The respondent's name is only optional, so they have the choice to remain anonymous, and no personally identifiable information was required unless voluntarily provided. The collection of data is used only for academic purposes and is strictly protected from unauthorized access. At every stage from data collection to analysis and reporting, the researcher keeps the confidentiality of the respondents, ensuring that no individual respondent can be identified from the published findings.

In addition, the researchers obtained informed consent from all participants before survey administration, both in online (Google Forms) and onsite distribution formats. Participants were free to withdraw at any time without penalty. The researcher ensured that the language used in the questionnaire was respectful, culturally sensitive, and appropriate for the community context of Hagonoy and Calumpit, Bulacan.

RESULTS

Demographic Profile of the Respondents

The study gathered a total of 100 respondents from selected barangays in Hagonoy and Calumpit, Bulacan. The gathered data was distributed to the barangays in Sta. Monica, Hagonoy (33), San Sebastian, Hagonoy (30), San Jose, Hagonoy (17), Bulusan, Calumpit (10), Calizon Calumpit (10). Researchers concluded that 85% of the residents have resided in their respective barangays for 10 years or more, and the rest (15%) have lived there from 1 to 5 years, indicating the significant majority of the respondents have deep-rooted geographical and familiarity with the local tidal conditions. The duration of residency of the respondents ensures that the data gathered is supported by a long-term exposure to the area’s tidal conditions.

SOP 1: Current High Tide Prediction Practices

The researcher gathered an open-ended survey, showing that the barangays in Hagonoy and Calumpit employ a combination of manual records, official information sources, digital platforms, and traditional knowledge in predicting high tide events.

Most of the respondents stated that they are relying on calendars and tide charts distributed by local agencies and water districts generally. The use of official announcements, alerts, and weather advisories, particularly from PAGASA, established the reliance of the community on authoritative and systematically grounded information. Additionally, the expanding use of social media platforms, especially Facebook and YouTube, and news was evident in the responses. Many residents, particularly older individuals and fishermen from the barangay, continue to rely on traditional knowledge such as calendars, observing moon phases, wind direction, and rising water levels.

Table 1
Awareness in Flood Prediction Practices

Awareness Statement	SA (4)	A (3)	D (2)	SD (1)	WM
I am aware of the flood predicting in our barangay.	32	67	1	0	3.31
I know how to read tidal charts and understand the difference between high and low tide levels.	36	36	17	11	2.97
I rely on tide prediction practices to measure high tide in real-time.	51	43	5	1	3.44
I am aware of the effects of an inaccurate tide prediction on the residents of the barangay.	56	42	2	0	3.54
I am aware of where to find reliable local tide tables or digital forecasting tools (e.g., mobile apps or official government websites) for my specific area.	50	35	11	4	3.31

Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree

The highest awareness level was found in recognizing the effects of inaccurate tide prediction (WM = 3.54), then real-time reliance on prediction practices (WM = 3.44). Also, the general awareness and knowledge of digital forecasting tools are at WM = 3.31, while the ability to read tidal charts is lowest (WM = 2.97), recommending a significant gap between information access and data literacy.

Unlike previous studies that focus purely on the availability of early warning systems, these results suggest that in Bulacan, the bottleneck for disaster resilience is not the lack of information but the community's inability to decode technical tidal instruments. This provides a new insight: local DRRMOs should pivot from merely distributing charts to educating residents on how to read them.

SOP 2: Respondents' Perception of Effectiveness

2.1 Accuracy

Table 2 shows the perception of the respondents on the accuracy of tide predictions from the LGU and PAGASA. The weighted mean of 4.00 shows that official tide predictions often match the actual water levels experienced by the residents, which is translated as an "often" level of agreement.

Table 2
Public Perception on the Accuracy of Official Tide Predictions

Statement	Always (5)	Often (4)	Sometimes (3)	Rarely (2)	Never (1)	WM
Official tide predictions (LGU/PAGASA) match the actual water levels in our street.	30	44	23	1	2	4.00

2.2 Timeliness

Table 3 shows that, with a weighted mean of 4.08, residents indicate that barangay warnings generally give them enough time to prepare. While many consistently get ready for high tides, others do not maintain the same level of preparation, suggesting variable adoption of early warning information.

Table 3
Public Perception on the Timeliness of Official Tide Predictions

Statement	Always (5)	Often (4)	Sometimes (3)	Rarely (2)	Never (1)	WM
The warnings provided by the Barangay give me enough time to prepare.	44	27	23	5	1	4.08

2.3 Accessibility

Table 4 indicates that the weighted mean of 4.27 on accessibility is the highest among the three effectiveness frameworks, showing that the flood warnings from the LGU are generally easy

to understand and reach residents promptly. This suggests strong communication works, particularly through social media platforms.

This validates the "Hybrid Information Model" seen in coastal studies across Southeast Asia, where official digital alerts are only trusted if they align with traditional environmental cues.

Table 4

Accessibility of Official Tidal Flood Warnings (LGU Communications)

Statement	Always (5)	Often (4)	Sometimes (3)	Rarely (2)	Never (1)	WM
The flood warnings communicated by our LGU are clear, easy to understand, and reach me in a timely manner.	50	30	17	3	0	4.27

SOP 3: Impact on Preparedness, Attitude, and Disaster Response

Table 5 presents the impact of accurate high-tide prediction on disaster preparedness behaviors and attitudes. The influence on disaster response was also analyzed through qualitative data.

Table 5

Impact of Accurate High-Tide Prediction on Preparedness and Attitude (n=100)

Statement	SA (4)	A (3)	D (2)	SD (1)	WM
Accurate predictions allow me to save household appliances and assets	59	40	1	0	3.56
Accurate predictions of high tides help me prepare for evacuation as early as possible	66	34	0	0	3.66
Inaccurate predictions in the past make me hesitant to follow current evacuation orders	54	43	3	0	3.51

Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree

Based on the findings, accurate predictions strongly support evacuation readiness (WM = 3.66), followed by risk reduction (WM = 3.56). Also, past inaccuracies create a lingering "Reliability Paradox"; even when current predictions are accurate, prior errors reduce community compliance with evacuation orders (WM = 3.51). Qualitative analysis showed that respondents also showed the importance of the speed of water rise (matulin ang pagtaas ng tubig), highlighting that the timeliness of warnings is as important as accuracy. These findings are consistent with Lagos et al. (2022), who noted the growing insufficiency of traditional tide prediction methods due to progressive land subsidence in the region.

The results contribute new evidence that land subsidence is altering the "predictability" of tides. Because the land is sinking, tides that were previously manageable now rise with a velocity that renders traditional charts less effective. This provides a specific geographical context that official PAGASA tide tables, which are often based on broader regional markers, may fail to capture at the barangay level.

DISCUSSIONS

1. **Demographic Profile.** The study amassed a total of 100 respondents from five barangays. 85% responded having resided in their respective barangays for more than 10 years, translating to the majority of the respondents having familiarity with the area and environment due to the longevity of their residence.
2. **Current Prediction Practices.** A mixed approach combining official PAGASA warnings, tidal charts, social media updates, and traditional methods, such as the lunar phase, is used by the residents. Flood prediction awareness is moderate (WM = 3.31), while the capability in interpreting tidal charts is lower (WM = 2.97), implying there is a significant gap between general awareness and literacy.
3. **Perception of Effectiveness.** Tide predictions from LGU/PAGASA are perceived as matching the actual water levels (WM = 4.00). Timeliness of warnings (WM = 4.08) and high accessibility (WM = 4.27) translate to a strong community communication infrastructure. However, there is a difference in readiness between residents, indicating inconsistent opinions within the community.
4. **Impact on Preparedness and Response.** Early evacuation is supported by an accurate tide prediction (WM = 3.66) and asset protection (WM = 3.56). On the other hand, the past prediction inaccuracies have a lesser effect on the community trust (WM = 3.51), making some residents hesitant to follow current evacuation orders.
5. **Influence on Disaster Response Efficiency.** High tide in these areas is characterized not just by depth but by the speed of rising water, which contributes to inaccurate predictions resulting in delayed response times. Elevation and infrastructure play a role in the risk perception of the residents in elevated areas or those with heightened infrastructure, who perceive lower risk, which can lead to a relaxed disaster-response posture.

CONCLUSIONS

According to the summary of findings, residents and barangay officials of Calumpit and Hagonoy used a hybrid-reliance system to operate, which combines modern digital tools (PAGASA and Facebook alerts and official LGU warnings) with traditional environmental observations and manual tide charts. However, many residents struggle to technically interpret tidal charts despite being aware of their existence, meaning there is a significant gap between information access and data analysis.

"Reliability Paradox" represents the state of the residents, while current prediction practices are generally perceived as accessible and reliable. Even though official predictions are often accurate, community trust is uncertain. Accessibility is high due to social media influence, but timeliness is frequently compromised by rapid water surges rather than a gradual rise, as in some areas, high tides have a flash nature. A practice is only perceived as effective if the warning reaches the resident before the water arrives.

Trust and evacuation attitudes are the primary considerations in the accuracy of high tide predictions, as past inaccuracies have created residual doubt, where even a slight margin of error leads to a "wait and see" attitude among residents. This behavior puts lives and assets at risk, particularly during rapid rises of water in tide events. Though current prediction mechanisms are generally effective, integrating traditional knowledge about high tide with digital monitoring systems and implementing localized forecasting based on the geographics of these municipalities can reinforce the disaster resilience of the community.

Based on the findings and conclusions, the following recommendations are offered. For the Local Government Units (LGU) and Barangay Officials, they should implement sensors that can track the tidal flow. This will prevent the residual doubt found in the study by separating daily high tide alerts from complex typhoon and dam release alerts and make the data more site-specific for the residents in Hagonoy and Calumpit. In addition, officials should work with local fishermen (the ones using phases) to digitize their traditional observations into the LGU's official forecasting alerts (application), which bridges the gap between the 2.97 technical literacy mean and the 3.31 general awareness mean.

Regarding the residents, they should apply the cyclical nature of high tides to create a permanent household evacuation plan. Instead of waiting for the water (which this study found to be a high-risk attitude), residents should follow initial warnings to mitigate property damage. Also, residents should participate in barangay training on how to use digital forecasting tools to reduce their dependence on "feeling sage" based on road heightening alone.

For computer engineers, students, and developers, since high tide is a recurring, predictable event, researchers should develop mobile applications that store tidal calendars offline and make them more accessible. This ensures that even without an active internet connection, residents can still have access to the localized knowledge needed to prepare their assets before water rises. Additionally, many barangays around the Philippines lack alert systems, and high tide is a serious matter, especially to the barangays around Hagonoy and Calumpit; therefore, developers should make a system that can alert and notify the community more efficiently. Finally, for future researchers, since the study was delimited to high tide only, future researchers should investigate further the interaction between high tides and Angat/Bustos dam releases, as this would provide a more disaster response model for the province of Bulacan.

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Supervision: Navarra, Lech Walesa M.

Declaration of Generative AI Utilization

During the preparation of this manuscript, the authors used Gemini 3.1 Pro to assist with language editing and polishing of the draft. The tool was used solely to improve clarity, grammar, and overall readability. The authors reviewed and revised the output as necessary and take full responsibility for the content of the manuscript.

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