Physico-chemical water quality characteristics and phytoplankton community in Cayanga River, Dagupan City, Pangasinan, Philippines

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Abstract. Oyster farming in the Philippines is an important livelihood in many coastal communities and the most popular and commercially desirable among oyster species is *Magallana bilineata* (Roding, 1798). Good water quality is indispensable to the growth of oyster larvae. However, there has been little information about the nursery culture of *M. bilineata* or about the environmental factors, specifically the physico-chemical water parameters that influence its growth. This study aims to assess the physico-chemical water parameters and the diversity and abundance of phytoplankton affecting the growth of *M. bilineata* larvae in the Cayanga River in Dagupan City, Pangasinan, Philippines. Water samples were analyzed at BFAR-NFDC's Environmental Monitoring Unit. Samples were preserved for three days, concentrated, and examined under an inverted microscope. Phytoplankton were identified using literature guides, and abundance was calculated following Boyd & Linchktoppler (1979). The physico-chemical water quality parameters of Cayanga River indicated that there were no statistically significant differences in the environmental parameters among the stations, suggesting a uniformity in the environmental conditions across the study area. The majority of physico-chemical parameters were within the desirable range for the growth of phytoplankton species and *M. bilineata* larvae. Three phytoplankton phyla were identified: Bacillariophyta (diatoms), Cyanophyta (blue-green algae), and Dinophyta (golden-brown algae), with Bacillariophyta being the most abundant (78-95%). The genus *Chaetoceros* was the most abundant (24.36-30.88%). Phytoplankton diversity was moderate, with a Shannon-Wiener index of 2.5-2.99. Collection time significantly affected oyster larval stages, indicating that the spatfall season was important for the abundance of oyster larvae.
Key Words: environmental factors, larvae growth, *Magallana bilineata*, oyster farming.

Introduction. Oyster farming is one of the most profitable industries in Southeast Asia (Besana et al 2019). Oysters are both an excellent source of income and a cheap supply of nourishment (Besana et al 2019). Their accessibility to low-income segments of society places them among the most in-demand bivalves in local markets (Besana et al 2019). In the Philippines, four species of oysters are cultured: *Crassostrea iredalei* [Faustino 1932; accepted name *Magallana bilineata* (Roding 1798)], *C. malabonenis*, *C. palmipes* and *Saccostrea cucullata* (Lovatelli 1988; Samsin 1988). The most popular and commercially desirable among these is the slipper-shaped oyster *Magallana bilineata* (Roding 1798), which grows at a faster rate to a larger size and has a straight shell margin making it easier to open (Lebata-Ramos et al 2021). As filter feeders, oysters are important ecosystem engineers reducing water turbidity, phytoplankton biomass, and suspended solids (Chang et al 2016).

However, despite the importance of *M. bilineata* in the livelihood of the fisherfolk in the country, publication on this oyster species in the Philippines has been very limited. There is no published literature on the nursery culture of *M. bilineata* in Pangasinan, a province in Ilocos Region of Northern Luzon, the chief island of the Philippines. Moreover, there is limited work that has been carried out on the physico-chemical water quality characteristics and plankton abundance and diversity in Cayanga River. This study aims to assess the environmental factors, particularly the physico-chemical water parameters, and to determine the diversity and abundance of phytoplankton that influence the growth and development of *M. bilineata* larvae in the Cayanga River in Dagupan City, Pangasinan, Philippines. This study may serve as primary information about the potential effects of physico-chemical water quality parameters and plankton abundance on the availability of *M.*

bilineata larvae in Cayanga River. Since physico-chemical water parameters can influence the growth of oyster larvae and the abundance of plankton in the river, this research could serve as a starting point for farmers and agencies to produce good quality oyster larvae stocks.

Material and Method

Description of the study site. The study was conducted at Cayanga River, a major river in the province of Pangasinan, a province in Ilocos Region of Northern Luzon, Philippines (Figure 1). It is located along the southern part of the Municipality of San Fabian (16.1132°N, 120.37701°E), which drains into Lingayen Gulf (wikimapia.org). Its major tributaries include Angalacan River and Bued River. Elevation at these coordinates is estimated at 5.7 m above mean sea level. The river is 6.53 km long and 140.2 m wide (Bandojo & Rosario 2021). The river is situated close to the localities of Bonuan Binloc, Tamiong, Sagud-Bahley and Longos. Cayanga is a barangay in the municipality of San Fabian, in the province of Pangasinan. Its population, as determined by the 2020 census, was 4735 (PhilAtlas.com). This represented 5.42% of the total population of San Fabian (PhilAtlas.com). The main uses of Cayanga River are water supply for agriculture, fisheries, and recreational activities (fishing, sailing, etc.).

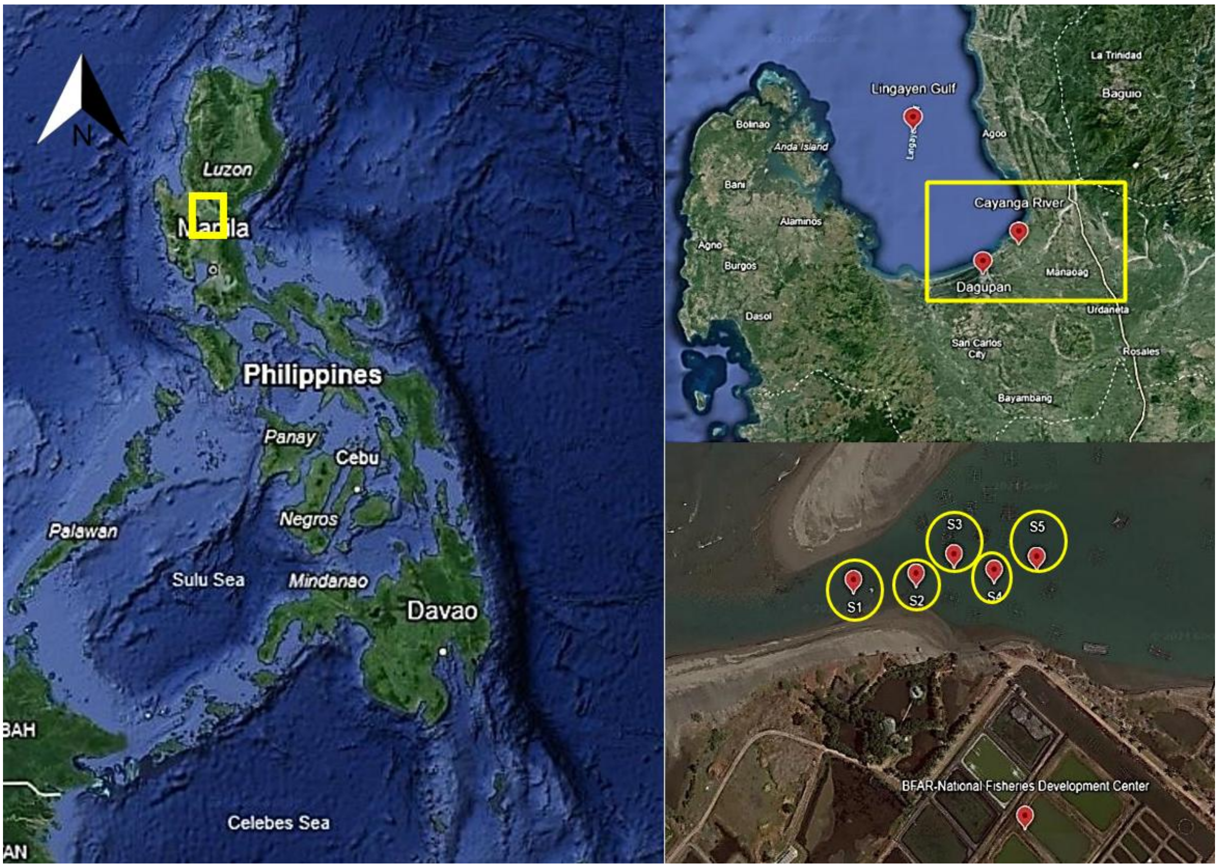

Figure 1. The location of Cayanga River, Dagupan City, Pangasinan, Philippines (map generated using Google Earth).

Sampling stations. A total of five sampling stations were selected on the Cayanga River. The stations had a distance of 20 m between them, starting from the river mouth. A handheld Global Positioning System (GPS) was used to record the exact location of the collection sites. Each sampling station was replicated thrice. The sampling site was situated in the upper part of the river water, near the river mouth, where the oyster nursery site was located. Table 1 shows the GPS coordinates of the sampling stations.

Table 1

Location of the five sampling stations in Cayanga River, Dagupan City, Pangasinan, Philippines

Station	*Location*	*Distance from river mouth (m)*
1	N16°26.10''51' E120°43.20"08'	0
2	N16°46.15''23' E120°52.10"08'	20
3	N16°56.30''51' E120°53.20"08'	40
4	N16°06.10''51' E120°45.04"08'	60
5	N16°36.40''51' E120°43.02"08'	80

Collection of water samples. The sampling period was conducted in July, 2022 in Cayanga River, adjacent to the Bureau of Fisheries and Aquatic Resources, National Fisheries Development Center (BFAR-NFDC). In each station, collection of water sample for phytoplankton and *M. bilineata* was done separately and in triplicate in every station. A plankton net with 48 μm mesh size was towed vertically to the water surface. The net-filtered water for phytoplankton identification was stored in a 50 mL falcon tube and immediately preserved using 0.15 mL of Lugol's solution. Collection of *M. bilineata* larvae was made three times obtaining the larvae from surface, middle, and bottom of the river. One liter of water was collected and filtered using a plankton net. The filtered water samples were transferred into 50 mL falcon tubes with 10 % of buffered formalin for preservation. Additionally, 500 mL of water was collected in each station for water quality analyses.

Analysis of physico-chemical parameters. The analysis of water quality of the Cayanga River was done using the Horiba U-50G multiparameter equipment to measure on-site water quality parameters such as pH, temperature, salinity, and total dissolved solids (TDS). Dissolved oxygen (DO) was measured using YSI ProDO instrument. Secchi disk visibility depth (SDVD) was also determined and water depth was measured using a depth sonar. The total suspended solids (TSS) and total ammonia nitrogen (TAN) levels were analyzed at the laboratory of Environmental Monitoring Unit at BFAR-NFDC.

Phytoplankton identification and enumeration. The preserved water samples for phytoplankton were placed in a dark place for three days for the settlement of phytoplankton. Preserved samples were carefully decanted by siphoning the supernatant, leaving 10 mL of concentrate. A volume of 1 mL concentrate was dispensed into Sedgewick-rafter counting chamber. The counting chamber was placed on a clean paper towel to avoid scratching the bottom surface before placing it beneath the inverted microscope. A cover slip was slid in place to assure no air bubbles are trapped in the slides. The plankton was allowed to settle before counting. The identification of phytoplankton was guided by available literature and identification keys (Omura et al 2012). Abundance of phytoplankton was computed according to the formula from Boyd & Linchktoppler (1979).

Determination of the larval stage of oyster. At the laboratory, the sample was stirred to let the oyster larvae settle at the center. One milliliter of water was collected using a pipette and placed into a Sedgewick rafter. A stereoscope was used to count the stages of oyster larvae. *M. bilineata* larvae were classified according to their developmental stages: D-shaped (57-105 μm), early umbo (105-150 μm), medium umbo (150-235 μm), and large umbo-eyed pediveliger (>235 μm) (Pouvreau et al 2024) (Table 2).

Table 2

Developmental stages of *Magallana bilineata* larvae (Pouvreau et al 2024)

Stage	*Classification*	*Size*
Stage I	D-shaped straight hinge larvae	Shell length between 57 and 105 μm
Stage II	Early umbo evolved larvae	Shell length between 105 and 150 μm
Stage III	Medium umbo larvae	Shell length between 150 and 235 μm
Stage IV	Large umbo eyed pediveliger	Shell length >235 μm

Statistical analysis. Paleontological Statistics Software and Statistical Package for the Social Sciences (SPSS) were used to analyze the results. Variations between sampling day were compared using one-way ANOVA, followed by Tukey's post-hoc test. Significance of differences was defined at $p<0.05$. Diversity indices such as Shannon-Wiener Index, evenness and dominance were computed using Paleontological Statistics Software (PAST) version 3.21.

Results and Discussion

Physico-chemical water parameters. The mean reading of physico-chemical water parameters from the five sampling stations in Cayanga River, Dagupan City, Pangasinan are summarized in Table 3. It can be observed that temperature, DO, pH, salinity and Secchi disk visibility depth (SDVD) had no significant differences among stations. However, it could be observed that TAN values for station 1 (0.008±0.001 mg L^{-1}) and 3 (0.012±0.001 mg L^{-1}) had no significant differences, but were significantly different from the values at stations 2 (0.012±0.0006 mg L^{-1}), 4 (0.026±0.001 mg L^{-1}), and 5 (0.011±0.0006 mg L^{-1}) ($p<0.05$). On the other hand, TSS values for stations 1 (45.51±6.58 mg L^{-1}), 3 (44.82±1.19 mg L^{-1}), 4 (44.49±2.77 mg L^{-1}), and 5 (42.47±1.66 mg L^{-1}) had no significant differences, whereas the TSS value in station 2 (56.83±19.16 mg L^{-1}) was significantly different from the values in the four other stations ($p<0.05$).

These water quality parameters (temperature, dissolved oxygen - DO, pH, salinity, and SDVD) tend to be influenced by broader environmental factors, such as weather conditions, which are mostly sunny or cloudy with occasional rain. This suggests that, within the studied area, there may not be distinct variations in these physico-chemical factors across the sampling points.

TAN levels are typically influenced by organic matter decomposition and agricultural runoff. The variation across stations could be due to local pollution that either concentrates or dilutes ammonia nitrogen differently at each sampling location. Station 4, with the highest TAN levels, was receiving more pollutants from nearby agricultural and human activities, such as the use of fertilizers in nearby fish pen culture in the river.

Table 3

Mean physico-chemical water parameters in five sampling stations at Cayanga River, Dagupan City, Pangasinan, Philippines

Parameter	*Station 1*	*Station 2*	*Station 3*	*Station 4*	*Station 5*
Temperature (°C)	$30.81±1.03^a$	$30.81±1.03^a$	$30.81±1.02^a$	$30.81±1.03^a$	$30.80±1.03^a$
DO (mg L^{-1})	$5.84±0.79^a$	$5.84±0.79^a$	$5.84±0.79^a$	$5.84±0.79^a$	$5.84±0.79^a$
pH	$8.03±0.06^a$	$8.03±0.06^a$	$8.03±0.06^a$	$8.027±0.06^a$	$8.03±0.06^a$
TDS (mg L^{-1})	$24.92±8.27^a$	$24.87±8.27^a$	$24.86±8.33^a$	$24.80±8.31^a$	$24.76±8.29^a$
Salinity (ppt)	$26.25±9.54^a$	$26.20±9.45^a$	$26.16±9.49^a$	$26.11±9.46^a$	$26.05±9.43^a$
SDVD (cm)	$75.34±30.53^a$	$75.23±30.58^a$	$75.34±30.62^a$	$75.18±30.73^a$	$75.29±30.77^a$
TAN (mg L^{-1} NH_3)	$0.001±0.00^a$	$0.01±0.00^b$	$0.01±0.00^a$	$0.03±0.00^b$	$0.01±0.00^b$
TSS (mg L^{-1})	$45.51±6.58^b$	$56.83±19.16^a$	$44.82±1.19^b$	$44.49±2.77^b$	$42.47±1.66^b$

Note: DO – dissolved oxygen; TDS – total dissolved solids; SDVD – Secchi disk visibility depth; TAN – total ammonia nitrogen; TSS – total suspended solids; means±SD in rows with the same superscript have no significant differences ($p≥0.05$).

Physico-chemical water parameters of Cayanga River relative to water quality standard for water environment are presented in Table 4. The mean temperature (31.95°C) and DO level (5.84 mg L^{-1}) of the Cayanga River were slightly beyond the standard recommended by the Department of Environment and Natural Resources (DENR) Administrative Order (2016), which is 25-31°C and 5 mg L^{-1}, respectively. A temperature of 24-28°C is optimum for the growth and survival of juvenile *C. nippona* (Wang & Li 2018), whereas the larval development of *C. gigas* was highest at 27°C, while larval settlement occurred most effectively at 32°C (Rico-Villa et al 2009). Meanwhile, a DO level of at least 3.2 mg L^{-1} is necessary for oyster development, though levels of 5.5 mg L^{-1} or higher are ideal (Oesterling & Petrone 2012). Temperatures and dissolved oxygen levels slightly above the mean values were still acceptable for the growth of *M. bilineata*. Meanwhile, temperatures between 13.5 and 32°C are recommended for the growth of planktonic organisms (Buttner et al 1993). Cayanga River has parameter values within the recommended range for temperature and DO for oyster and planktonic organisms.

Table 4
Physico-chemical parameters of water in Cayanga River relative to water quality standards for River

Parameters	*Cayanga River*	*Water quality standard for River*	*References*
Temperature (°C)	31.81	25-31	DAO 2016-08
DO (mg L^{-1})	5.84	5.0	PHILMINAQ, 2007; DAO 2016-08
pH	8.03	6.5-8.5 6.5-9.0	PHILMINAQ, 2007; DAO 2016-08
TDS (mg L^{-1})	24.84	100-1000	Bhuyan et al 2020
Salinity (ppt)	26.15	18-30	US-EPA 2009
SDVD (cm)	75.26	30-45	Boyd 2004
TAN (mg L^{-1} NH_3)	0.014	0.05 0.06	DAO 2016-08 DAO 2021-19
TSS (mg L^{-1})	46.83	80	DAO 2016-08

Note: DAO – DENR Administrative Order; DO – dissolved oxygen; PHILMINAQ - Project on Mitigating Impact from Aquaculture in the Philippines; TDS – total dissolved solids; SDVD – Secchi disk visibility depth; TAN – total ammonia nitrogen; TSS – total suspended solids; US-EPA - United States Environmental Protection Agency.

The mean reading of pH (8.03) was within the recommended standard for DENR Administrative Order (2016) and PHILMINAQ (6.5-9). A pH below or above this range is detrimental to the flora and fauna in water. A pH of 7.5-8.5 is recommended to prevent acidity that can harm oysters and disrupt their shell formation (Asia Farming 2023). High pH values promote the growth of algae and results in heavy bloom (Nandan & Patel 1992). The pH values above 8 in natural water are produced by photosynthetic rates that demand more CO_2 than quantities furnished by respiration and decomposition (Dhanam et al 2016). Based upon the result, Cayanga River pH values were within the desirable range for the growth of oyster and within the limiting level for phytoplankton growth.

TDS have no set standard from DENR (2016, 2021). However, the TDS level in Cayanga River was slightly lower than in the studies of Bhuyan et al (2020) and Moran (2018). According to Bhuyan et al (2020), TDS amount of river water is between 100-1000 mg L^{-1} and according to Moran (2018), the TDS amount of seawater and brackish water is 500-30000 ppm and 30-40000, respectively. The mean TDS value of Cayanga River was 24.84 mg L^{-1}, which indicates that the river is not turbid.

The mean salinity of Cayanga River was 26.15 ppt. According to the Environmental Protection Agency (2009), salinity of the water within the estuary with a value of 18-30 ppt is referred to as polyhaline, where water is moderately saline, but less saline than sea water. This means that Cayanga River is considered polyhaline. Meanwhile, O'Connor et al (2008) reported the optimal survival of *C. iredalei* juveniles was at 30 ppt in 23°C, while Fang et al (2016) reported that eggs of *C. iredalei* developed into normal D-hinged larvae at salinities of 5 to 30 ppt and 15 to 30 ppt with a 70% survival rate.

Secchi disk visibility of the water has no set standard. However, a Secchi disk reading of more than 60 cm can be interpreted as too clear, with inadequate productivity (Boyd 2004). At lower visibility, plankton blooms may occur, lowering DO levels. Higher visibility indicates insufficient phytoplankton productivity to support higher links in the food chain. The mean Secchi disk visibility of the five stations was 75.26 cm. During the sampling period, the intensity of sunlight was high and it might have affected the visibility.

TAN and TSS of Cayanga River were 0.014 and 46.83 mg L^{-1}, respectively. These readings were within the standard recommended levels of 0.05 mg L^{-1} and 0.06 mg L^{-1} (DENR 2016) and 80 mg L^{-1} (DENR 2016), respectively. The TAN value of Cayanga River was tolerable for oyster and other aquatic organisms. Oysters can also regulate phytoplankton community structures and reduce the concentration of nitrogen by filtering phytoplankton and suspended nutrients, having a positive influence on improving water quality and the health of the aquatic ecosystem (Jiang et al 2020). Meanwhile, the TSS value of Cayanga River could have been affected by the weather conditions during the conduct of this study.

Based upon the classification of the DENR, Cayanga River belongs to Class C, which is intended for propagation and growth of fish and other aquatic resources and for boating.

Abundance of phytoplankton. Three phyla of phytoplankton were identified in the five sampling stations in the Cayanga River, and these belong to the phyla Bacillariophyta (diatoms), Cyanophyta (blue-green algae), and Dinophyta (dinoflagellates) (Table 5). Phylum Bacillariophyta had the highest mean abundance of 4.70±6.35 ind mL^{-1}, followed by Dinophyta, with 3.48±3.46 ind mL^{-1}. Phylum Cyanophyta had the lowest mean abundance, of 1.56±1.21 cells mL^{-1}. Phylum Bacillariophyta was the most abundant in all stations, from 1 to 5, with the values of 4.76±7.76, 4.76±6.6, 4.68±6.85, 4.69±5.73, and 4.60±5.22 ind mL^{-1}, respectively.

Bacillariophyta (diatoms) is the dominant group across all stations, with the highest abundance. The abundance stays relatively consistent across the five stations, indicating that these diatoms are well-distributed in the Cayanga River. Dinophyta (Dinoflagellates) ranks second in abundance overall, with an average of 3.48±3.46 cells mL^{-1}, lower than Bacillariophyta, but still present in all stations. However, the standard deviation is also significant, suggesting some variability in the distribution of dinoflagellates across stations. Cyanophyta (blue-green algae) shows the lowest mean abundance of 1.56±1.21 cells mL^{-1}, which may indicate that they are less dominant in the river environment compared to the other two groups.

The dominance of Bacillariophyta could be a result of their high tolerance to chemicals and nutrients, nitrates, phosphates, and other metals (Çelekli & Külköylüoğlu 2007). Diatoms react rapidly to environmental changes by shifting their community composition due to eutrophic conditions (Case et al 2008). The dominance of diatoms may be attributed to the nutrients in Cayanga River. Additionally, diatoms are mainly found in shallow waters, such as rivers, due to their size and sinking rate (Karthik et al 2012). Fertilizer runoff in the Cayanga River, resulting from human activities such as the application of fertilizer in fish pens, can lead to a higher abundance of diatoms. This process is known as eutrophication, which occurs when excess nutrients, such as nitrogen and phosphorus (commonly found in fertilizers), enter the river water. The high availability of nutrients from fertilizers can stimulate the growth and reproduction of diatoms. Variation in the abundance of phytoplankton in the sampling stations of Cayanga River could be affected through human activities such as household waste discharge in the water, feeds given to cultured milkfish and trevallies and agricultural inputs like fertilizer that could have contributed to the growth of Bacillariophyta in all sampling stations.

The phylum Cyanophyta had the lowest abundance in the five sampling stations. Cyanobacteria have been recognized as a major symptom of eutrophication in fresh water, as their blooms are prevalent in waters affected by cultural nutrient enrichment (Reynolds 1984; Moss 1998). The lowest abundance of Cyanophyta may be a good sign, because it is generally considered harmful in aquatic environments, particularly when it leads to eutrophication or water contamination.

Chaetoceros, under the phylum Bacillariophyta, was the most abundant genus identified, accounting for 24.36% to 30.88% of the population. *Chaetoceros* is one of the largest marine planktonic diatom genera, comprising species with cosmopolitan distributions as well as some with more limited distributions (Li et al., 2013).

Table 5
Abundance of phytoplankton phyla in Cayanga River, Dagupan City, Pangasinan, Philippines

	Abundance (ind mL^{-1})					
Phylum	*Station 1*	*Station 2*	*Station 3*	*Station 4*	*Station 5*	*Mean±SD*
Bacillariophyta	4.76±7.05	4.76±6.60	4.68±6.85	4.69±5.73	4.60±5.52	4.70±6.35
Cyanophyta	0.88±0.54	0.64±0.98	1.12±0.41	3.08±2.11	2.12±2.02	1.56±1.21
Dinophyta	3.38±3.85	3.44±3.83	3.67±3.20	3.12±2.56	3.78±3.86	3.48±3.46

Diversity indices of phytoplankton. In all water samples observed from the five sampling stations, 22 genera of phytoplankton were identified, representing four phyla: Bacillariophyta (with 17 genera), Cyanophyta (1 genus), and Dinophyta (4 genera) (Table 6). Phylum Bacillariophyta was the most abundant in all sampling stations comprising 78-95% of the phytoplankton present, followed by phylum Dinophyta (5-23%) and phylum Cyanophyta (0.2-6%).

Table 6
Phytoplankton taxa found in Cayanga River, Dagupan City, Pangasinan, Philippines

No	*Taxa*	*Genus*
1	Bacillariophyta	*Pinnularia*
2		*Chaetoceros*
3		*Skeletonema*
4		*Thalassiosira*
5		*Nitzschia*
6		*Bacteriastrum*
7		*Synedra*
8		*Pseudosolenia*
9		*Rhizosolenia*
10		*Navicula*
11		*Asterionella*
12		*Aulacoseira*
13		*Asterionellopsis*
14		*Coscinodiscus*
15		*Pseudonitzschia*
16		*Thalassionema*
17		*Melosira*
18	Cyanophyta	*Anabaena*
19	Dinophyta	*Noctiluca*
20		*Ceratium*
21		*Protoperidinium*
22		*Pyrocystis*

The diversity indices such as Shannon-Wiener index (H'), evenness and dominance index are presented in Table 7.

Table 7
Diversity index of phytoplankton phyla in five sampling stations in Cayanga River, Dagupan City, Pangasinan, Philippines

		Diversity index		
Phylum	*Station*	*H'*	*J'*	*D*
Bacillariophyta	1	2.308	0.0558	0.1707
	2	2.372	0.5954	0.1567
	3	2.325	0.5679	0.1681
	4	2.449	0.6429	0.134
	5	2.487	0.6682	0.1311
Dinophyta	1	0.9392	0.6395	0.4937
	2	0.9111	0.6218	0.4822
	3	1.111	0.7592	0.3923
	4	1.149	0.7884	0.3757
	5	1.048	0.7132	0.4452

Note: H' – Shannon-Wiener diversity index; J' – evenness index; D – dominance index.

H' was higher in Station 5 (H'=2.742) and Station 4 (H'=2.721). The lowest value for H' was recorded in Station 1 (H'=2.548) and Station 2 (H'=2.594). Diversity indices computed for Cayanga River can be categorized as moderate (2.64) in terms of species diversity, where values <1.99 were considered very low, 2 to 2.49 were low, 2.5 to 2.99 were moderate, 3 to 3.49 were high and >3.5 were very high (Fajardo et al 2022). If the value of dominance is approaching 1, it indicates that a species tends to dominate in the stations. In this study, the highest value of dominance (D) was in Station 1 (D=0.1342), in which *Chaetoceros* was the most abundant. On the other hand, station 5 attained the lowest calculated value (D=0.10003). Evenness was highest in Station 5 (J'=0.6744) and lowest in Station 1 (J'=0.5555). The calculated diversity of phytoplankton phyla in all sampling stations is presented in Table 8. The H' value of Bacillariophyta in all stations ranged from 2.308 to 2.487, while for Dinophyta it ranged from 0.9111 to 1.149. Bacillariophyta could be categorized as low in terms of diversity, because the highest diversity computed was H'=2.487 in Station 5. Low values of J' ranging from 0.0558 to 0.6682 were calculated in five sampling stations for Bacillariophyta, and in two sampling stations for Dinophyta (Stations 1 & 2). Meanwhile, calculated D value in all stations ranged from 0.1311 to 0.4937. The overall calculated diversity of the river, with a Shannon Index of 2.64, places it within the moderate diversity range. The evenness value of 0.6112 and the dominance value of 0.1176 indicate a fairly uniform distribution of phytoplankton genera across the river, without any particular genus dominating, which reflects a healthy and diverse ecosystem.

Table 8
Overall diversity index of phytoplankton in five stations in Cayanga River, Dagupan City, Pangasinan, Philippines

	Diversity index		
Station	*H'*	*J'*	*D*
1	2.548	0.5555	0.1342
2	2.594	0.5819	0.124
3	2.597	0.5837	0.1277
4	2.721	0.6605	0.1023
5	2.742	0.6744	0.10003
Overall	2.6404	0.6112	0.1176

Note: H' – Shannon-Wiener diversity index; J' – evenness index; D – dominance index.

Larval stages of oyster. The overall number of oyster larvae observed in the five sampling stations is presented in Table 9. Three larval stages were observed: early umbo evolved larvae (105-150 μm), medium umbo larvae (150-235 μm), and large umbo-eyed pediveliger

(≥235 μm). The highest count of larvae was in the large umbo-eyed pediveliger stage, in Station 1 (22 ind mL^{-1}), followed by the medium umbo (12 mL^{-1}). Among the five sampling stations, Station 1 had the highest number of larvae counted from stages II to IV. Station 1 was situated near the river mouth, where oysters are usually found.

The peak and natural spatting season of oyster usually occurs from January to February and from May to September (Brosas 2022). This study was conducted in July, when spat collectors are deployed in the river. High number of oyster larvae found on large-umbo pediveliger (stage IV) indicates that, during this month, the dominant life stage of oyster larvae is close to settling and searching for a suitable substrate.

Table 9

Slipper-shaped oyster (*Magallana bilineata*) larvae in five sampling stations in the Cayanga River, Dagupan City, Pangasinan, Philippines

	M. bilineata larvae (ind mL^{-1})			
Station	*57-105*	*105-150*	*150-235*	*≥235*
1	1	8	12	22
2	3	5	8	15
3	5	3	6	10
4	2	6	8	8
5	0	2	4	2

Conclusions. The physico-chemical water parameters of Cayanga River were generally within acceptable ranges for aquatic life, with slight deviations from ideal values for temperature and DO still being tolerable for organisms like oysters and plankton. The river's water quality conforms to the standards set by the Department of Environment and Natural Resources (DENR), being classified as Class C water, suitable for aquatic resource propagation.

Bacillariophyta (diatoms) was the most abundant phytoplankton group, with consistent abundance across stations, likely influenced by nutrient-rich conditions, such as agricultural runoff, leading to eutrophication. Cyanophyta (blue-green algae) had the lowest abundance, which could be a positive sign, as their blooms often indicate water quality problems. Diversity indices indicated moderate species diversity in the river, with a relatively even distribution of phytoplankton genera, suggesting a healthy and balanced ecosystem.

Furthermore, notable abundance of oyster larvae, particularly near the river mouth, indicates that the river supports oyster reproduction. The presence of large umbo-eyed pediveliger larvae suggests that the river is an important breeding ground during the study period, aligning with the peak oyster spatting season.

Overall, while there are localized variations in certain parameters, Cayanga River exhibits a generally favorable environment for aquatic life, with specific attention needed for managing local pollution sources to maintain its ecological health and support the growth of oysters and other marine organisms.

For further studies, it is suggested to assess other biological parameters of water, such as fecal coliform, macroinvertebrates, and fish, and to extend the duration of data collection in order to determine the variation in the water parameters over time, which will provide a more comprehensive understanding of the ecological health and quality of the Cayanga River.

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