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Physicochemical and biological assessment of coastal water quality in selected beach resort areas of Northwestern Philippines

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Abstract

This study assessed the physicochemical and biological water quality of selected beach resort areas in Northwestern Philippines. Sampling was conducted in four beach resort stations (Ilocos Norte, Ilocos Sur, La Union, and Pangasinan) from July to December 2018. Water quality was evaluated in terms of physical parameters (temperature, salinity, turbidity, total suspended solids), chemical parameters (pH, dissolved oxygen, nitrate, phosphate), and biological parameters (chlorophyll a, total coliform, and fecal coliform). Descriptive statistics and the Kruskal-Wallis H test were employed to determine spatial variations among sampling stations. Results revealed significant differences in several physical parameters, particularly salinity ($p = .022$), turbidity ($p = .007$), total suspended solids ($p = .002$), and temperature ($p = .027$). Among chemical parameters, only nitrate showed significant variation ($p = .007$), while pH, dissolved oxygen, and phosphate showed no significant differences. Likewise, biological parameters (chlorophyll a, total coliform, and fecal coliform) showed no statistically significant spatial differences among sampling stations ($p > .05$). Overall, the findings indicate that physical parameters are the most variable components of coastal water quality in the study area, while chemical and biological parameters were relatively stable, except for nitrates and localized coliform presence. Although most parameters remained within generally acceptable environmental limits, elevated turbidity and coliform levels in some stations suggest localized anthropogenic influence. These results highlight the need for continuous monitoring and strengthened coastal management in tourism-based marine environments.

Keywords: coastal water quality, salinity, turbidity, dissolved oxygen, chlorophyll a, coliform bacteria, Northwestern Philippines

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1. Introduction

Marine coastal waters are among the most productive and ecologically valuable ecosystems. These systems serve essential life-support functions that maintain biodiversity and ecological processes. They provide goods and services for human use, such as food resources, pharmaceutical compounds, genetic materials, and coastal protection. Economic activities such as tourism, fisheries, and coastal transportation depend strongly on these ecosystem support functions. In this context, biodiversity is considered a primary indicator of marine ecosystem health, reflecting habitat complexity and ecological stability (Zhang et al., 2023; Ali & Kamraju, 2023). Coastal ecosystems are highly significant to the Philippines, an archipelagic nation comprising more than 7,000 islands situated between major marine bodies including the West Philippine Sea and the Pacific Ocean. These geographic conditions make coastal resources vital to environmental sustainability and socio-economic development, particularly in tourism-oriented coastal communities (Ali & Kamraju, 2023).

Tourism is one of the major economic activities in coastal regions of the country. Coastal development continues to expand, particularly in major beach destinations in Northern Luzon where resort establishments are increasing. Pagudpud, for instance, is often referred to as the “Boracay of the North.” While tourism development contributes to economic growth, it can also exert pressure on fragile coastal environments. Coastal ecosystem degradation has been observed in several countries during tourism expansion, including Thailand, India, and Malaysia (Khan, 2017). In the Philippines, similar concerns have been documented in several coastal and aquatic systems. Jose et al. (2015) reported water quality-related ecological changes in Manila Bay, while Lago (2010) documented coastal water quality issues in Cagayan de Oro. Garcellano et al. (2022) further highlighted anthropogenic influences affecting coastal waters in Puerto Princesa Bay, suggesting gaps in environmental regulation enforcement.

A critical example of tourism-related environmental degradation is Boracay Island, where uncontrolled development and weak enforcement of environmental policies led to deterioration of coastal waters, resulting in temporary closure for rehabilitation (Limates et al., 2016). Similar concerns have been reported in other Southeast Asian tourism destinations where ecological degradation required regulatory intervention and restoration efforts (Khan, 2017; Yamamoto et al., 2019). Similar environmental pressures are emerging in the northern Luzon coastline, particularly in coastal provinces of Region I where beach resorts are rapidly expanding. Although these areas are recognized tourism destinations, increased human activity may result in environmental stress such as wastewater discharge, solid waste accumulation, shoreline modification, and increased coastal disturbance. Since marine biodiversity is closely linked to water quality conditions, regular scientific assessment is necessary to evaluate ecosystem sustainability (Ali & Kamraju, 2023; Jose et al., 2015).

Although environmental regulations such as Republic Act No. 9275 (Philippine Clean Water Act) are in place, challenges remain in implementing site-specific monitoring in rapidly developing coastal tourism zones. Thus, localized assessment of water quality is essential to support evidence-based environmental management. Accordingly, this study assessed the coastal water quality in selected beach resort areas of Northwestern Luzon in terms of its physical, chemical, and biological characteristics. It further examined spatial variations among sampling stations and generated baseline data to support coastal resource management and science education initiatives. The study contributes to contextualized environmental learning by providing empirical data applicable to science instruction in coastal communities.

2. Literature Review

Coastal water quality is a critical indicator of marine ecosystem condition, stability, and sustainability. Coastal ecosystems deliver essential ecosystem services, including nutrient cycling, habitat provision, shoreline protection, and support for fisheries and tourism-related livelihoods. However, these systems are increasingly subjected to anthropogenic pressures associated with coastal development, tourism expansion, urban runoff, and wastewater discharge, all of which may alter physicochemical and biological conditions in nearshore waters (Ali & Kamraju, 2023; Khan, 2017). In the Philippines, where coastal environments are closely linked to economic activity and environmental sustainability, regular scientific assessment of water quality remains necessary to guide environmental management and sustain coastal ecosystem function (Limates et al., 2016). Physical water quality parameters play a fundamental role in regulating coastal ecological processes and serve as primary indicators of environmental variability. Salinity reflects the balance between freshwater inputs and marine water intrusion. It is influenced by river discharge, tidal exchange, rainfall variability, and coastal hydrodynamics. Garcellano et al. (2022) and Limates et al. (2016) reported significant spatial differences in salinity across sampling stations, highlighting its role as a key structuring factor in aquatic ecosystems influenced by the balance between freshwater inputs and marine water intrusion.

Turbidity and total suspended solids are likewise important indicators of water clarity and sediment loading. Elevated turbidity is commonly associated with sediment resuspension, shoreline disturbance, runoff, dredging, and coastal construction activities, reducing light penetration and potentially affecting primary productivity and habitat quality (Yamamoto et al., 2019). Temperature serves as a key environmental regulator because it directly affects metabolism, growth, reproduction, and species distribution in aquatic organisms (Jose et al., 2015). Chemical characteristics of coastal waters provide further insight into ecosystem condition and nutrient dynamics. Dissolved oxygen is a key indicator of aquatic ecosystem health as it reflects the balance between oxygen production and consumption processes such as photosynthesis, decomposition, and water mixing. Low dissolved oxygen levels may indicate organic pollution or restricted water circulation, while higher levels generally reflect better ecological conditions (Abouelsaad et al., 2022).

Nutrient concentrations, particularly nitrate and phosphate, are important regulators of coastal productivity. While low concentrations may indicate relatively unpolluted conditions, elevated levels can result from agricultural runoff, domestic wastewater discharge, and surface drainage, potentially leading to eutrophication (Khan, 2017; Zhang et al., 2023). Meanwhile, pH is an important parameter influencing chemical balance, nutrient availability, and organism tolerance. Slightly alkaline conditions are typically observed in marine waters due to their natural buffering capacity (Ali & Kamraju, 2023). Biological water quality indicators complement physicochemical assessment by reflecting ecosystem productivity and microbial safety conditions. Chlorophyll a is widely used as an indicator of phytoplankton biomass and primary productivity, reflecting trophic status in coastal waters (Mondal & Banerjee, 2023). In contrast, total coliform and fecal coliform bacteria are commonly used indicators of microbial contamination and sanitary quality. Their presence in coastal waters is often associated with untreated wastewater discharge, stormwater runoff, and increased human activity in coastal areas (Cui et al., 2021; Sy & Ong, 2022).

Regarding spatial variability, some coastal systems remain within acceptable environmental thresholds (Garcellano et al., 2022), whereas others exhibit localized degradation linked to human activities (Khan, 2017). In the Philippines, anthropogenic influence has been identified as a key factor affecting coastal and bay ecosystems, with water quality directly responding to the intensity of surrounding human activities (Jose et al., 2015; Lago, 2010; Limates et al., 2016). Overall, existing literature indicates that groups of water quality parameters are interconnected and collectively influence coastal ecosystem condition. However, integrated assessments simultaneously examining all three components remain limited in tourism-influenced coastal waters of Northwestern Philippines. This gap limits the establishment of baseline environmental conditions necessary for evidence-based coastal management, particularly in rapidly developing beach resort areas. From an educational perspective, existing studies emphasize the value of real-world environmental data in enhancing science learning.

Coastal water quality datasets can be used as contextualized instructional materials for teaching environmental science, marine ecology, and sustainability concern.

3. Methodology

Research Design - This study used a quantitative research approach focused on the objective measurement of coastal water quality in selected beach resorts in Northwestern Philippines. It examined the physicochemical and biological components of coastal waters to evaluate environmental conditions. A descriptive survey design was also applied to describe existing water quality conditions and to identify spatial differences among sampling stations. This design is appropriate for studies that aim to characterize current environmental conditions and establish baseline information on coastal ecosystems. Field sampling and laboratory analysis were conducted to obtain reliable and updated data. In environmental studies, field sampling is widely used because it allows direct observation of in situ aquatic conditions (Adeniji et al., 2019; Cui et al., 2021; Jose et al., 2015; Garcellano et al., 2022).

Ethical Considerations - Ethical clearance was obtained from the institutional research ethics committee prior to data collection. Permissions for field sampling were secured from relevant local government units and environmental authorities. All sampling activities were conducted in accordance with established environmental research protocols, ensuring minimal ecological disturbance. No human participants were involved in the study; thus, informed consent was not required. All collected data were used strictly for academic and research purposes. Environmental safety, sample integrity, and laboratory procedures were strictly observed throughout the study.

Sources of Data (Sampling Stations) - The study was carried out in Northwestern Philippines (Region I), covering selected coastal beach resorts in Ilocos Norte, Ilocos Sur, La Union, and Pangasinan. The area lies along the western coastline of Northern Luzon and faces the West Philippine Sea. Sampling stations were chosen based on accessibility, tourism activity, and coastal exposure. Geographic coordinates were recorded using a Global Positioning System (GPS) in coordination with relevant local and environmental agencies. The four sampling stations included: Station I – Pagudpud, Ilocos Norte (Blue Lagoon area), Station II – Santiago Cove, Ilocos Sur, Station III – San Juan, La Union, and Station IV – San Fabian, Pangasinan. These stations represent tourism-influenced coastal environments used for comparative analysis of water quality.

Figure 1. Location Map of Sampling Stations

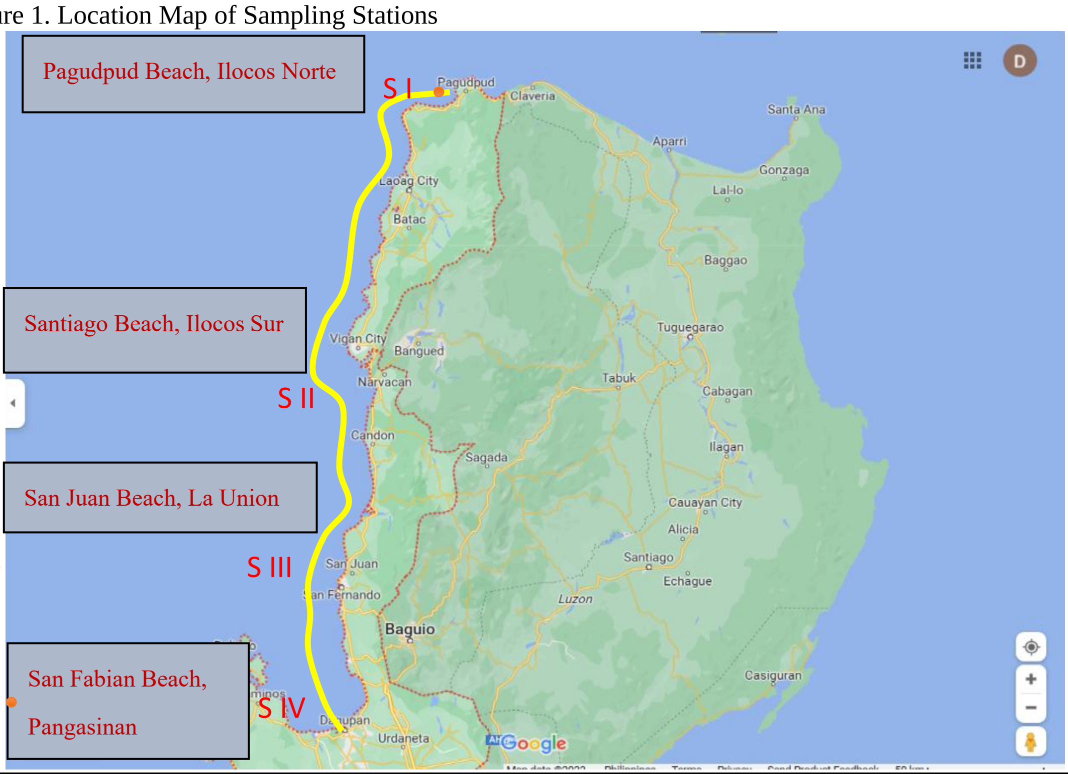

Figure 1 shows the four sampling stations along the Northwestern Philippines coastline: Pagudpud (Ilocos Norte), Santiago Cove (Ilocos Sur), San Juan (La Union), and San Fabian (Pangasinan). The map was generated using GPS coordinates and Google Earth (2018).

Sampling Period - Water sampling was conducted from July to December 2018 at 14-day intervals. The schedule was based on tidal conditions, particularly low tide and ebb tide, to maintain consistency in data collection. Fieldwork was adjusted due to weather disturbances such as typhoons and monsoon events. Each station was sampled on separate days because of distance and logistical limitations. Field assistance was provided by trained local personnel and fisheries graduates.

Instrumentation and Data Collection Procedure

Water Sampling Procedure - Water samples were collected from designated points along transect lines established in each sampling station. Sampling was conducted between 7:00 A.M. and 12:00 noon to minimize variation caused by diurnal changes in water conditions. All samples were collected in sterilized containers, stored in ice chests, and transported immediately to the Bureau of Fisheries and Aquatic Resources – National Integrated Fisheries Technology Development Center (BFAR-NIFTDC) for laboratory analysis.

Water Quality Parameters

Physical parameters - were measured in situ using a multiparameter water quality meter provided by BFAR-NIFTDC: Temperature, Salinity, Turbidity, and Total Suspended Solids (TSS).

Chemical Parameters - were analyzed following standard laboratory procedures: pH, Dissolved Oxygen (DO), Nitrate, and Phosphate.

Samples were stored in sterilized bottles and maintained at low temperature (below 4°C) prior to analysis to preserve sample integrity.

Biological Parameters - Biological water quality assessment focused on total coliform and fecal coliform. The Multiple Tube Fermentation Technique was used following BFAR-NIFTDC laboratory protocols (Adeniji et al., 2019; Sy & Ong, 2022). All samples were processed in certified laboratory facilities to ensure accuracy and reliability. Chlorophyll a values were reported at the detection limit of the analytical method, resulting in uniform recorded values across stations.

Data Analysis - Collected data were organized, tabulated, and analyzed using appropriate statistical tools. Descriptive statistics were used to summarize water quality parameters across sampling stations. To determine significant differences among stations, the Kruskal-Wallis H test was applied, followed by post-hoc pairwise comparisons using Bonferroni correction in IBM SPSS Statistics version 23. All statistical tests were evaluated at a 95% confidence level ($\alpha = 0.05$).

4. Results and Discussion

This section presents the physical, chemical, and biological characteristics of coastal water in Northwestern Philippines, along with the statistical differences among sampling stations. The discussion follows the study objectives and integrates interpretation, comparison with related studies, and implications for environmental monitoring and science education.

4.1 Physical, Chemical, and Biological Characteristics of Coastal Water in Northwestern Philippines

Table 1 presents the mean values of physical, chemical, and biological parameters of coastal water across the four sampling stations in Northwestern Philippines.

Table 1
Physical, Chemical, and Biological Characteristics of Coastal Water

Water Quality Parameters (Mean Values)	Ilocos Norte	Ilocos Sur	La Union	Pangasinan
Physical				
Salinity (ppt)	33.19	29.95	29.28	29.33
Turbidity (NTU)	8.86	14.84	10.80	57.32
Total Suspended Solids (mg/L)	31.85	35.05	36.36	50.61
Water Temperature (°C)	28.32	28.63	25.80	30.17
Chemical				
Dissolved Oxygen (mg/L)	5.42	4.31	4.89	5.11
Nitrates (mg/L)	0.02	0.02	0.02	0.01
Phosphates (mg/L)	0.06	0.12	0.10	0.11
pH	8.36	8.43	8.41	8.41
Biological				
Chlorophyll *a* (mg/m^3)	1.00	1.00	1.00	1.00
Total Coliform MPN/100 mL	1207.00	208.22	203.78	2824.89
Fecal Coliform MPN/100 mL	53.36	245.56	35.73	56.96

Physical Characteristics - The physical parameters of coastal waters across the four sampling stations showed clear spatial variability in salinity, turbidity, total suspended solids (TSS), and water temperature. Salinity ranged from 29.28 ppt in La Union to 33.19 ppt in Ilocos Norte, indicating differences in freshwater influence and seawater mixing among sites. This variability reflects the interaction of riverine inputs, tidal exchange, and coastal morphology, which regulate salinity distribution in nearshore environments (Garcellano et al., 2022). Turbidity showed pronounced variation, from 8.86 NTU in Ilocos Norte to 57.32 NTU in Pangasinan, suggesting differences in water clarity and suspended particulates. Elevated turbidity is commonly associated with sediment resuspension, coastal runoff, shoreline disturbance, and tourism-related activities (Yamamoto et al., 2019). The higher value in Pangasinan may indicate stronger anthropogenic influence or land-based sediment input. Total suspended solids (TSS) showed a similar increasing pattern from Ilocos Norte (31.85 mg/L) to Pangasinan (50.61 mg/L), suggesting combined natural and anthropogenic sediment inputs such as runoff and coastal development activities. Water temperature ranged from 25.80°C to 30.17°C, which may be attributed to differences in depth, shading, coastal exposure, and circulation patterns. In tropical environments, even moderate temperature variation can influence metabolic processes, reproduction, and species distribution (Jose et al., 2015).

Chemical Characteristics - Chemical parameters showed relatively moderate spatial variability. Dissolved oxygen (DO) ranged from 4.31 mg/L to 5.42 mg/L, indicating generally sufficient oxygen conditions for aquatic life. DO is influenced by temperature, organic matter decomposition, and water movement, making it a key indicator of ecosystem health (Abouelsaad et al., 2022). Nitrate concentrations remained low (0.01–0.02 mg/L), suggesting minimal nutrient enrichment at the time of sampling. However, even low nutrient inputs may accumulate over time and contribute to eutrophication in coastal systems (Zhang et al., 2023). Phosphate levels (0.06–0.12 mg/L) showed slight variation without a clear spatial trend. These nutrients may originate from agricultural runoff, domestic wastewater, and surface drainage. pH values remained stable (8.36–8.43), indicating slightly alkaline conditions typical of marine waters and reflecting strong natural buffering capacity (Ali & Kamraju, 2023).

Biological Characteristics - Chlorophyll *a* values were uniform across stations (1.00 mg/m^3), consistent with values at the analytical detection limit of the method used, indicating limited measurable spatial variability. In contrast, total coliform and fecal coliform showed strong spatial variation. Total coliform ranged from 203.78 to 2824.89 MPN/100 mL, while fecal coliform ranged from 35.73 to 245.56 MPN/100 mL. These variations indicate uneven microbial contamination influenced by sanitation practices, tourism activity, and surface runoff. The presence of coliform bacteria across all stations indicates varying levels of anthropogenic influence. Detection of fecal coliform in recreational waters highlights potential public health concerns and the need for sanitation management in coastal tourism areas (Cui et al., 2021; Garcellano et al., 2022; Sy & Ong, 2022).

4.2 Significant Differences in Coastal Water Quality among Sampling Stations

Table 2
Kruskal-Wallis H-Test Results for Differences in Coastal Water Quality among Sampling Stations

Parameters	H (Kruskal–Wallis)	p-value
Physical		
Salinity	9.606*	0.022
Turbidity	11.981*	0.007
Total Suspended Solids	14.449*	0.002
Temperature	9.211*	0.027
Chemical		
Dissolved Oxygen	4.725	0.193
Nitrates	12.043*	0.007
Phosphates	0.223	0.974
pH	1.434	0.698
Biological		
Chlorophyll *a*	Not applicable	> 0.05
Total Coliform	6.134	0.105
Fecal Coliform	7.126	0.068

Note: *p < 0.05 indicates statistical significance

Physical Parameters - Significant differences were observed in salinity, turbidity, total suspended solids, and temperature ($p < .05$), indicating that physical parameters are the most dynamic components of coastal water quality. These variations reflect hydrodynamic processes such as freshwater inflow, tidal mixing, and sediment transport. Turbidity and suspended solids further suggest localized anthropogenic pressure from coastal activities, tourism development, and shoreline modification (Yamamoto et al., 2019). Temperature differences, although moderate, remain ecologically relevant due to their influence on metabolic and biological processes in marine organisms (Jose et al., 2015).

Chemical and Biological Parameters - Among chemical parameters, only nitrate exhibited significant variation ($p = .007$), indicating localized nutrient input rather than widespread contamination. Dissolved oxygen, phosphate, and pH did not show statistically significant differences, suggesting minimal spatial variation in chemical conditions across stations. Biological parameters (chlorophyll a, total coliform, and fecal coliform) also did not show statistically significant differences ($p > 0.05$). However, the presence of fecal coliform indicates episodic contamination that may not be fully captured through single-period sampling.

5. Conclusion

The physicochemical and biological characteristics of coastal waters in selected beach resort areas of Northwestern Philippines are influenced by both natural coastal processes and human activities from surrounding communities and tourism-related development. Physical parameters showed the greatest spatial variability among stations, particularly salinity, turbidity, total suspended solids, and temperature. These variations are primarily driven by hydrodynamic processes such as freshwater inflow, tidal mixing, and sediment transport. Chemical parameters were generally stable across stations. However, nitrate showed significant variation, suggesting localized nutrient inputs possibly associated with land-based runoff or human activities. Dissolved oxygen, phosphate, and pH remained relatively consistent, indicating generally stable chemical conditions. Biological parameters showed no significant spatial differences, although the detection of total and fecal coliform in some stations indicates localized microbial contamination, likely linked to tourism activities and inadequate wastewater management. Overall, most measured parameters remain within generally acceptable environmental conditions. However, observed variations in nitrates, turbidity, suspended solids, and coliform levels highlight the need for continued monitoring and strengthened coastal management, particularly in areas with increasing human and tourism pressure.

Study Limitations - This study is limited by its temporal coverage and seasonal scope, as sampling was conducted within a defined period from July to December 2018. As such, seasonal variations outside the sampling period were not fully captured. In addition, while the study covered four major coastal tourism areas in

Northwestern Philippines, localized micro-environmental conditions within each station may still vary and were not separately analyzed in finer spatial detail. Future studies may consider multi-year monitoring and higher spatial resolution sampling to capture long-term trends and micro-scale variability in coastal water quality.

Synthesis of Findings and Educational Implications - Overall, physical parameters exhibited the highest spatial variability, followed by chemical parameters, while biological parameters showed lower spatial variability and did not show statistically significant differences among stations. This pattern suggests that coastal water quality in Northwestern Philippines is primarily influenced by natural hydrodynamic processes such as tidal exchange, freshwater inflow, and sediment transport, while chemical and biological conditions are comparatively buffered, though still responsive to localized anthropogenic activities.

Implications for Environmental Management - Elevated turbidity, suspended solids, and coliform levels indicate emerging anthropogenic pressure in tourism-driven coastal areas. These findings highlight the need for continuous monitoring, improved wastewater management, and integrated coastal zone management strategies.

Educational Implications - From an educational perspective, the findings have significant value for science instruction in coastal communities. For Teachers - the dataset can be used as a real-world teaching resource in environmental science, marine biology, and earth science courses. It supports inquiry-based learning, data interpretation exercises, and case-based instruction on water quality assessment. For Students - the study provides authentic scientific data that can enhance understanding of environmental processes, pollution impacts, and ecosystem monitoring, strengthening scientific literacy and critical thinking skills. For Schools and Institutions - the results can serve as baseline material for developing localized environmental education programs, coastal awareness campaigns, and community-based sustainability initiatives. This integration of environmental monitoring and science education supports contextualized learning aligned with real environmental issues in Philippine coastal regions.

Ai Declaration Statement - The authors declare that artificial intelligence tools, specifically ChatGPT (OpenAI) and Perplexity AI, were used solely as supportive tools for language refinement, grammar correction, manuscript organization, APA 7th edition formatting guidance, and preliminary reference checking. These tools were not used to generate scientific data, results, or interpretations. All scientific content, including data analysis, interpretation, conclusions, and final manuscript revisions, were independently reviewed, verified, and finalized by the authors. The authors take full responsibility for the accuracy, originality, and integrity of the manuscript.

Author contributions - MARIA DENISE LOU C. AGUILAN – Lead Author / Principal Researcher is responsible for the following - conceptualization of the research framework, development of methodology and research design, data acquisition and field investigation, formal analysis and interpretation of results, preparation of tables, figures, and graphical representations, writing of the original manuscript draft, and overall execution and completion of the dissertation research project. ELIZABETH I. OLARTE – Dissertation Adviser / Co-Author is responsible for the following - supervision of the research process, validation of research design, methodology, and analytical framework, critical review and scholarly editing of the manuscript, technical refinement and proofreading prior to final defense, and final approval of the manuscript for publication.

6. References

Abouelsaad, O., Matta, E., Omar, M., & Hinkelmann, R. (2022). Numerical simulation of dissolved oxygen as a water quality indicator in artificial lagoons—Case study El Gouna, Egypt. *Regional Studies in Marine Science, 56*, Article 102697. https://doi.org/10.1016/j.rsma.2022.102697

Adeniji, O. O., Sibanda, T., & Okoh, A. I. (2019). Recreational water quality status of Kidd's Beach as determined by its physicochemical and bacteriological quality parameters. *Heliyon, 5(6)*, Article e01893. https://doi.org/10.1016/j.heliyon.2019.e01893

Ali, M. A., & Kamraju, M. (2023). *Natural resources and society: Understanding the complex relationship between humans and the environment.* Springer. https://doi.org/10.1007/978-3-031-46720-2

Cui, K., Dong, Y., Sun, X., Zhao, L., Du, H., Liu, J., Wang, C., Liang, C., Zhao, Y., Chen, S., Xuan, J., Li, S., Zhao, Y., & Xiao, T. (2021). Long-term temporal and spatial distribution of coliform bacteria in Jiaozhou Bay associated with human activities and environmental governance. *Frontiers in Marine*

*Science, 8***,** Article 641137. https://doi.org/10.3389/fmars.2021.641137

Garcellano, R. C., Japson, L. S., & Wy, S. I. (2022). Water quality of Puerto Princesa Bay in relation to the presence of informal settlers in its coastal areas. *The Palawan Scientist, 14*(1), 84–99. https://www.palawanscientist.org/tps/wp-content/uploads/2022/06/10_Garcellano-et-al.-2022_TPS141.pdf

Jose, E. C., Furio, E. F., Borja, V. M., Gatdula, N. C., & Santos, M. D. (2015). Zooplankton composition and abundance and its relationship with physico-chemical parameters in Manila Bay. *Journal of Oceanography and Marine Research, 3*(1), Article 1000136. https://doi.org/10.4172/2332-2632.1000136

Khan, H. R. (2017). Impacts of tourism activities on environment and sustainability of Pattaya Beach in Thailand. *Journal of Environmental Management and Tourism, 8*(24), 1469–1473. https://doi.org/10.14505/jemt.v8.8(24).02

Lago, R. G. M. (2010). Water quality assessment of coastal waters of Bayabas and Bonbon in Cagayan de Oro City, Philippines. *Cagayan de Oro Journal of Technology, 7*(1), 1–12. https://ejournals.ph/article.php?id=698

Limates, V. G., Cuevas, V. C., & Benigno, E. (2016). Water quality and nutrient loading in the coastal waters of Boracay Island, Malay, Aklan, Central Philippines. *Journal of Environmental Science and Management, Special Issue 2*, 15–29. https://doi.org/10.47125/jesam/2016_sp2/02

Mondal, A., & Banerjee, S. (2023). Impact of critical eddy diffusivity on seasonal bloom dynamics of phytoplankton in a global set of aquatic environments**.** *Scientific Reports, 13*, Article 43745. https://doi.org/10.1038/s41598-023-43745-z

Sy, K. H., & Ong, A. K. S. (2022). Fecal coliform reduction management in Manila Bay bathing beaches: A case study in the Philippines. In *Proceedings of the First Australian International Conference on Industrial Engineering and Operations Management*. https://ieomsociety.org/proceedings/2022australia/250.pdf

Yamamoto, T., Nadaoka, K., & Quintanilla, J. R. (2019). Assessment of coastal turbidity improvement potential by terrigenous sediment load reduction in Banate Bay, Philippines. *Science of the Total Environment, 656***,** 1386–1400. https://doi.org/10.1016/j.scitotenv.2018.11.243

Zhang, P., Wu, S., Xu, M., et al. (2023). Spatiotemporal nutrient patterns and eutrophication assessment in Tieshan Bay coastal water, China. *Journal of Marine Science and Engineering, 11*(8), Article 1602. https://doi.org/10.3390/jmse11081602