BILINGUAL PUBLISHING GROUP

Journal of Environmental & Earth Sciences

https://journals.bilpubgroup.com/index.php/jees

ARTICLE

Spatial Distribution of Dinoflagellates Associated with Harmful Algal Blooms (HAB) in Laguimit Bay, Samar, Philippines

Ruel H. Amascual [1*] , ***Andrew M. Gamba*** [2] , ***Edelyn Oliverio-Echapare*** [3] , ***Rezy V. Mendaňo*** [3] , ***Ma. Luningning L. Amparado*** [2]

[1] *College of Industrial Technology, Samar State University, Main Campus, Catbalogan City, Samar 6700, Philippines*

[2] *College of Fisheries and Marine Sciences, Samar State University, Catbalogan City, Samar 6700, Philippines*

[3] *College of Arts and Sciences, Samar State University, Main Campus, Catbalogan City, Samar 6700, Philippines*

ABSTRACT

Laguimit Bay is among the few areas in the Philippines where green mussels thrive. However, no studies have been conducted on Harmful Algal Bloom (HAB) in the area. This study investigates the spatial distribution of dinoflagellates associated with HAB in the surface water of the bay. Multiparameter water quality testers were used to determine the physicochemical characteristics while a plankton net was used to filter the dinoflagellates and counting was carried out in a compound microscope. Based on the results, the surface water temperature is between 27–31 °C while the pH ranges from 8.1–8.2 and dissolved oxygen is 6.3–6.5 mg/L at salinity ranges from 30–31 ppt. This indicates that the water quality of the Bay is sustainable for farming mussels. Microscopic examination of the samples showed that the only dinoflagellate associated with HAB is *Pyrodinium bahamense var. compressum* which causes Paralytic Shellfish Poisoning with an average concentration of 22 cells/L. Other non-HAB species were *Protoperidinium depressum* with an average of 489 cells/L and the rest are *Ceratium macroceros*, *Ceratium furca*, *Ceratium trichoceros*, *Ceratium lunula*, *Dinophysis caudata*, *Dinophysis miles*. The Shannon-Wiener diversity index was 1.8723 in station 1 and 1.8406 in station 2 and 1.7439 in station 3 which indicates a low diversity index. The presence of *P. bahamanse* has the potential for recurrence of HAB formation in Laguimit Bay which could affect the economic livelihood of fisherfolk in the country.

*CORRESPONDING AUTHOR:
Ruel H. Amascual, College of Industrial Technology, Samar State University, Main Campus, Catbalogan City, Samar 6700, Philippines; Email: ruel.amascual@ssu.edu.ph

ARTICLE INFO
Received: 21 February 2025 | Revised: 14 March 2025 | Accepted: 19 March 2025 | Published Online: 15 May 2025
DOI: https://doi.org/10.30564/jees.v7i5.8823

CITATION
Amascual R.H., Gamba A.M., Echapare, E.O., et al., 2025. Spatial Distribution of Dinoflagellates Associated with Harmful Algal Blooms (HAB) in Laguimit Bay, Samar, Philippines. Journal of Environmental & Earth Sciences. 7(5): 507–519. DOI: https://doi.org/10.30564/jees.v7i5.8823

Continued monitoring and management are recommended to mitigate potential HAB risks and ensure the sustainability of shellfish resources.

Keywords: *Pyrodinium bahamense*; Green Mussel; Biotoxin; Shellfish Red Tide

1. Introduction

In the Philippines, oysters and mussels are two essential aquaculture fishery commodities. The slipper-shaped oyster (talabang tsinelas) and the green mussel (tahong) are the Philippines' most commercially cultivated mollusc species, mainly for their meat and consumption by Filipinos. One significant problem in existing shellfish areas is the over-congestion of farms. Many farming structures were abandoned. Reclamation of oyster grounds to expand the national highway was also cited as one of the reasons why the production of the commodities decreased. Environmental factors such as pollution and siltation, which harm the productivity of culture grounds, also limit the rate and intensity with which production can be increased. Oysters and mussels are grown in rivers and estuaries that contain variable quantities of pollution, particularly animal waste. In the Philippines, outbreaks of harmful algal blooms (HABs) or paralytic shellfish poisoning (PSP) are also a significant impediment to the industry's growth. Several studies on environment-friendly aquaculture were done to address the problem of the deteriorating environment, one of which is integrated multi-trophic aquaculture (IMTA) [1]. The inside process of IMTA design aims not to eliminate the organic waste matter but to convert it into a usable compound [1].

Mussel farming represents a vital economic activity for coastal communities in the Philippines, specifically in Samar Province, which provides livelihoods among fisherfolk. Based on the Philippine Fisheries Profile of 2021, Samar province is among the top producers of green mussel and other commercial bivalves in the Eastern Visayas. Major sources of green mussel production were reported in Villareal, Jiabong, Catbalogan, Daram, and Tarangnan, Samar [2]. The total shellfish production reached 1,919.59 metric tons, wherein green mussels accounted for 99.6 % of the total production, while 0.4% was from oyster commodities. However, Harmful Algal Blooms (HAB) or Red Tide cause tremendous economic losses in the province due to the banning of harvesting, transporting, and selling of green mussels resulting in unemployment for both the fishermen and the secondary industries such as processing, middlemen, and suppliers. A similar study was conducted by Echapare et al. [3] wherein the fisherfolk have a high awareness of the economic repercussions of the HAB known as the red tide in their community which affects the livelihood and reduces the income of the fisherfolk and farmers during the event [3].

Samar Island consists of various bays such as Maqueda Bay, Irong-irong Bay, Cambatutay Bay and Villareal Bay. These bays are the site of the first reported toxic *Pyrodinium bahamense* in late 1983 and the incidences of *Pyrodinium* blooms have been increasing in recent years with shellfish bans imposed every month [4]. However, in Laguimit Bay, no studies have been conducted on dinoflagellates associated with HAB, despite the fact that mussels and oysters are farmed in this area.

The rise in dinoflagellate populations in the chosen bays of the Philippines has been linked to heightened human activities. Various physicochemical and hydrobiological factors influence water quality, with dinoflagellates, which are microscopic algae that form the foundation of the food web, being an important biological component [5]. Although a rise in dinoflagellate density is typically advantageous for fisheries by supporting the production of fish food, dense algal blooms can result in detrimental effects, such as fish kills caused by oxygen depletion and shellfish poisoning in humans [6]. Similar to Manila Bay, studies often focus on Harmful Algal Species (HAS) or water quality, and physical profiles, typically concentrating on the near-bottom layer of the bay. Proliferation of harmful bacteria such as Escherichia coli has been reported in the river by Amascual et al. [7], which could affect the water quality of the Bay [7]. However, a limited correlation between these factors has been reported. According to the study conducted by Estudillo et al. (1984), a harmful dinoflagellate bloom of *Pyrodinium bahamense var. compressa* and the resulting paralytic shellfish poisoning, occurred for the first time in Philippine waters [8]. These studies have been instrumental in HAB dynamics and management in the coastal areas of Samar Island.

Dinoflagellates, as key primary producers, act as indicators of environmental problems. As a result, research on dinoflagellates in Manila Bay typically concentrates on locations that have previously experienced toxic shellfish poisoning and fish mortality or is conducted over brief durations [9]. Dinoflagellates are included in these investigations to either support or challenge existing hypotheses. Although there are assertions of a reduction in dinoflagellate populations due to changes in the ecosystem, there is a lack of definitive data. Numerous dinoflagellate species, such as *Pyrodinium bahamense* [10], *Alexandrium minutum* [11,12], *Prorocentrum cordatum* [13,14], Chattonella subsalsa [15], and *Skeletonema* sp. [16], have been observed and linked to algal blooms. Escobar et al. [16] revealed *Rhizosolenia* sp. [11], *Takayama* sp. [17,18]. On the other hand, *P. bahamense* and *A. tamarense* have also generated blooms in Manila Bay [10], the nation's socioeconomic center, and the watershed that drains Metro Manila and several nearby watersheds and A. minutum [12].

Based on the research by Hallegraeff et al. [19], there were 3,800 recorded cases of PSP globally between 1985 and 2018, with 2,555 of those cases occurring in the Philippines, resulting in a total of 165 fatalities [19]. Most of these incidents were reported from western Samar and Biliran Island. Recently, last September 2024, there were Paralytic Shellfish Poisoning (PSP) cases reported in Samar wherein a total of 33 individuals were hospitalized after they consumed green mussels locally known as green mussels. Similar cases happened last January 14, 2025, in which two individuals reported shellfish poisoning after they consumed green mussels they bought from an ambulant vendor and were admitted to City Hospital in Tacloban City for seven days. Based on the symptoms, the patients experienced headache, body numbness, extremity numbness, dizziness, vomiting, and abdominal pain, but all recovered after immediate medical attention. In the study conducted by Amascual et al. [20], it was found out that histamine substances caused by *Staphylococcus aureus* were detected at all stages of the supply chain [20]. The most common varieties of fishes showed a significant concentration of histamine concentration are the *balanak*, *baysa*, *bolinao*, *dinorado*, *galunggong*, *lambiao*, *lusod*, *and tamban* (Amascual et al., 2020) [21].

Despite a rise in the occurrence of *Pyrodinium bahamense* blooms and ongoing monthly restrictions on red tide, there is a significant deficiency in comprehensive ecological research on dinoflagellates in the area, resulting in a limited understanding of bloom formation and their potentially harmful impacts [22]. This situation is particularly concerning as the islands rely heavily on marine resources for food and economic activities, with reports of human deaths associated with mussel consumption after *P. bahamense* outbreaks. Unfortunately, there is a lack of published data regarding the primary hotspots of HAB in the Philippines, particularly in Eastern Visayas, where *Pyrodinium* blooms have occurred frequently.

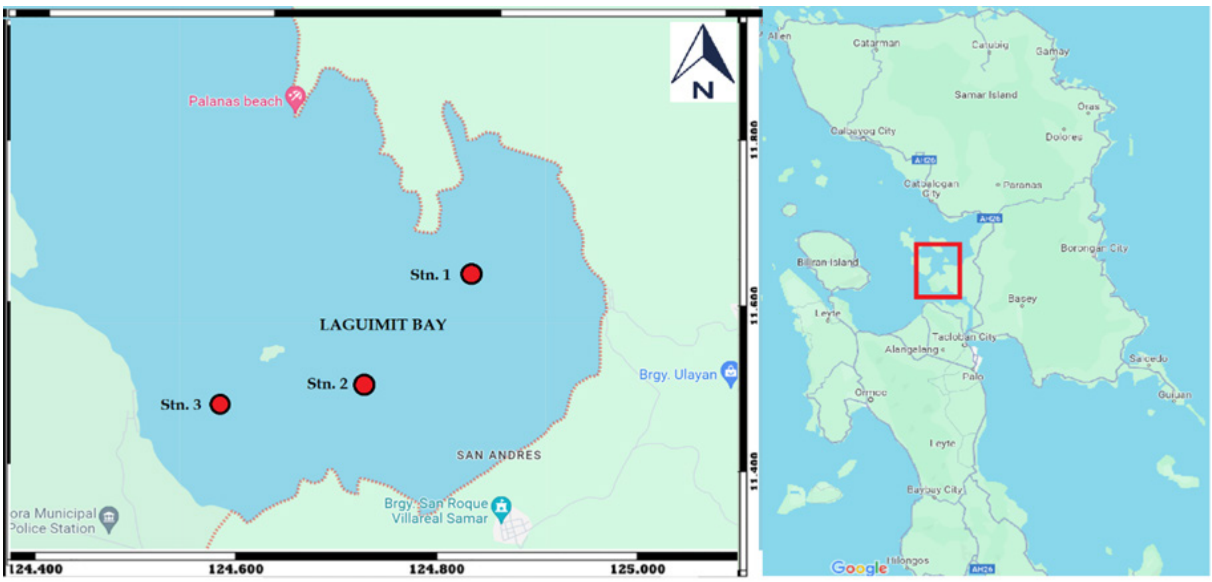
Laguimit Bay, located within the municipal waters of Villareal, Samar, currently lacks baseline data on dinoflagellate composition and red tide monitoring, as the bay has not been included in the sampling plans of the Bureau of Fisheries and Aquatic Resources (BFAR). Despite this, the bay is known for its significant cultivation of green mussels and oysters. This study aims to evaluate the spatial distribution of dinoflagellates in Laguimit Bay, with a particular focus on those species associated with HAB species. The results of this study will serve as essential baseline data for policy formulation and regular monitoring efforts aimed at ensuring toxin-free shellfish products in the market. By providing a scientific foundation for decision-making, the study will contribute to the development of regulatory measures that enhance consumer safety and protect public health. Furthermore, the findings will support sustainable seafood consumption in the country by promoting responsible aquaculture practices, strengthening food safety standards, and fostering long-term environmental and economic sustainability in the seafood industry.

2. Materials and Methods

2.1. Sample Collection and Study Site

Water samples were collected from the surface waters in three sampling stations situated in Laguimit Bay, Villareal, Samar, at latitude 11°32′ N, longitude 124°52′ E as presented in **Figure 1**.

Using the plankton net, water sample collections were vertically towed, and the resulting 50-mL water sample was transferred to a sterilized translucent bottle and promptly fixed in situ with a 5-mL formalin solution for preservation. Simultaneously, another set of surface water samples was obtained using a bucket in triplicate at each station within a 1-meter depth. All samples were transferred into 1-L plastic bottles without corrugation to ensure the settling of all dinoflagellates at the bottom. All samples were immediately fixed in situ using a 1% formaldehyde solution and stored in a storage box until arrival at the HAB laboratory at the Research and Innovation Center, where they were left undisturbed for at least 24 hours. Then the upper layer of water was carefully removed using plastic capillary tubing and a pump, and the remaining 250 mL was transferred to a straight plastic container with a relatively small diameter and allowed to settle for another 24 hours. The upper layer of water was once again discarded, leaving behind the remaining 50 mL of seawater and the concentrated collected dinoflagellate as the final samples.



[Scale: 225 cm = 1,439 m]

Figure 1. Map and Sampling Stations along Laguimit Bay in Samar, Philippines.

2.2. Sample Preparation

The volume of samples to be analyzed was measured using a 500 mL graduated cylinder. Then, a 1.0 mL aliquot sample was taken and placed in the Sedgewick Rafter counting chamber and examined using the inverted microscope. Quantitative and taxonomic analysis of dinoflagellates was done using the method of Omura et al. (2012) [23]. An aliquot of 1 ml for each sample was mounted on a Sedgewick-R after the chamber grid slide was analyzed using an inverted microscope. Dinoflagellates were identified based on the characteristics described by Matsuoka and Fukuyo (2000) [24]. The densities (cells L^{-1}) were calculated by multiplying the concentrated volume by the number of cells. A combination microscope with a 100X total magnification was used to count each sample bottle three times. According to the AlgaeBase database and the identification guidelines given by Omura et al. (2012) [25], dinoflagellates were identified using micrographs [23].

2.3. Physico-Chemical Characteristics

Determination of the physico-chemical characteristics of surface waters in three (3) sampling stations such as water temperature (°C), pH, dissolved oxygen (DO, ppm), and salinity (ppt) were done on-site using a multiparameter water tester (Hanna Instrument, Woonsocket, RI, USA) while salinity was measured using a handheld refractometer (Atago, Saitama, Japan). Regular calibration checks were performed before and during the study to detect and correct any deviations that could affect the consistency of the findings.

2.4. Statistical Analysis

Dinoflagellate abundances were measured using the Species diversity index (H') according to Shannon & Wiener and Sampson index (H') (1949). Anova: Single Factor was carried out to determine the significant differences of each sampling site in terms of the average cell density.

The Cell Density and Diversity of species were calculated using

$$\text{Cell Density} = \frac{(\textit{Number of Cells counted})(\textit{volume of water in ml})}{(\textit{Depth of plankton net})(\textit{Mouth of plankton net})} \times 1000\text{ml} \quad (1)$$

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \quad (2)$$

Where:

H′: Shannon diversity index

S: Total number of species

pi: Proportion of individuals belonging to the i-th species

ln: Natural logarithm

$$\text{Percentage Composition} = \left(\frac{\text{Number of individuals of a species}}{\text{Total number of individuals of species}}\right) \times 100 \quad (3)$$

3. Results and Discussions

3.1. Physico-Chemical Characteristics

The physicochemical properties of seawater, influenced by natural processes and human activities, are essential for understanding the dynamic nature of marine ecosystems, particularly for shellfish habitats. Assessing these properties, such as pH, DO, salinity, and water temperature, provides valuable insights into the health and sustainability of these environments.

Based on the results as shown in **Figure 2**, the surface water temperature was measured between 27–31 °C at an average of 7.0 meters sampling depth. Although water temperature›s effect on communities and ecosystem processes is debated, it affects the dinoflagellate growth rate. A similar study conducted by Renaud et al. (2002) mentioned that dinoflagellate tolerates a range of temperatures 20–30 °C and the optimum temperature for dinoflagellate development is 27–30 °C [26]. Similarly, pH values were relatively alkaline from 8.1–8.2.

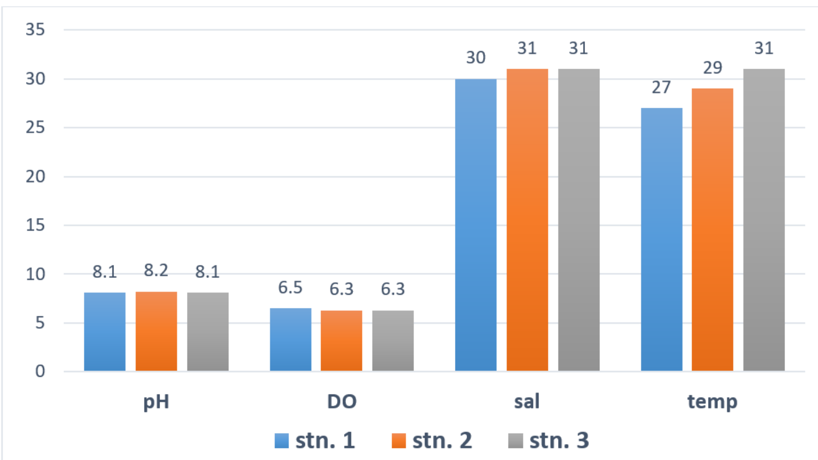


Figure 2. Physico-Chemical Characteristics of the Surface Water.

Ravelo et al. (2022) reported variations in water quality across different bays of Samar Island [27]. Salinity ranged from 27–34 ppt in Villareal Bay, 30–34 ppt in Cambatutay Bay, and 31–35 ppt in Irong-Irong Bay. Dissolved oxygen levels were 5–7 ppm in Cambatutay and Irong-Irong, while Villareal Bay had slightly lower levels (5–6 ppm).

Total suspended solids (TSS) were relatively higher in Cambatutay, Irong-Irong, and Villareal (0.3–0.1 mg/L). These findings highlight environmental differences among the study sites, which may influence local aquatic ecosystems.

However, marine dinoflagellates in general are resistant to climate change in terms of ocean acidification and do not increase or decrease in their growth rate according to ecologically relevant ranges of pH and CO2 [28]. In the other part, dissolved oxygen (DO) was also measured ranging from 6.3–6.5 mg/L which indicates sufficient oxygen present in the water column. Dissolved oxygen levels in surface water are due to the photosynthetic process of dinoflagellates and the vertical mixing of atmospheric oxygen into the water column [29]. Similarly, salinity concentration was found to be 30–31 ppt. Salinity is the main physical parameter that can be attributed to the dinoflagellate diversity and acts as a limiting factor, which influences the distribution and growth of dinoflagellate communities [30]. This was also supported in the study conducted by Thomas (1969) [31], wherein the co-dominance of these dinoflagellate blooms in the three major bays in Samar Island can be associated with the interplay of the environmental factors such as nutrient loads in the water column and the increase of water temperature in the area. Since nutrient content such as nitrate and phosphate is the primary limiting parameter for the growth of marine phytoplankton and is accompanied by heavy rainfall, surface currents and wind force are among other major factors contributing to HAB development [32]. The relative lack of turbulence is thought to favor dense populations of dinoflagellates [33], which results in blooming in primarily warm, stratified waters from late spring to early autumn [34]. Bays with low turbulence such as the Laguimit Bay create an ideal environment for dinoflagellate growth and bloom formation where water exchange is limited and seasonal stratification occurs. The frequency of HAB events showed an increasing trend over the last several decades owing to the changing environmental conditions of the bay, such as decreasing wind turbulence, increasing surface temperature, etc [35]. A similar study by Estrada and Berdalet (1997) found that the relationship between water dynamics and phytoplankton communities was influenced by a combination of environmental factors [36]. As a result, the hydrodynamic characteristics of a given area significantly impact the temporal fluctuations and composition of dinoflagellate populations.

3.2. Cell Density of Dinoflagellate

Cell density plays a crucial role in shaping trophic interactions within aquatic ecosystems. As shown in **Figure 3**, *Protoperidinium depressum* exhibited the highest cell density across all stations, averaging 489 cells/L. Other species such as *Ceratium macroceros* contained 322 cells/L, *Ceratium furca* at 133 cells/L, *Ceratium trichoceros* at 300 cells/L, *Ceratium lunula* at 61 cells/L, *Dinophysis caudata* at 150 cells/L, *Dinophysis miles* at 217 cells/L, and *Pyrodinium bahamense var. compressum* at 22 cells/L. The same study was also conducted by Ravelo et al. (2022) in different bays in the Eastern Visayas region [25]. The following HAB-causing species were identified in the study: *Pyrodinium bahamense*, *Dinophysis caudata*, *Dinophysis miles*, *Prorocentrum lima*, *Prorocentrum sigmoides*, *Ceratium furca*, *Ceratium fusus*, *Ceratium inflatum*, and *Prorocentrum micans*. The presence of bloom-forming harmful algal species (73 HAB species in 27 genera), including 43 potentially toxic species, recorded in considerable cell density from coastal and near-shore waters, imposes a threat to the fisheries industry and human health [35].

Monitoring dinoflagellate cell densities allows for early detection of harmful algal blooms, which can produce toxins harmful to marine life and humans. It predicts and manages harmful algal blooms, ensuring the safety and sustainability of the shellfish industry and protecting marine ecosystems.

3.3. Percentage Composition and Abundance of Dinoflagellate

Understanding the composition of dinoflagellates in aquatic ecosystems such as Laguimit Bay provides crucial insights into the health and dynamics of marine environments. The percentage composition of dinoflagellate species was presented in **Figure 4**, which provides insightful information about the ecological dynamics and environmental conditions within Laguimit Bay. **Figure 4** shows the micrographs of dinoflagellate species in the surface waters.

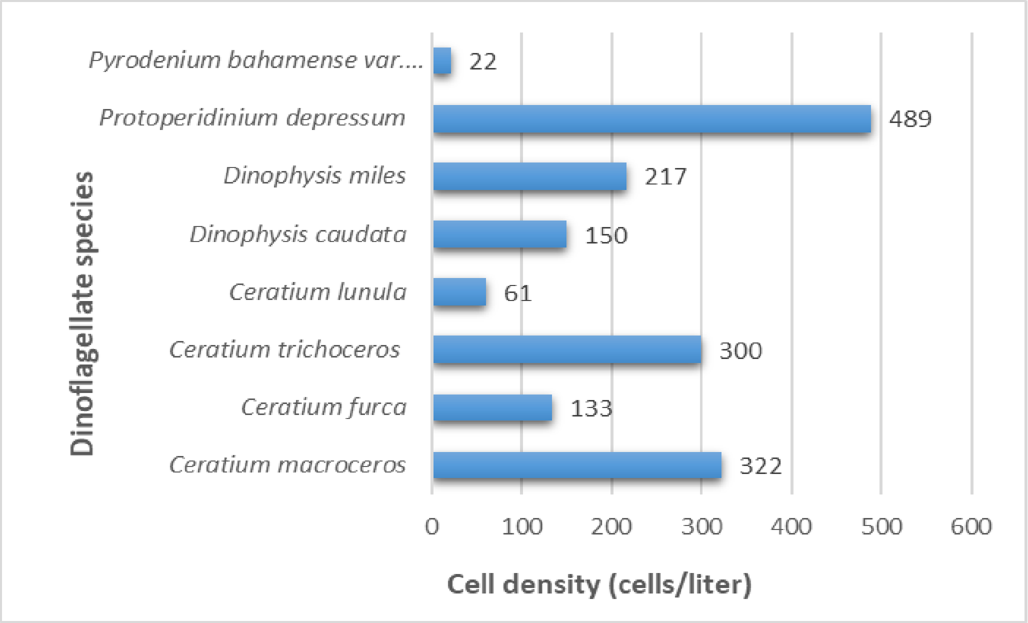


Figure 3. Average Cell Density (cells/L) from the Surface Water in 3 Sampling Stations.

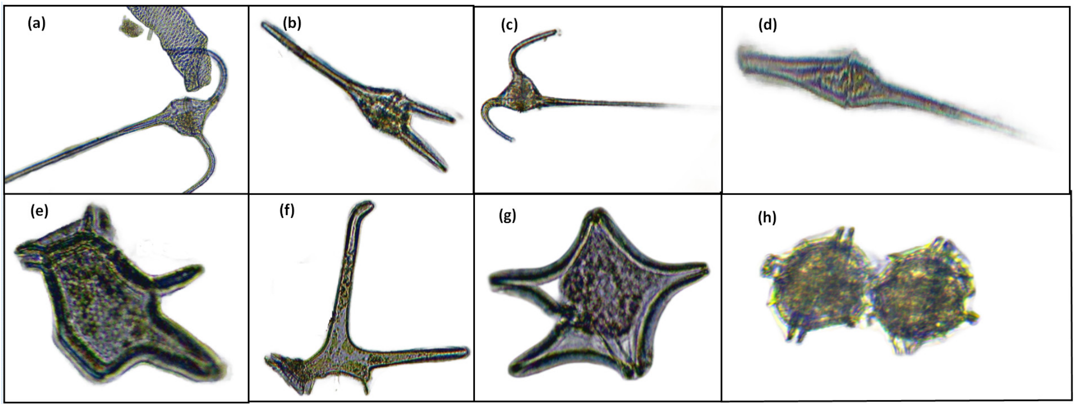


Figure 4. Micrographs of Dinoflagellate Species Found in the Surface Water of Laguimit Bay. (**a**) *C. macroceros.* (**b**) C. *furca.* (**c**) *Ceratium lunula* (**d**) *C. trichoceros.* (**e**) *D. caudata.* (**f**) *dynophysis miles* (**g**) *P. depressum.* (**h**) *Pyrodinium bahamense var. compressum*.

For the percentage composition, among the identified dinoflagellate species, as presented in **Figure 5**, *Protoperidinium depressum* dominates the composition, comprising 29% of the total dinoflagellate abundance. This high percentage suggests that conditions within the bay may be favorable for the growth and proliferation of *Protoperidinium depressum*. Additionally, *Ceratium macroceros* and *Ceratium trichoceros* are relatively abundant, constituting 19% and 18% of the dinoflagellate composition, respectively. These species are characteristic of dinoflagellates, which are common in marine environments and often indicate healthy aquatic ecosystems. The presence of *Ceratium* species suggests suitable environmental conditions, such as adequate light and temperature, supporting their growth.

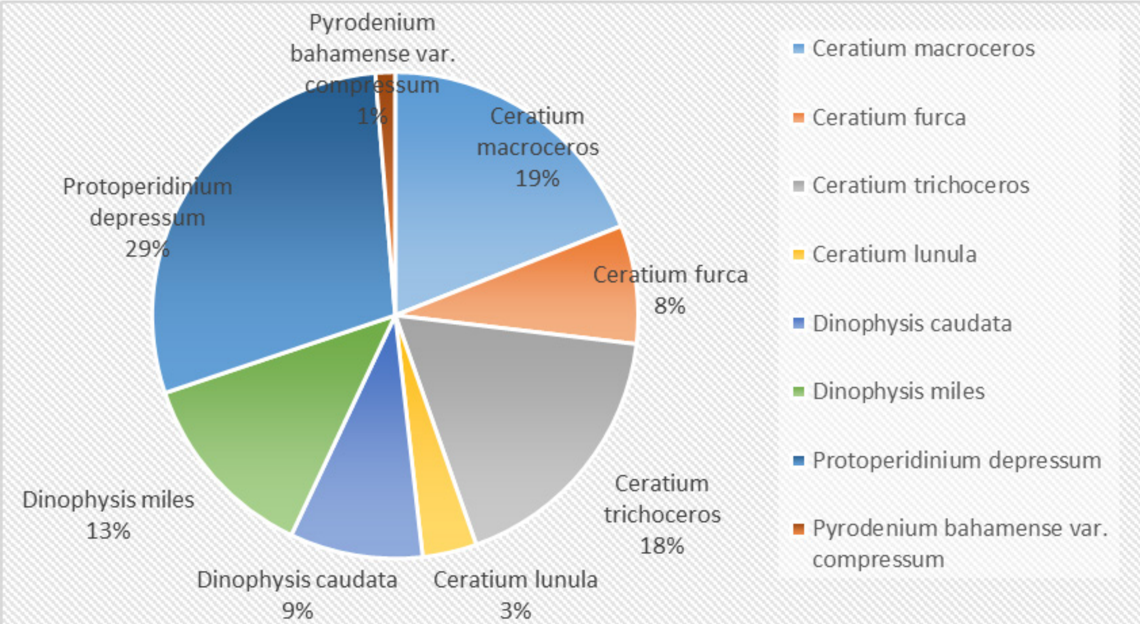


Figure 5. Percentage Composition of Dinoflagellates of the Total Cell Counts.

Furthermore, *Dinophysis caudata* and *Dinophysis miles* collectively contribute 22% to the dinoflagellate composition as shown in **Figure 5**. Less abundant species include *Ceratium furca*, *Ceratium lunula*, and *Pyrodinium bahamense var. compressum*, each comprising smaller percentages of the total dinoflagellate composition. Although their contributions are relatively minor, their presence adds to the overall biodiversity of dinoflagellates within Laguimit Bay, highlighting the bay's ecological richness and complexity. According to certain data, the Philippines' mariculture and wild shellfish harvesting locations are hotspots for HAB episodes [37]. For instance, the red tide outbreak in Samar is caused by *P. bahamense*. In reality, there was a discernible rise in the relative density of *P. bahamense* in Samar's three bays between September and November, which also happened to be the same time that BFAR 8 declared several red tide bans for the province [27]. Furthermore, because they are filter feeders by nature, mussels have the capacity to amass large amounts of phytoplankton that produce STXs. It is possible that live *P. bahamense* can be found in the feces and digestive tract of mussels from the contaminated location.

This same also in the study conducted by Baula et al. (2011) in Bolinao [38], Pangasinan, in the northern part of the Philippines, wherein dinoflagellate cysts are comparatively lower than in other coastal areas where cysts have been studied.

Similarly, the abundance of dinoflagellates across three sampling stations, as presented in **Figure 6**, provides valuable insights into the ecological dynamics within Laguimit Bay. *Protoperidinium depressum* emerges as the dominant species across all stations, with station 3 exhibiting the highest percentage composition at 35%, followed by stations 1 and 2 at 25% and 28%, respectively.

Additionally, *Ceratium macroceros* demonstrates consistency in its abundance, with percentages remaining relatively stable across all stations, indicating uniform environmental suitability for this species throughout the sampling area. Conversely, *Ceratium furca* exhibits slight variability, with station 2 showing the highest abundance at 11%, suggesting that localized environmental factors influence its distribution. *Dinophysis caudata* and *Dinophysis miles* display similar patterns across stations, indicating relatively stable environmental conditions for these species within Laguimit Bay. However, the lower percentages of these dinoflagellates compared to *Protoperidinium depressum* suggest differences in ecological niches. *Ceratium lunula* and *Pyrodinium bahamense var. compressum* exhibit low abundance across all stations, indicating limited ecological significance within the bay's dinoflagellate community.

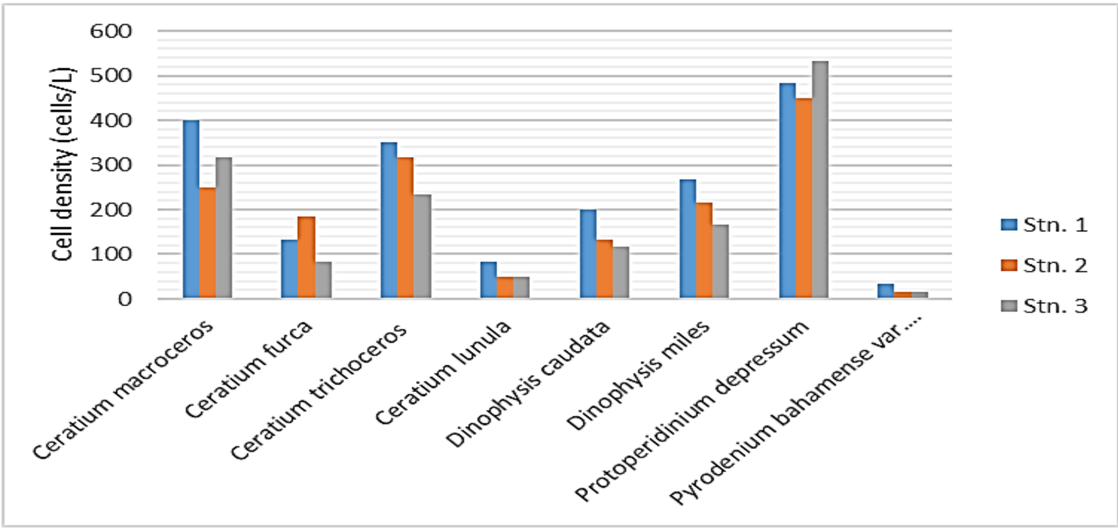


Figure 6. Abundance of Each Species in Every Sampling Station.

Recording of dinoflagellate species along Laguimit Bay in Villareal, Samar is considered to be the first study ever conducted, and is very crucial in HAB monitoring since there are dense mussel farming activities. The presence of *Pyrodinium bahamense var. compressum*, which causes Paralytic Shellfish Poisoning (PSP), is very alarming. A similar study was also conducted by Ravelo et al. (2022) in Villareal Bay, an adjacent water of Laguimit Bay [27], which reported identifying some of harmful algal bloom-causing species such as *Pyrodinium bahamense var. compressum*, *Dinophysis* sp. and *Ceratium* sp. The same study conducted by Folio and Yap-Dejeto (2021) wherein *Pyrodinium bahamense* was present in all sampling months with a total mean cell density of 0.08 × 104 cells/L but was never the dominant species in Irong-irong Bay in Samar [39]. Other dinoflagellates have been identified such as *P. bahamense*, *N. scintillans*, and species of Ceratium co-dominated in the coastal waters of Samar Island.

3.4. Shannon-Wiener Diversity Index (H')

The H' is a fundamental measure employed in ecological studies to assess the diversity of a biological community as presented in Table 1. It provides a comprehensive understanding of species richness and evenness within the community. Based on the data the H' of dinoflagellates population was 1.8723 in Station no. 1, while 1.8406 in station no. 2 and 1.7439 for station no. 3. This suggests a low diversity or a relatively low abundance of dinoflagellate species in the area which indicate that the community is dominated by a few species or the dinoflagellate community but not very diverse. Because competition, predation, and succession are important biological processes that affect species diversity, changes in these processes can affect the species diversity index by changing evenness [40]. Dinoflagellate communities' species diversity index can reveal whether pollution or eutrophication is affecting the ecosystem [41].

Table 1. Shannon-Wiener Species Diversity Index in Three Sampling Stations.

Species	*Station 1*				*Station 2*				*Station 3*			
	Cells /L	*pi*	*ln pi*	*pi ln pi*	*Cells /L*	*pi*	*ln pi*	*pi ln pi*	*Cells /L*	*pi*	*ln pi*	*pi ln pi*
Ceratium macroceros	*400*	*0.21*	*–1.58*	*–0.32*	*250*	*0.15*	*–1.87*	*–0.29*	*317*	*0.21*	*–1.57*	*–0.33*
Ceratium furca	*133*	*0.07*	*–2.68*	*–0.18*	*183*	*0.11*	*–2.18*	*–0.25*	*83*	*0.05*	*–2.90*	*–0.16*
Ceratium trichoceros	*350*	*0.18*	*–1.72*	*–0.31*	*317*	*0.20*	*–1.63*	*–0.32*	*233*	*0.15*	*–1.87*	*–0.29*

Table 1. *Cont.*

Species	*Station 1*				*Station 2*				*Station 3*			
	Cells /L	*pi*	*ln pi*	*pi ln pi*	*Cells /L*	*pi*	*ln pi*	*pi ln pi*	*Cells /L*	*pi*	*ln pi*	*pi ln pi*
Ceratium lunula	83	0.04	–3.15	–0.13	50	0.03	–3.48	–0.11	50	0.03	–3.41	–0.11
Dinophysis caudata	200	0.10	–2.28	–0.23	133	0.08	–2.50	–0.21	117	0.08	–2.56	–0.20
Dinophysis miles	267	0.14	–1.99	–0.27	217	0.13	–2.01	–0.27	167	0.11	–2.21	–0.24
Protoperidinium depressum	483	0.25	–1.39	–0.35	450	0.28	–1.28	–0.36	533	0.35	–1.05	–0.37
Pyrodinium bahamense var. compressum	33	0.02	–4.07	–0.070	17	0.01	–4.57	–0.047	17	0.011	–4.51	–0.05
	1950	1.00		–1.87	1617	1.00		–1.84	1517	1.00		–1.74
			H’=	**1.87**			**H’=**	**1.84**			**H’=**	**1.74**

A low diversity index observed in 90% of the samples is a common feature of ecosystems experiencing unstable equilibrium, such as estuaries or polluted environments undergoing localized eutrophication [42]. The enrichment of water masses initially promotes the dominance of a few species, leading to a significant decline in overall species diversity [43].

The study on the spatial distribution of dinoflagellates responsible for HABs in the Philippines is critical for protecting human health, preserving marine ecosystems, supporting sustainable fisheries, promoting tourism and coastal development, and building resilience to climate change. Understanding the spatial distribution of dinoflagellates responsible for HABs in the Philippines is essential for safeguarding human health, preserving marine ecosystems, and supporting sustainable coastal development. By studying where HAB-forming dinoflagellates are most prevalent, authorities can implement targeted monitoring and management strategies to protect public health by minimizing exposure to harmful toxins in seafood. Moreover, knowledge of HAB distribution enables researchers to assess the potential impacts on marine biodiversity and ecosystem dynamics, informing conservation efforts to maintain the resilience of coastal ecosystems. Sustainable fisheries management is also supported through anticipation and mitigation of HAB events, ensuring the long-term viability of marine resources vital for food security and livelihoods. Additionally, understanding HAB distribution aids in promoting tourism and coastal development by minimizing disruptions to coastal activities and safeguarding the economic benefits derived from coastal areas. Finally, insights into HAB dynamics contribute to climate change resilience efforts, enabling the development of adaptation strategies to mitigate the impacts of climate change on HAB occurrence and associated risks to human health and marine ecosystems. Through comprehensive study and management of the spatial distribution of HAB-forming dinoflagellates, the Philippines can effectively address the multifaceted challenges posed by HABs while promoting sustainable coastal development and resilience in the face of environmental change.

4. Conclusions

Based on the results of the study, Laguimit Bay meets Class SA water quality standards, making it suitable for shellfish farming. However, the presence of harmful algal bloom (HAB) species, particularly *Pyrodinium bahamense var. compressum* (22 cells/L), poses risks to fisheries, public health, and the local economy. The dominance of a few dinoflagellate species suggests low phytoplankton diversity, likely influenced by water quality and hydrodynamic conditions. To address these challenges, regular HAB monitoring, water quality monitoring, and community-based coastal resource management are essential. Additionally, sustainable finance mechanisms, such as blue bonds and ecosystem service payments, can help balance economic productivity with marine conservation. Future research should focus on long-term HAB trends, socioeconomic impacts, and nature-based solutions like seagrass restoration to mitigate risks and promote ecosystem resilience. By integrating science, policy, and finance, sustainable management strategies can help protect both Laguimit Bay's ecosystem and local livelihoods.

5. Recommendations

The Bureau of Fisheries and Aquatic Resources (BFAR) should include Laguimit Bay and the other bays on Samar Island in its monitoring and management programs for early detection of red tide occurrences. This is particularly important for harmful algal blooms (HABs) caused by organisms such as *Pyrodinium bahamense*. Such measures are essential to ensure consumer safety, protect public health, and maintain the sustainability of shellfish resources in Samar Island. Likewise, the Samar Provincial Government should establish a dedicated Marine Biotoxin Laboratory that will conduct analysis for marine biotoxins (saxitoxin, domoic acid, okadaic acid,) in support of food safety measures as well as provide technical assistance to the Local Government Units, fisherfolk, shellfish industries, non-government agencies, and other government agencies.

Author Contributions

Conceptualization and Methodology, A.R., G.A.; analysis data: E.E.; writing—original draft preparation, review and editing, M.R., A.M. All authors have read and agreed to the published version of the manuscript.

Funding

This work was supported by Samar State University—Center for Fisheries and Aquatic Resources Research and Development under the Research and Extension Office.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Acknowledgments

The authors would like to thank Samar State University (SSU) and the Center for Fisheries and Aquatic Resources Research and Development (CFARRD) for the funding support and the facilities used in the study.

Conflict of interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

[1] Troell, M., Joyce, A., Chopin, T., et al., 2009. Ecological engineering in aquaculture—potential for integrated multi-trophic aquaculture (IMTA) in marine offshore systems. Aquaculture. 297, 1–9.

[2] BFAR Region-8, 2021. Philippine Fisheries Profile 2021. Bureau of Fisheries and Aquatic Resources: Manila, Philippines.

[3] Echapare, E.O., Mendaňo, R.V., Cabaguing, A.M., et al., 2023. Understanding The Knowledge, Beliefs, and Practices Of Samareños on Red Tide Phenomenon: Implications For Sustainable Management. Journal of Namibian Studies. 36, 263–292.

[4] Meniano, S., 2020. BFAR Warns Anew vs. red tide in Eastern Visayas. Available from: https://www.pna.gov.ph/articles/1119358 (cited 22 October 2024).

[5] Legendre, L., 1990. The Significance of Microalgal Blooms for Fisheries and for the Export of Particulate Organic Carbon in Oceans. Journal of Dinoflagellate Research. 12, 681–699. DOI: https://doi.org/10.1093/plankt/12.4.681

[6] Hallegraeff, G., 2002. Aquaculturists' Guide to Harmful Australian Microalgae. School of Plant Science: Hobart, Australia.

[7] Amascual, R.H., Panganoron, H.O., Gamba, A.M.,

et al., 2024. Water Quality Assessment of Antiao River in Samar, Philippines. Water Conservation & Management. 8(2), 227–233. DOI: https://doi.org/10.26480/wcm.02.2024.227.233

[8] Estudillo, R.A., 1984. Dinoflagellates blooms (red tide) in Maqueda bay of Western Samar. Bureau of Fisheries and Aquatic Resources, Technical Papers series. 7(1), 8.

[9] Poquita-Du, Rosa Celia & Todd, Peter. (2015). Understanding Harmful Algal Bloom (HAB) Occurences in Manila Bay, Philippines. DOI: https://doi.org/10.1142/9789814719155_0002

[10] Azanza, R.V., Taylor, F.J.R., 2001. Are *Pyrodinium* blooms in the Southeast Asian region recurring and spreading? A view at the end of the millennium. Ambio. 30, 356–364. DOI: https://doi.org/10.1579/0044-7447-30.6.356

[11] Azanza, R. V. and G. A. Benico. 2013. Toxic Alexandrium blooms in fish farming sites in Bolinao, Pangasinan. Journal of Environmental Science and Management (Special Issue). 1, 44–49.

[12] Benico, G.A., 2015. Taxonomy and toxicity of Alexandrium spp. Isolated from Northwestern and Western Philippines. Master's thesis. Marine Science Institute: Port Aransas, TX, USA.

[13] Azanza, R., Fukuyo, Y., Yap-Dejeto, L., et al., 2005. Prorocentrum minimum bloom and its possible link to a massive fish kill in Bolinao, Pangasinan, Northern Philippines. Harmful Algae. 4, 519–524. DOI: https://doi.org/10.1016/j.hal.2004.08.006.

[14] San Diego-McGlone M.L., Azanza, R.V., Villanoy, C.L., et al., 2008. Eutrophic waters, algal bloom and fish kill in fish farming areas in Bolinao, Pangasinan, Philippines. Marine Pollution Bulletin. 57, 295–301.

[15] Lum, W.M., Benico, G., Furio, E., et al., 2019. Eutrophic conditions during the 2010 fish kill in Bolinao and Anda, Pangasinan, Philippines. Journal of Environmental Management. 16, 29–35.

[16] Escobar, M.T.L., Sotto, L.P.A., Jacinto, G.S., et al., 2013. Eutrophic conditions during the 2010 fish kill in Bolinao and Anda, Pangasinan, Philippines.Journal of Environmental Management. 16, 29–35.

[17] Benico, G.A., Takahashi, K., Azanza, R.V., et al., 2018. Morphology and phylogeny of harmful dinoflagellate Takayama sp. associated the recent fish kill events in the Philippines. In Proceedings of the PICES 2018 Annual Meeting (Yokohama: North Pacific Marine Science Organization).

[18] Benico, G. A., Takahashi, K., Lum, W.M., et al., 2019. First report of Biecheleriopsis adriatica in Bolinao, Northwestern Philippines and its wide distribution in Southeast Asia and adjacent waters. Philippine Journal of Natural Sciences. 24, 34–41.

[19] Hallegraeff, G.M., Anderson, D.M., Belin, C., et al., 2021. Perceived global increase in algal blooms is attributable to intensified monitoring and emerging bloom impacts. Communications Earth & Environment. 2, 117. DOI: https://doi.org/10.1038/s43247-021-00178-8

[20] Amascual, R.H., Panganoron, H., Gamba, A., et al., 2023. Physicochemical and microbiological attributes of dried anchovies (*Stolephorus commersonnii*) in the formation of histamine along the supply chain. Italian Journal of Food Safety. 12(3), 11319. DOI: https://doi.org/10.4081/ijfs.2023.11319

[21] Amascual, R.H., Panganoron, H.O., Irene, E.A., et al., 2020. Histamine profile of dried-salted fish sold in local supermarkets of Samar, Philippines. Italian Journal of Food Safety. 9(1), 8322. DOI: https://doi.org/10.4081/ijfs.2020.8322

[22] Anderson, D.M., Glibert, P.M., Burkholder, J.M., 2002. Harmful algal blooms and eutrophication: Nutrient sources, composition, and consequences. Estuaries. 25, 704–726. DOI: https://doi.org/10.1007/BF02804901

[23] Omura, T., Iwataki, M., Valeriano, B., et al., 2012. Marine Phytoplankton of the Western Pacific. Nippon Suisan Gakkaishi (Japanese Edition). 79(3), 486–488. DOI: https://doi.org/10.2331/suisan.79.486

[24] Matsuoka, K., Fukuyo, Y., 2000. Technical Guide for Modern Dinoflagellate Cyst Study. Morphology and molecular phylogeny of the harmful raphidophyte Chattonella subsalsa isolated from Bolinao, Philippines. Philippine Journal of Natural Sciences. 24, 50–56. DOI: https://doi.org/10.13140/RG.2.2.34697.08801

[25] Guiry, M.D., Guiry, G.M., 2019. AlgaeBase. World-Wide Electronic Publication, National University of Ireland: Galway, Ireland. Available from: http://www.algaebase.org (cited 21 September 2024).

[26] Renaud, S., Thinh, L.V., Lambrinidis, G., et al., 2002. Effect of temperature on growth, chemical composition and fatty acid composition of tropical Australian microalgae grown in batch cultures. Aquaculture. 211(1–4), 195–214. DOI: https://doi.org/10.1016/S0044-8486(01)00875-4

[27] Ravelo, S.F., Yap-Dejeto, L.G., Silaras, M.L.S., et al., 2022. A Snapshot on the Distribution of Coastal Dinoflagellate Communities in Five HAB-Affected Bays in Eastern Visayas, Philippines. Frontiers in Marine Science. 9. DOI: https://doi.org/10.3389/fmars.2022.730518

[28] Berge, T., Daugbjerg, N., Andersen, B., et al., 2010. Effect of lowered pH on marine phytoplankton growth rates. Marine Ecology Progress Series. 416,

79–91. DOI: https://doi.org/10.3354/meps08780

[29] Ramaraj, R., Tsai, D., Chen, P.H., 2010. Algae growth in natural water resources. Journal of Soil and Water Conservation. 42, 439–450.

[30] Sridhar, R., Thangaradjou, T., Kumar, S.S., et al., 2006. Water quality and phytoplankton characteristics in the Palk Bay, southeast coast of India. Journal of Environmental Biology. 27(3), 561–566.

[31] Thomas, W.H., 1969. Phytoplankton nutrient enrichment experiments off Baja California and in the eastern equatorial Pacific Ocean. Journal of the Biological Board of Canada. 26, 1133–1145. DOI: https://doi.org/10.1139/f69-104

[32] Mallin, M.A., Corbett, C.A., 2006. How hurricane attributes determine the extent of environmental effects: multiple hurricanes and different coastal systems. Estuaries Coast. 29, 1046–1061. DOI: https://doi.org/10.1007/BF02798667

[33] Sommer, U., 1988. Some size relationships in phytoflagellate motility. In: Jones, R.I., Ilmavirta, V. (eds). Flagellates in Freshwater Ecosystems. Developments in Hydrobiology, vol 45. Springer, Dordrecht, The Netherlands. pp. 125–131. DOI: https://doi.org/10.1007/978-94-009-3097-1_10

[34] Smayda, T.J., 1980. Phytoplankton species succession. In: Morris, I. (ed.). The physiological ecology of phytoplankton. Blackwell Scientific Publ.: Boston, USA. pp. 493–570.

[35] Smayda, T.J., 1990. Novel and nuisance phytoplankton blooms in the sea: evidence for a global epidemic. In: Graneli, E., Sundstrom, B., Edler, L., et al. (eds.). Toxic marine phytoplankton. Proceedings of the 4th International Conference on Toxic Marine Phytoplankton; 26–30 June 1989; Lund, Sweden. Elsevier: New York, NY, USA. pp. 29–40.

[36] Estrada, M., Berdalet, E., 1997. Phytoplankton in a turbulent world. Scientia Marina. 61(1), 125–140.

[37] Yñiguez, A.T., Lim, P.T., Leaw, C.P., et al., 2021. Over 30 years of HABs in the Philippines and Malaysia: what have we learned? Harmful Algae. 102, 101776. DOI: https://doi.org/10.1016/j.hal.2020.101776

[38] Baula, I., Azanza, R., Fukuyo, Y., 2011. Dinoflagellate cyst composition, abundance and horizontal distribution in Bolinao, Pangasinan, Northern Philippines. Harmful Algae. 11. DOI: https://doi.org/10.1016/j.hal.2011.07.002.

[39] Folio, F.P., Yap-Dejeto, L.G., 2021. Phytoplankton Composition during a Period of the Red Tide Bans in 2017 in Irong-Irong Bay, Western Samar, Philippines. Philippine Journal of Science. 151(S1), 237–253. DOI: https://doi.org/10.56899/151.S1.16

[40] Stirling, G., Wilsey, B., 2001. Empirical Relationships between Species Richness, Evenness, and Proportional Diversity. The American Naturalist. 158, 286–299. DOI: https://doi.org/10.1086/321317

[41] Nassar, M., Gharib, S., 2014. Spatial and temporal patterns of phytoplankton composition in Burullus Lagoon, Southern Mediterranean Coast, Egypt. The Egyptian Journal of Aquatic Research. 40(2), 133–142. DOI: https://doi.org/10.1016/j.ejar.2014.06.004

[42] Llebot, C., Sole, J., Delgado, J., et al., 2011. Hydrographical forcing and phytoplankton variability in two semi-enclosed estuarine bays. J. Mar. Syst. 86(3–4), 69–86.

[43] Margalef, R., 1980. La diversidad. In: Margalef, R. (ed.). Ecologia. Omega: Barcelona, Spain. pp. 359–382.