Occurrence and Spatial Distribution of Cyanobacteria in Recreational Waters of Honda Bay, Palawan: Environmental Conditions and Public Health Implications

Ben Jan E. Hisona[1], Edgar P. Paalan[1,2], Jhonamie A. Mabuhay–Omar [1,2]

[1]*College of Fisheries and Natural Sciences, Western Philippines University, Puerto Princesa Campus, Puerto Princesa City, Palawan, Philippine*
[2]*Aquatic, Biodiversity, Biotechnology and Aquaculture Research and Development Center, Western Philippines University–Puerto Princesa Campus, Puerto Princesa City, Palawan*
**Corresponding Author: 19hisona@gmail.com*

ABSTRACT

The increasing occurrence of cyanobacteria in coastal waters poses ecological and human safety concerns. However, baseline information for recreational areas in Honda Bay, Palawan remains limited. This study assessed cyanobacteria occurrence and spatial distribution, determined associated environmental conditions, and evaluated public health risks. Water samples were collected at five stations (Wharf, Cowrie Island, Pandan Island, Starfish Island, and Luli Island) using the vertical tow method. Cyanobacteria were identified microscopically and expressed as cells/L; potentially toxin–producing genera were identified for public health risk assessment. Physicochemical parameters measured on–site included temperature, pH, salinity, dissolved oxygen, conductivity, oxidation–reduction potential, total dissolved solids, total suspended solids, water transparency, and depth. Cyanobacteria were present at all stations, ranging from 168 to 3,032 cells/L with marked spatial variation. Dominant and potentially harmful genera included *Planktothrix* sp., *Nodularia* sp., *Trichodesmium* sp., *Synechococcus* sp., and *Merismopedia* sp., which are associated with skin irritation, allergic reactions, and poisoning posing risks to tourism and recreation. Analysis showed that water transparency influenced cyanobacterial density; clearer waters with increased light penetration enhanced photosynthetic efficiency, supporting cyanobacterial growth. These findings provide baseline data for Honda Bay and highlight the need for regular monitoring to support local coastal water management and risk reduction strategies.

Keywords: coastal waters, dissolved oxygen, light availability, cyanobacterial density, spatial variation.

INTRODUCTION

Cyanobacteria, also known as blue–green algae, are photosynthetic prokaryotes widely distributed in illuminated aquatic environments (Whitton 2012). They are among the most abundant organisms on planet Earth. Most surface waters contain cyanobacteria, which are common microorganisms. One of the main causes of their excessive development is high nutrient concentration (Merel et al. 2013). While some cyanobacteria are beneficial, many are capable of producing harmful algal blooms (HABs) when environmental conditions are favorable, such as warm temperatures, stagnant water, and elevated nutrient levels (Paerl and Otten 2013). These blooms can threaten aquatic ecosystems, livelihoods, and human health.

HABs are a growing global challenge, increasing in frequency due to climate change and nutrient loading, with conditions declining in many regions including Palawan, Philippines (Paerl and Otten 2013). Current management and regulations of HABs in Palawan include issuing HAB alerts to local government units (LGUs) when cell density reaches 200 cells/L or above, implementing mandatory bans on shellfish harvesting, and expert recommendations for LGUs to address sewage and domestic waste in coastal areas to reduce nutrient loading.

There is growing public awareness that toxic cyanobacteria pose significant health risks, particularly in recreational waterways (World Health Organization 2020). Potential health implications of cyanobacterial toxins include gastrointestinal illness, respiratory issues, and allergic reactions, concerns of growing importance for tourists and communities that depend on coastal bays for recreation and livelihood. Many countries have enacted regulations to protect human health from these toxins. The World Health Organization (WHO) has established provisional guideline values for cyanotoxins in drinking water and released guidelines for protecting human health in recreational waterways (Chorus et al. 2021).

Recreational waters such as lakes, rivers, and beaches present particular concern because people often have direct and prolonged contact with the water. When these waters become contaminated with cyanobacterial blooms, people engaging in leisure activities such as swimming, wading, or water sports may contact harmful cyanobacterial toxins (World Health Organization 2020). Exposure can lead to skin rashes, eye and ear irritation, and respiratory problems. If contaminated water is accidentally ingested, it may cause serious health complications.

Honda Bay, located on the eastern coast of Puerto Princesa City, Palawan, Philippines, is one of the most visited islands in the province due to its rich biodiversity, vibrant tourism sector, and active fisheries, making it an ecologically and economically significant body of water. However, increasing anthropogenic activities such as tourism, coastal development, and agricultural runoff may alter water quality by increasing nutrient levels, which can lead to cyanobacteria proliferation and toxin production that pose serious health risks to both communities and tourists. Despite the importance of Honda Bay, baseline data for cyanobacteria occurrence are limited in the area, and little is known about how environmental factors may influence cyanobacteria distribution.

This study aimed to assess the occurrence and spatial distribution of cyanobacteria in Honda Bay by identifying taxa to the lowest possible taxonomic level, determining their cellular density expressed as cells/L, and characterizing their distribution patterns across five selected sampling stations. The study also determined environmental factors by measuring key physicochemical parameters, including temperature, salinity, pH, dissolved oxygen, conductivity, total dissolved solids, water transparency, and depth, in relation to observed cyanobacterial densities across sampling stations. Furthermore, the study evaluated the public health risks associated with cyanobacterial occurrence in Honda Bay by identifying potentially toxigenic genera capable of producing toxins.

METHODS

Study site

This study was conducted in Honda Bay, a premier tourist destination located on the eastern coast of Puerto Princesa City, Palawan, approximately 10–12 kilometers northeast of the city proper. Five recreational water areas within Honda Bay were investigated: Wharf, Cowrie Island, Pandan Island, Starfish Island, and Luli Island as shown in Figure 1.

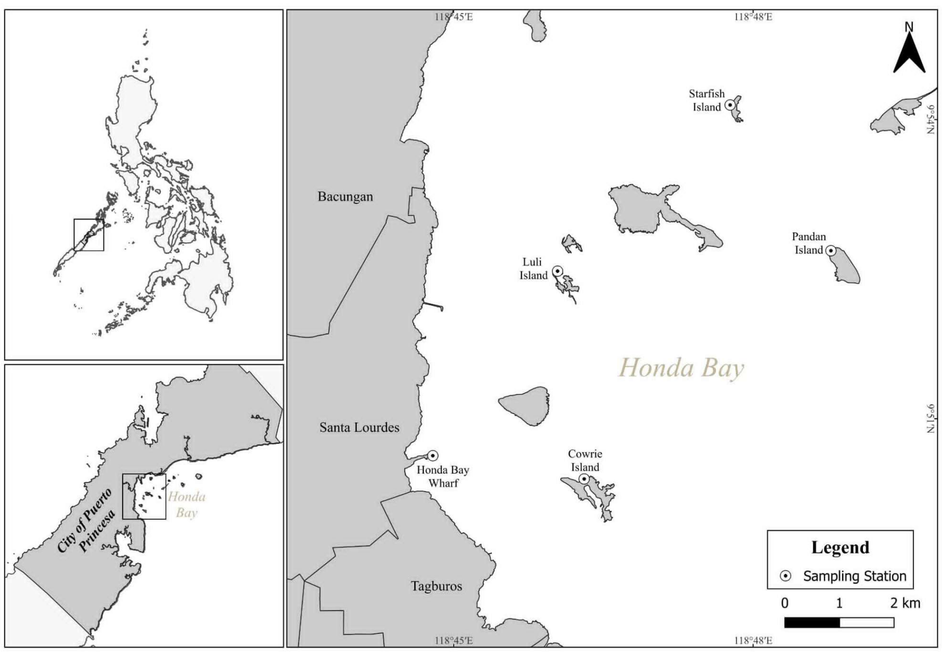

Figure 1. Map showing the sampling sites in Honda Bay, Puerto Princesa City, Palawan.

Sampling procedure

This study was conducted on May 31, 2025 during daytime at 8 o`clock in the morning. Measurements of water parameter and collection of water samples was collected in five different sites in Honda Bay. Water samples were placed into labeled bottles and added immediately with five percent formalin solution to preserved and eliminate zooplankton that might consume the target samples which are the phytoplankton including cyanobacteria, the samples were viewed and analyzed in the laboratory using compound microscope.

Water parameters

The water parameter was measured to front, middle and back of the boat one meter below the water surface to compute the average mean of the pH, ORP(mv), Dissolved Oxygen(mg/L), conductivity(uS/cm), Total Dissolved Solids (mg/L), salinity (ppt), and Temperature(°C) were measured using multi parameter. Secchi disk was used to measure the water transparency (m) by averaging the water depth at which the device disappears and reappear, while the Water depth (m) was be measured by submerging the Secchi disk until it reached the seafloor. And the Total Suspended Solids (TSS) were determined by using gravimetric filtration method.

Cyanobacteria in the water column

Cyanobacteria samples were collected in the water column using vertical tow method, at which the plankton net was vertically towed two meters deep below the water surface and rested for at least 30 seconds before pulling it up. A plankton net that has one meter in length, a mouth that has 30cm in diameter, and a mesh size of 20 µm was used to filter the seawater, by squeezing the net down to the mesh the seawater condensed in the codend at which where the water samples was collected. The seawater samples were transferred to a pre–labeled bottles and then preserve immediately by adding 5% formaldehyde solution. A portion of one ml from concentrated water samples in triplicates were analyzed using Sedgewick rafter counting cells (20grids by 50grids) and viewed under compound microscope with 100x magnifications.

Environmental condition analysis

Water quality parameters including temperature, pH, dissolved oxygen, salinity, conductivity, total suspended solids, total dissolved solids, and water transparency were analyzed using descriptive statistics such as mean and standard deviation. Cyanobacteria density was compared across sampling sites to examine potential associations with environmental variables.

Public health risks assessment

Potential public health implications were assessed based on the presence and abundance of potentially toxin–producing cyanobacteria. Identified taxa were compared with documented toxin–producing genera reported in previous literature and World Health Organization (WHO) recreational water guidelines.

Data analysis

Data for cyanobacteria composition, mean density, relative abundance, and frequency of occurrence will be recorded in an excel sheet and presented in a table. Standard Deviation (SD) will be calculated for density data. Toxic Cyanobacteria/Cyanocenter Taxonomic reference list of toxic cyanobacteria was used for identification of potential harmful cyanobacteria species. For the water samples, cyanobacteria density was calculated by using the equation below.

$$\text{Density (Expressed in cells/L)} = \frac{(N\,x\,V_1)}{V_s}$$

Where N = number of cells in one ml aliquot; V_1 =total of cyanobacteria sample; V_s = volume of seawater filtered by plankton net within hauling depth.

RESULTS

Species composition of Cyanobacteria

Several Cyanobacteria taxa were identified across five sampling stations in Honda Bay including filamentous, unicellular, and colonial forms Figure 2. Filamentous taxa such as *Planktothrix* sp., *Schizothrix* sp., *Pseudoanabaena* sp., and *Trichodesmium* sp. were distinguish primarily by their cylindrical filaments, but were further differentiate based on specific morphological characteristics. *Planktothrix* sp. exhibits unbranched filaments, *Trichodesmium* sp. forms clustered filaments, and *Pseudoanabaena* sp. is characterized by fine, thin filaments. In contrast, *Oscillatoria* sp. and *Schizothrix* sp. possess relative thicker filaments. *Nodularia* sp. was identified by its filamentous structure regularly spaced heterocytes and a discoid appearance. Among the unicellular and colonial taxa, *Prochlorococcus* sp. was identified by its extremely small, individual coccoid cells. *Aphanocapsa* sp. exhibits spherical coccoid cells, while *Synechoccus* sp. is characterized its organized cellular arrangement forming ovoid colonies.

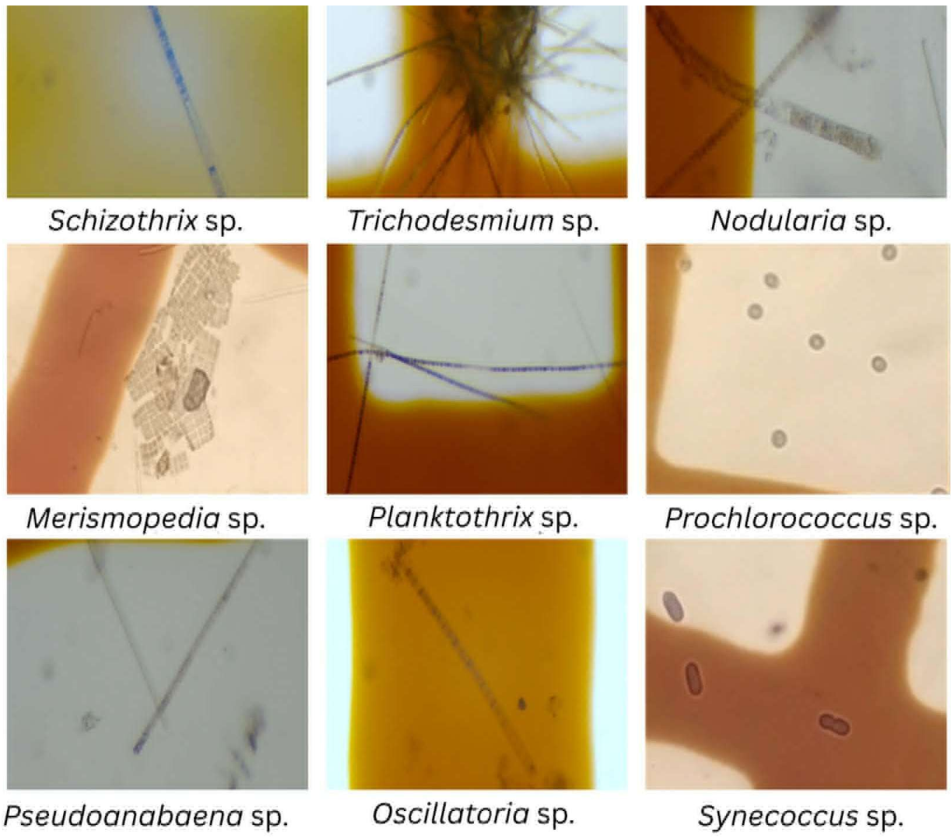

Figure 2. Cyanobacteria taxa identified across five sampling sites.

Cyanobacterial densities

Across the five sampling stations, Pandan Island exhibited the highest total cyanobacterial density (3,032 cells/L), followed by Starfish Island (2,314 cells/L) and Cowrie Island (2,267 cells/L), while Wharf showed the lowest density (168 cells/L) Figure 3. *Planktothrix* sp. dominated the assemblage at Pandan Island and Starfish Island, reaching the highest recorded densities. *Merismopedia* sp. was abundant at Cowrie Island and Pandan Island but was absent at Starfish and Luli Islands. Several taxa, including *Synechococcus* sp. and *Pseudoanabaena* sp., were recorded only at Starfish Island, whereas *Prochlorococcus* sp. was absent at Wharf.

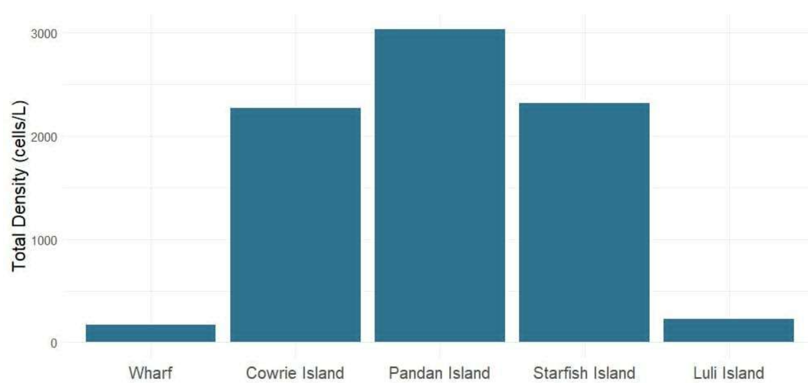

Figure 3. Cyanobacteria density Cells/L across five sampling station.

Environmental condition of the study sites

The physicochemical conditions of five sampling stations showed relatively uniform values for temperature, salinity, pH, and dissolved oxygen, while conductivity, oxidation–reduction potential (ORP), water transparency and depth, and total suspended solids exhibited more variation Figure 4. Surface water temperature remained stable across the study area, ranging from a minimum of 29.96°C at Luli to a maximum of 30.54°C at Cowrie. Conductivity values were consistent (approximately 47–48 µS/cm) at most stations, with the exception of Cowrie, which recorded a notably lower value of 34.89 µS/cm. Salinity levels showed minimal fluctuation, with values between 30.54 psu (Luli) and 31.26 psu (Wharf and Cowrie). In contrast, the Oxidation–Reduction Potential (ORP) showed an increasing trend across the stations, starting at 35.63 mV at the Wharf and reaching a peak of 47.29 mV at Luli. The pH levels were consistently alkaline, ranging narrowly from 8.32 to 8.39, indicating a stable chemical environment. Similarly, Dissolved Oxygen (DO) levels showed very little variance, maintaining a range between 2.25 mg/L and 2.30 mg/L across all five stations. The physical characteristics of the water column showed significant spatial differences: Water Depth and Transparency: Depth increased progressively from the Wharf (0.65 m) to Luli (11.35 m). At the first four stations, transparency was equal to the total depth, suggesting that the euphotic zone extended to the benthos. However, at Luli, transparency was limited to 3.95 m despite a depth of 11.35m. Total Suspended Solids (TSS): TSS concentrations fluctuated between stations, with the highest concentration recorded at the Wharf (37.95 mg/L) and the lowest at Pandan (21.85 mg/L).

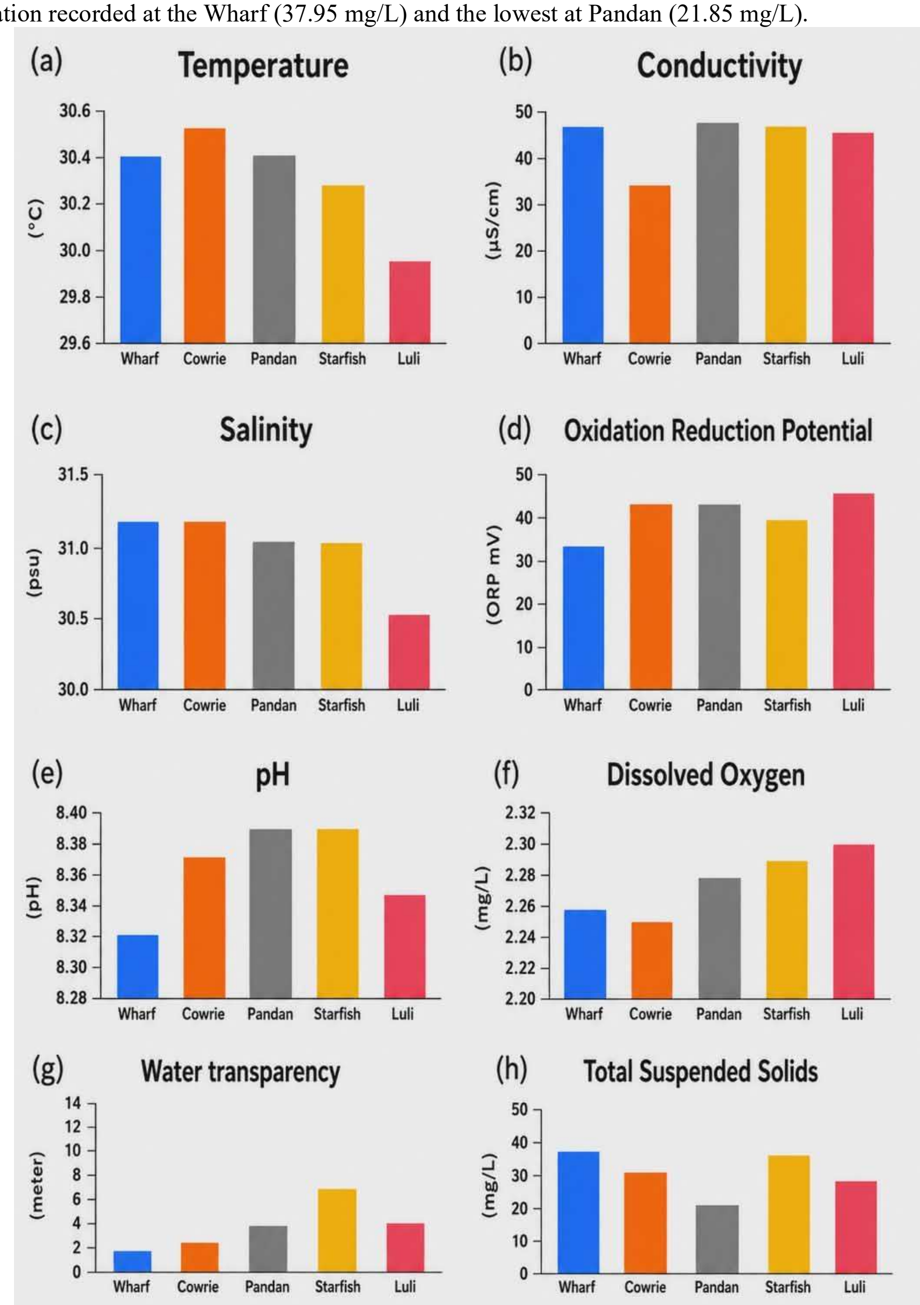

Figure 4. Physicochemical parameters across Honda Bay. (a) showing temperature; (b) showing conductivity; (c) showing salinity; and (d) showing ORP; (e) showing pH value; (f) showing Dissolved Oxygen; (g) showing water transparency and depth; and (h) showing Total suspended solids.

Occurrence of Potentially Harmful Cyanobacteria taxa

Composition and distribution of cyanobacteria taxa, cyanobacteria in Honda Bay as shown in Figure 5 revealed the presence of several potentially toxic taxa across all sampled sites. The community composition was characterized by a mix of filamentous and colonial genera, with varying relative abundances depending on the location. In contrast, *Merismopedia* sp. showed a highly site–specific distribution. It was the dominant taxon at the Cowrie site, comprising 56% of the recorded taxa, and maintained a significant presence at Pandan (24%) and the Wharf (12%). Notably, this genus was entirely absent from the Starfish and Luli stations. Minor taxa and non–toxic composition other potentially toxic genera were recorded in lower frequencies: *Oscillatoria* sp. was consistently present across all sites, peaking at Pandan (11%) and remaining below 10% at the other four locations. *Trichodesmium* sp. was most abundant at Cowrie (11%) and Pandan (9%), but was not detected at the Luli station. *Nodularia* sp. maintained a relatively low but stable presence, ranging from 1% to 6% across the five sites. *Synechococcus* sp. was the least frequent taxon, appearing only at the Starfish site with a minimal relative abundance of 1%. The non–toxic cyanobacteria taxa represented a significant portion of the community at the Wharf, accounting for 48% of the total. At the remaining sites, the proportion of non–toxic taxa was considerably lower, ranging from 8% at Cowrie to 22% at Luli.

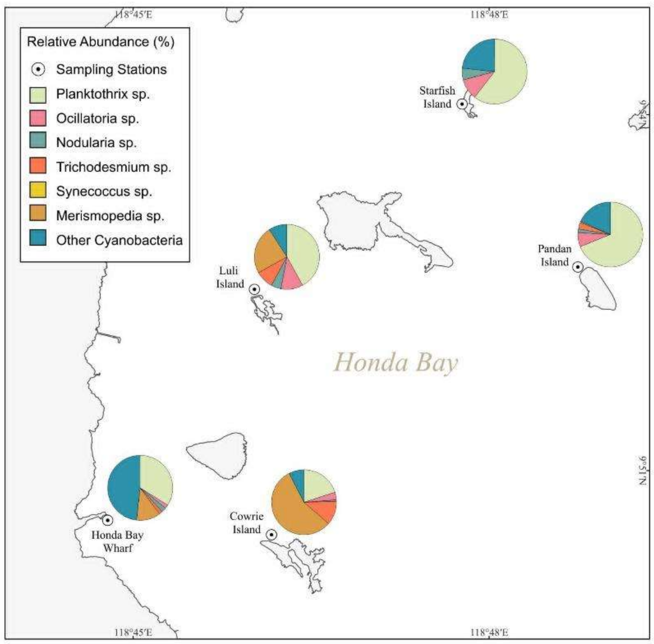

Figure 5. Potentially toxic cyanobacteria distribution across five sampling sites in Honda Bay.

The potentially toxic cyanobacteria identified in the Honda Bay, along with their associated toxins and known health risks Table 1. Several taxa were linked to hepatotoxins, including *Planktothrix* sp., *Nodularia* sp., *Synechococcus* sp., and *Merismopedia* sp., which are known producers of microcystins or nodularin associated with liver damage. Neurotoxins such as anatoxin, saxitoxin, palytoxin, and 42–hydroxy–palytoxin were associated with *Planktothrix* sp. and *Trichodesmium* sp., posing risks of paralytic shellfish poisoning and other severe seafood–related intoxications. Some taxa were also linked to cytotoxic effects and bioaccumulation in seafood.

Table 1. Possible public health risks associated with cyanobacteria.

Potentially toxin–producing taxa	Toxin	Known health risks If Level 2 of WHO ALF is reached (100,000cells/mL)	Routes
Plantothrix sp.	Microcystins Neurotoxic Anatoxin Planktocylin Aplysiatoxin	Liver damage Paralytic Shellfish Poisoning (PSP)	Accidental ingestion of contaminated water, and consumption of contaminated seafood.
Nodilaria sp.	Hepatotoxic Nodularin	Liver damage	Accidental ingestion and inhalation of airborne aerosols.

Teichodesmium sp.	Palytoxin and 42–Hydroxy palytoxin	Clupeotoxisma severe form of seafood poisoning from eating plankton–feeding fish	Accidental ingestion and inhalation of airborne aerosols.
Oscillatoria sp.	Neurotoxin and Saxitoxin	Paralytic Shellfish Poisoning (PSP)	Consumption of contaminated seafood.
Synechoccus sp.	Microcystins and Cytotoxin	Bioaccumulation in seafood, LPS irritation	Skin contact, and accidental ingestion of contaminated water.
Merismopedia sp.	Microcystins	Liver damage	Accidental ingestion of contaminated water.

DISCUSSION

Spatial Distribution of Cyanobacteria in Honda Bay

Cyanobacterial density varied markedly among stations, with the lowest density recorded at Wharf and the highest density observed at Pandan Island, followed by Starfish Island. Intermediate densities were recorded at Cowrie and Luli Islands. This spatial pattern suggests that cyanobacteria in Honda Bay are not uniformly distributed and are influenced by localized environmental conditions. The low cyanobacterial density at Wharf may be attributed to shallow depth, low water transparency, and frequent anthropogenic disturbances such as boat traffic and docking activities, which can increase turbidity and disrupt phytoplankton growth. According to Harris et al. (2024), environmental conditions can limit the occurrence of cyanobacteria through abiotic mechanisms such as physical transport, hydraulic flushing, and water column mixing, which disrupt the stratification and may cause buoyant cyanobacteria to sink. In contrast, island stations such as Pandan and Starfish Islands exhibited clearer waters and greater depths, allowing enhanced light penetration that supports photosynthetic activity and cyanobacterial proliferation. Light availability and water column stability are important environmental conditions for cyanobacterial growth, as clearer water enhance photosynthesis. According to Journey et al. (2013), cyanobacterial abundance is strongly influenced by environmental factors including light availability, hydrology, and water column stratification, Changes in light penetration caused by water turbidity or clearer water conditions can alter phytoplankton community and influenced cyanobacterial production, while stable water conditions can further support cyanobacterial proliferation.

Water Parameters

Water temperature across all stations ranged from 29.96°C to 30.54°C, which falls within the optimal range for cyanobacterial growth in tropical marine environments, where warmer waters are often observed to favor population growth. Although temperature was consistently high, its limited variability among stations suggests that water temperature acted as a supporting factor rather than a primary driver of spatial differences in cyanobacterial density.

Water transparency and depth showed relatively clear spatial variation and were closely associated with cyanobacterial density patterns. Stations with higher transparency and deeper waters, such as Pandan and Starfish Islands, supported higher cyanobacterial densities. Increased light availability enhances photosynthetic efficiency, favoring cyanobacterial growth (Ho et al. 2017). Conversely, Wharf exhibited the lowest transparency and depth, which likely restricted light penetration and reduced cyanobacterial abundance.

The relationship observed between Cyanobacteria density and Total Suspended Solids (TSS) suggest a notable inverse correlation across the majority of the sampling stations. At Starfish Island, the study recorded the highest Cyanobacteria density (3,032 cells/L) corresponding with the lowest TSS concentration of 21.85 mg/L. Conversely, the Wharf station exhibited the highest TSS level (37.95 mg/L) alongside the lowest Cyanobacteria density of 168 cells/L. This inverse relationship can be attributed to several ecological factors such as light limitation, and physical interference. These findings emphasize the importance of optical conditions in regulating cyanobacterial occurrence in coastal marine waters.

Increasing water pH significantly impacts Cyanobacterial growth and productivity, even for halo–alkaliphilic species adapted to high pH environments. As pH increased the biomass yield decreased (Yi et al. 2024). The pH values across stations were slightly alkaline and exhibited minimal variation. Such conditions are generally favorable for cyanobacteria; however, the narrow pH range suggests that pH did not significantly contribute to differences in cyanobacterial density among stations.

Dissolved oxygen concentrations were relatively low at all stations. Low DO levels may reflect high microbial respiration or biological oxygen demand associated with planktonic activity. While cyanobacteria contribute oxygen through photosynthesis, bloom decay and microbial decomposition can reduce oxygen levels, potentially affecting overall water quality.

Salinity values were stable and characteristic of marine environments, supporting the presence of marine cyanobacterial taxa. The limited variation in salinity and conductivity among stations indicates that these parameters had minimal influence on spatial differences in cyanobacterial density.

Public Health Implications

Honda Bay is a major recreational and tourism area where activities such as swimming, snorkeling, and island–hopping increase human exposure to coastal waters leading to significant dermal exposure that may cause acute skin irritation, rashes, and blisters (Rzymski and Poniedzialek 2012), and high risk of accidental water ingestion particularly in children (O`Keefe 2024). Inland exposure near contaminated waters also increases the risk of inhaling toxic Cyanobacteria as toxins from Cyanobacteria, can become airborne aerosols which can be transported (Lim et al. 2023).

Overall, the occurrence of cyanobacteria, including potentially toxic taxa, raises public health concerns due to possible exposure through skin contact, accidental ingestion, and inhalation of aerosols. Although cyanobacterial densities observed in this study do not necessarily indicate active bloom conditions. The lack of baseline data in Palawan makes it difficult to assess long–term risks. This study provides essential baseline information that can support future public health monitoring and early warning systems for recreational waters.

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GENERATIVE AI STATEMENT

The OpenAI's ChatGPT was used only to improve grammar, clarity, and formatting references. The authors reviewed and verified all AI–generated content to ensure accuracy and compliance with academic standards.

ETHICAL CONSIDERATIONS

No animals were harmed, and no human subjects were involved during this study.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no competing interests to any authors.

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