MALAYSIAN JOURNAL OF SCIENCE
MJS
ISSN 1394-3065

Regular Issue

Malaysian Journal of Science 45(1): 17-26 (March 2026) https://mjs.um.edu.my

Diversity of Phytoplankton in The Mangrove Area of Kerteh River: A Preliminary Study

Nurul Nadhirah Zulkafli[1a], Nurul Shahida Redzuan[2a]*, Monaliza Mohd-Din[3a] and Nadiah Wan Rasdi[4bc]

Abstract: Mangroves, which are among the world's most productive ecosystems, harbour thousands of species of phytoplankton. Phytoplankton are microorganisms that provide essential ecosystem services within mangrove ecosystems. This ecosystem is currently under threat for various reasons. A study was conducted in a mangrove ecosystem along the Kerteh River, Terengganu, which is experiencing metal pollution due to rapid industrialisation. This pollution has a strong potential to directly affect the species composition, occurrence, and abundance of phytoplankton. Therefore, this study aimed to determine the spatial diversity of phytoplankton species at three stations along the Kerteh River, selected for their exposure to anthropogenic activities. A single sampling event was conducted for two days in August 2019. The study recorded 56 phytoplankton species from four divisions: Bacillariophyta (45 species), Chlorophyta (4 species), Dinophyta (6 species), and Cyanophyta (1 species). Phytoplankton diversity, measured by the Shannon-Weiner index (H'), ranged from 2.60 to 3.0, and equitability (J'), measured by Pielou's evenness index, ranged from 0.75 to 0.80. A one-way analysis of variance (ANOVA) indicated a significant difference in phytoplankton diversity among stations ($p < 0.05$). *Chaetoceros curvisetus* had the highest relative abundance at Stations 1 and 3, while *Frustulia vulgaris* was most abundant at Station 2. Five Dinoflagellate species were recorded at the study site: *Ceratium* sp., *Dinophysis* sp., *Protoperidinium pallidum*, and *Protoperidinium* sp. 1 and sp. 2. This preliminary record of phytoplankton species in the Kerteh River sheds light on the impact of the shift caused by current and emerging anthropogenic activities in the area.

Keywords: *Phytoplankton, mangroves, diversity, Kerteh River.*

1. Introduction

Mangroves are a conducive habitat for phytoplankton, the underrated phylogenetically diverse producers. These microscopic producers are mostly diatoms of the division Bacillariophyta, green algae of the division Chlorophyta, and Cyanobacteria. Ecologically, phytoplankton can be sampled in the water column, mediating numerous ecosystem functions, such as contributing to overall ecosystem productivity (Janousek, 2005). The mangrove ecosystem is known to accommodate higher phytoplankton than the estuarine system (Rajkumar et al., 2009). In turn, phytoplankton aid mangroves in playing their vital roles in servicing the ecosystem.

Phytoplankton inhabiting the mangrove system can be considered extremophiles, as they withstand the ecosystem's unique conditions. These microscopic extremophiles are not only able to adapt in the low dissolved oxygen of the ecosystem but also able to tolerate exposure to tidal cycles, limited sunlight (Graham & Wilcox, 2000), and variable salinity levels (Owen et al., 2004; Stanković et al., 2024).

Frequently, studies on mangrove ecosystems focus on the overall groups of microalgae, including benthic (Jeslin et al., 2021), epiphytic (Chen et al., 2010), and suspended microalgae (also known as phytoplankton) (Saravanakumar et al., 2008; Hilaluddin et al., 2020). The mangrove ecosystem receives notable nutrients from terrestrial runoff, which may have led to greater attention to the relationship between phytoplankton occurrence in the system and physico-chemical parameters (Tanaka & Choo, 2000). The terrestrial runoff that intensifies domestic discharge or anthropogenic influence (Saravanakumar et al., 2008; Manna et al., 2010) consequently channels into the ecosystem. The additional nutrients will concentrate the already highly nutrient-enriched ecosystem originating from decomposing mangrove litter fall, which is consequently at high risk of causing eutrophication (Tanaka & Choo, 2000; Perumal et al., 2009; Xu et al., 2022).

Most research carried out on phytoplankton in mangrove areas has reported diatoms (Bacillariophyta) as the most abundant division in the ecosystem. Kamal et al., (2022) recorded four phytoplankton divisions in the tropical mangrove estuarine of the South China Sea, which comprised the Bacillariophyta, Cyanophyta (Cyanobacteria), Chlorophyta, and Chrysophyta. *Coscinodiscus*, the pennate diatom of Bacillariophyta, was with the highest total density at the research area. The species was the primary phytoplankton recorded in both wet and intermediate seasons. There was, however, a notable difference in species composition between the three seasons. Centric diatoms, *Pleurosigma normanii* recorded to be was the dominant species in wet season. On the other hand, the intermediate season showed a high abundance of Coscinodiscus lineatus, which is classified in the centric diatom group. However, phytoplankton of the division Bacillariophyta were commonly reported as the highest species richness across the three seasons, while cells of

Authors information:
[a]Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, MALAYSIA. E-mail: nadiyzz19@gmail.com[1]; nurulshahida@umt.edu.my[2]; monalizamd@umt.edu.my[3]
[b]Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, MALAYSIA. E-mail: nadiah.rasdi@umt.edu.my[4]
[c]Institute of Tropical Biodiversity and Sustainable development, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, MALAYSIA. E-mail: nadiah.rasdi@umt.edu.my[4]
*Correspondence: nurulshahida@umt.edu.my

Received: November, 2024
Accepted: January, 2025
Published: March, 2026

DOI:https//doi.org/10.22452/mjs.vol45no1.3
Malaysian Journal of Science 45(1): 17-26 (March 2026)

Dinophysis caudata of the Dinoflagellate were recorded with the highest density in the dry season.

Mangrove sediments are responsible for holding nutrients and for significant nutrient cycling pathways, which promote coastal development along mangrove ecosystems (Saifullah et al., 2016). In addition, refractive materials such as humic acid, which abound in mangroves, promote the growth of phytoplankton (Xu et al., 2022). Tanaka & Choo (2000) conducted a study of mangrove phytoplankton in Matang Mangrove Estuary in Malaysia. The study, which primarily focused on the influence of nutrient availability and tidal variations, also documented monospecies blooms driven by increased nutrient availability during spring tides. Nutrients containing concentrated phosphate were shown to influence Dinoflagellates, such as *Ceratium kofoidii*, to dominate the Matang mangrove ecosystem. In a more recent study in the Matang Mangrove ecosystem, Hilaluddin et al. (2020) reported the alterations in phytoplankton species composition structures attributed to reduced mangrove vegetation, aquaculture, and human settlements, which directly shift mainly the chemical parameters of the mangrove ecosystem.

Studies on phytoplankton in the mangrove environment generally examine the effects of monsoon-related nutrient inputs. Some research discussed that phytoplankton abundance decreased during monsoon months because the mangrove's water column is highly turbid, largely stratified, with variedly lower salinity temperature, and pH (Rajkumar et al., 2009; Redzuan & Milow, 2021). A study that was done on phytoplankton at Pahang Estuary by Chowdhury et al. (2011) indicated that the phytoplankton community during the monsoon was quite diverse and dominant during the non-monsoon season.

The Kerteh Mangrove Forest is described as a mangrove estuary as it receives inflow of seawater from the South China Sea as well as fresh water from the Kerteh River. Nutrients in mangrove estuaries provide ideal conditions for phytoplankton productivity. These nutrients, together with environmental factors altered by pollution, urbanization, industrialization, anthropogenic activities, and climate change, largely affected the species composition, distribution, and also the abundance of phytoplankton (Ajibare et al., 2019). In 2014, Kerteh and Paka River were strongly impacted by major effluent from municipal and industrial outflows post-flood (Azaman et al., 2017), which potentially contributed to the active development of chemical manufacturing industries, such as the oil and gas industries. In addition, petroleum plants, agricultural areas, fishery areas, and residential areas near the Kerteh River have high potential to contribute to heavy metal pollution in the river (Yaakob et al., 2017). According to Azaman et al. (2017), the Kerteh River had significant concentrations of metals such as Cadmium, Copper, Zinc, Cobalt, Nickel, Arsenic, Chromium, and Lead. Thus, metal pollution significantly affected the structure of marine and freshwater ecosystems, particularly phytoplankton, thereby reducing community diversity and species richness (Utami et al., 2019).

With regards that mangrove ecosystem of Kerteh River is facing threat due to rapid industrial growth and development of adjacent terrestrial areas, and the fact that the ecosystem is also exposed to natural shift due to climate change, frequent storm and rise of sea level, this present study was set to create a checklist on the species composition of phytoplankton at selected areas of Kerteh River mangrove ecosystem. Although the collected and presented data are from a one-off sampling occasion, this preliminary work can hopefully serve as an initial step toward more comprehensive biomonitoring in the future. Related data on the distribution, with integration of abundance, species richness, and phytoplankton composition, with respect to any patterns, are crucial for determining the condition of the ecological structure and functioning of the Kerteh River mangrove. Findings of this study, even preliminary, can also aid future management of the Kerteh River and conservation efforts for the river's mangrove area and its associated organisms.

2. Methodology

Study Area

Kerteh River, which lies on the grid of '4°31'37.4" N 103°26'40.0"E', was the study area for this preliminary study, which lies in the district of Kemaman, Terengganu, Malaysia (Figure 1). Kerteh is part of the Kemaman watershed with highly varied land use. According to the United Nations Department of Economic and Social Affairs (2019) in World Population Review, the estimated population of Kerteh is 24,401, with a total area of 256 km². Kerteh is often referred to as a district in Malaysia that is a complex of oil and gas-related industries and landing facilities. Being one of the main outlets of the Kemaman watershed, the Kerteh River receives downstream flows from the Batu Putih and Rangon Rivers. There are more than 30 species of mangrove in the Kerteh River. Based on the EcoCare Environmental Education Centre website, the common species that can be observed there are *Rhizophora apiculata, R. mucronata, Sonneratia alba, Bruguiera parviflora, Avicennia alba,* and *Nypa fruticans.* Therefore, it is worth noting that the Kertih River is also important in mitigating the effects of coastal erosion initiated by the annual monsoon and the rise in sea level. In October 2005, the Kerteh River Mangrove Rehabilitation Project was launched by the Malaysian Nature Society (MNS) through the ecoCare Environmental Education Centre (ECC). This project aims to rehabilitate and replant the mangrove ecosystem along the Kerteh River. EcoCare is the first environmental education centre in the East of Peninsular Malaysia that serves as a resource centre with facilities to promote awareness and conservation among communities.

In relation to the aim of the project, three station points were selected near ecoCare, in the vicinity of the Kerteh River mangrove, based on their exposure to potential pollutants. The sites were ST1, which receives anthropogenic discharges from the adjacent village of Gelugor via a non-centralized drainage system. ST2, a station located at the site of replanted mangrove trees (Figure 1). Finally, ST3 is located adjacent to a boat parking area. All stations are also exposed to runoff or discharge from Kerteh, however, at an unknown rate.

DOI:https//doi.org/10.22452/mjs.vol45no1.3
Malaysian Journal of Science 45(1): 17-26 (March 2026)

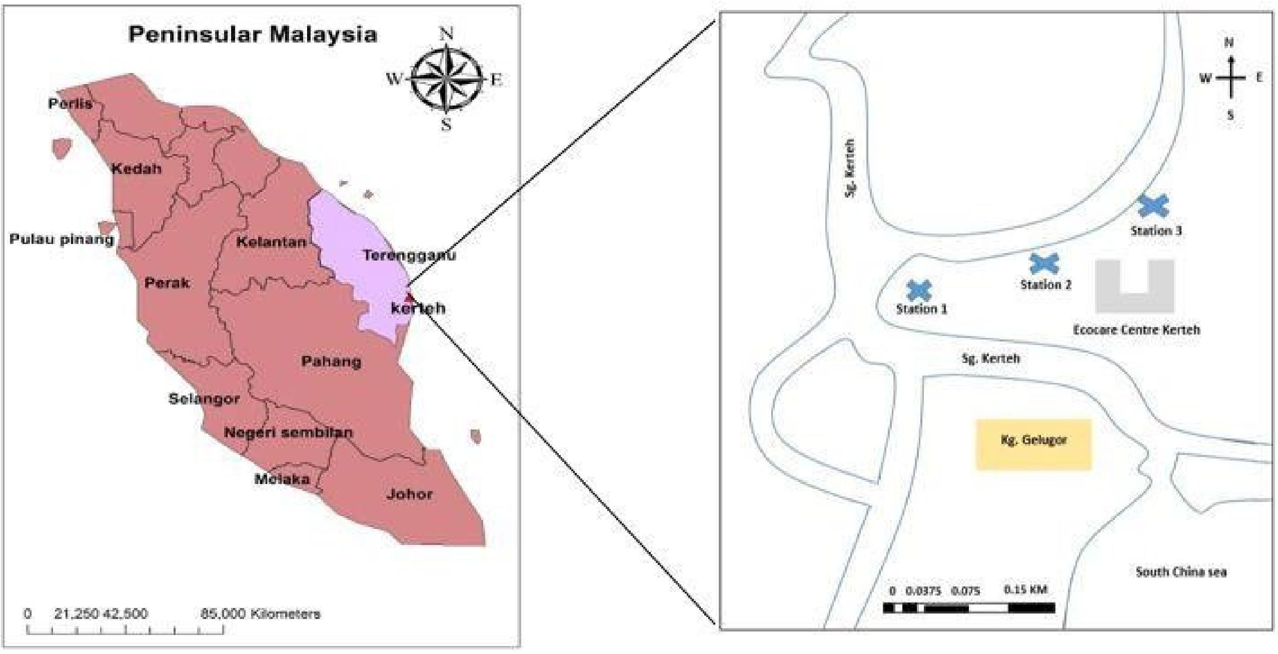

Figure 1. Location of sampling stations adjacent to the ecoCare Centre Kerteh: ST1 (4.525494°N, 103.441899°E), S2 (4.526935°N, 103.443382°E), and ST3 (4.527664°N, 103.444784°E).

Water temperature, DO, and pH at station 1 were recorded to be significantly lower than at stations 2 and 3 at $p < 0.05$. Station 2 showed a lower level of salinity than the other stations, with a salinity reading of 25.66±2.38 ppt ($p < 0.01$). The low salinity was concurrent with a low TDS at station 2. Physical parameter data were obtained in this study solely for the site characteristics record. No correlation analysis was carried out in this preliminary study to investigate the relationship between phytoplankton species diversity and the physical parameters.

Table 1. Physical water parameters at three different stations along the study site at Kerteh River. Also included the ANOVA scores of the spatial variability (n = 9).

Physical Water Parameters	Station			ANOVA SCORE
	1	2	3	
Temperature (°C)	28.90±0.01	29.30±0.18	29.68±0.54	$F_{2,9}$=4.83, p <0.05
Total dissolved solids (TDS) (g L^{-1})	28.61±1.99	26.20±2.19	28.25±2.83	$F_{2,9}$=20.41, p <0.01
Salinity (ppt)	28.31±2.18	25.66±2.38	28.18±2.76	$F_{2,9}$=16.67, p <0.01
Dissolved oxygen (DO) (mg L^{-1})	2.60±1.35	3.30±0.37	3.94±0.61	$F_{2,9}$=4.06, p <0.05
pH	5.53±0.17	5.90±0.02	6.04±0.03	$F_{2,9}$=5.94, p <0.05

Water Sampling and Physical Parameters Measurement for Site Characteristics

A one-off sampling was carried out in August 2019 for two consecutive days. Triplicate water samples were collected using a plankton net with a wire mesh of 30 µm during the high-tide period. The plankton net was towed for 10 m at approximately 10–20 cm below the water surface. Samples of filtered water containing phytoplankton were immediately transferred to 15 mL tubes, which were then preserved with 5 % formalin. The tubes were then fully wrapped in aluminium foil.

Abiotic physical water parameters, including water temperature, total dissolved solids (TDS), salinity, dissolved oxygen (DO), and pH, were measured in situ using a handheld YSI Multi-probe system (MPS) Model 556.

Phytoplankton Cells Extraction

Extraction of phytoplankton cells from water samples was done by separating the cells from water (with formalin) and suspended particles by means of centrifugation at 2300 rpm for 15 minutes. Excess formalin and distilled water, which were the supernatant, were siphoned off and discarded. Distilled water was then added to the samples (up to 0.5 cm). Phytoplankton samples in the water were concentrated and underwent frustule cleaning as the samples were centrifuged another five times at 2300 rpm for 15 minutes. The concentrated samples were retained in distilled water (up to 5 ml in the centrifuge tube) at room temperature.

DOI:https//doi.org/10.22452/mjs.vol45no1.3
Malaysian Journal of Science 45(1): 17-26 (March 2026)

Sedimentation Slides Preparation: Phytoplankton Cells Enumeration and Identification

One mL of sample was carefully pipetted into utermöhl sedimentation tube. The step was followed by the addition of 1 drop of Lugol's iodine. Sedimentation slides were prepared by following the preparation steps. by Bellinger & Sigee (2010). The abundance of phytoplankton was enumerated under a compound microscope by dividing the slides into 4 divisions. The calculation was carried out from one division to another (Evans, 1972). Only 200 phytoplankton cells were counted to represent the assemblage composition, which was expressed as relative abundance (%). Phytoplankton were identified to the lowest possible taxonomic level, either the genus or species level. The identification process was carried out by referring to taxonomic work by Redzuan (2012), Tomas (2007) and Salleh and Tajuddin (2006), by means of the phytoplankton cells' morphology, as guided in the mentioned taxonomic works.

Data Analyses

ANOVA was carried out to determine the variation in the means of the measured physical parameters between the 3 stations, using IBM SPSS Statistics 25. Species diversity of phytoplankton was analysed between stations and was investigated using the number of species or taxa S (S), Shannon Diversity Index (H'), and Pielou Evenness Index (J). The mentioned diversity indices were calculated using the Paleontological Statistics Software Package (PAST) version 4.16 (Hammer et al., 2001). Species data were pooled (n=3) to conduct the diversity analyses in PAST 4.16.

3. Results and Discussion

Phytoplankton Species Composition

Overall, a total of 56 phytoplankton species from four divisions were recorded in this one-off sampling survey. Division Bacillariophyta or the diatoms, had the highest recorded species with a total of 46 species, followed by 5 species of Dinophyta, 4 species of Chlorophyta, and finally, the Cyanophyta with a recorded S of only 1 species (Table 2). High Bacillariophyta taxa recorded in the mangrove ecosystem are well documented in most studies, such as reported by Canini et al. (2013), Saifullah et al. (2014), Fang & Sommer (2017) and Redzuan & Milow (2021).

Chaetoceros curvisetus (Figure 1a) of Bacillariophyta showed the highest abundance at Station 1 (27.08 ± 5.07) and Station 3 (8.80 ± 3.59), while at Station 2, it was *Frustulia vulgaris* with a relative abundance of 24.92 ± 3.44 (Table 2). Genus *Chaetoceros* is commonly reported to inhabit both oceanic and brackish ecosystems in the tropics. While in the temperate countries, *Chaetoceros* is reported to cause a spring bloom before the onset of summer heat. (Flynn et al., 2023; Onitsuka et al., 2018). Onset of *Chaetoceros* multi-species blooms proved to be significantly correlated to nitrate, phosphate, and temperature (Razali et al., 2015; Bosak et al., 2016; Redzuan & Milow, 2021; Mohd-Din et al., 2022). It is also reported that often, the blooms initiate as the genus increases its growth by proliferating rapidly and consequently increasing the cell numbers in a chain. (Begum et al., 2015; Shao et al., 2023).

C. curvisetus is also frequently disclosed as one of the species that causes a multispecies bloom of *Chaetoceros* spp (Fang & Sommer, 2017; Murty et al., 2017; Redzuan & Milow, 2021; Shao et al., 2023) worldwide. Interestingly, even in the multispecies blooms, numerous studies, including the present study, proved that the *C. curvisetus* was the dominant species in the blooms. (Fang & Sommer, 2017; Murty et al., 2017; Somsap et al., 2015). A number of studies reported a significant positive relationship between *C. curvisetus* and nitrate. (Begum et al., 2015) and temperature (Redzuan & Milow, 2021).

At Station 2, the significantly lower salinity and TDS of the newly replanted mangrove system, which characterized the station, possibly explained the different highest-abundance species, which was *Frustulia vulgaris* (Figure 1b). *Frustulia vulgaris,* although normally reported to inhabit the freshwater ecosystem (Odido et al., 2024), its occurrence in ocean-connected ecosystems, such as coastal rivers (Spaulding et al., 2021) and mangrove system (Redzuan & Milow, 2021) It is also well known. The species, however, has never been reported as either the dominant species or the species responsible for causing mono or multi-specific bloom in any ecosystem. Therefore, no comprehensive ecological study on this species has ever been reported.

Genus *Guinardia* showed the highest occurrence frequency, with all species of the genus present at all stations. *Guinardia* (Figure 1c) is known to be cosmopolitan and frequently reported as a dominant species in both temperate (Arsenieff et al., 2019) and tropical regions (Haridevi et al., 2022; Murty et al., 2017). Razali et al. (2022) reported that *Guinardia* sp. was the dominant species, as the species constituted 65–80% of the phytoplankton composition during a high biomass multi-species algal bloom in active aquaculture areas of the Johor Strait. *G. delicatula* blooms were reported in countries such as India, and most of the bloom events were the first report at the sites (Haridevi et al., 2022; Murty et al., 2017). Events of chain-forming species blooms in the Sub-tropical regions recorded multiple species of *Guinardia* blooms that dominated by 70 – 80 % of *Guinardia striata* (Taucher et al., 2018). Those multispecies *Guinardia* blooms, proven by Taucher et al. (2018) to closely relate to ocean acidification phenomena in the region.

Occurrence of five species of three genera from the division Dinophyta was also the highlight of this present study (Table 3) (Figure 2). Three of the five species, Ceratium sp. (Figure 2a), *Protoperidinium depressum* (Figure 2b), and *Alexandrium* sp. (Figure 2d), were present at all stations, indicating high occurrence frequency. The occurrence and distribution of harmful blooms by Dinophyta in both oceanic and estuarine ecosystems in Malaysia have been well reported by Usup et al. (2002), Lim et al. (2012), Lim et al. (2014) and Mohd-Razali et al. (2022). For example, harmful blooms involved shellfish toxin-producers *Alexandrium* species; *A. tamiyavanichii* (Usup et al., 2002; Mohammad-Noor et al., 2018; Liow et al., 2019) and *A. minutum* (Lim et al., 2012; Lau et al., 2017; Law et al., 2023); while fish killing-species caused high biomass blooms: *Margalefidinium polykrikoides*, *Noctiluca scintillans*, and *Karlodinium australe* (Lim

DOI:https//doi.org/10.22452/mjs.vol45no1.3
Malaysian Journal of Science 45(1): 17-26 (March 2026)

et al., 2012; Lim et al., 2014; Yñiquez et al., 2021; Mohd Razali et al., 2022) caused significant losses in the aquaculture industries in Malaysia. Global warming and increasing nutrient concentrations in oceanic ecosystems have been shown to stimulate the onset of harmful blooms. The three recorded species of Dinoflagellate recorded in this study were of the three genera listed as harmful taxon by Razali et al. (2015) that can either cause high biomass bloom forming water discoloration (Alvarez Dalinger et al., 2024) or shellfish toxin- producer (Ettoubi et al., 2020; Yñiguez et al., 2021).

Table 3. Abundance (in relative terms) of phytoplankton species recorded at Station 2, Station 3, and Station 4 in the chosen area of Kerteh River. The data were obtained through a one-off sampling occasion.

	Taxa	**Stations**		
	Division Bacillariophyta	**Station 1**	**Station 2**	**Station 3**
1	*Actinoptychus undulatus*	0.25 ± 0.29	*	1.02 ± 0.42
2	*Amphora* sp	*	*	0.42 ± 0.17
3	*Asterolampra* sp	*	*	0.21 ± 0.09
4	*Bacteriastrum delicatulum*	0.08 ± 0.02	*	*
5	*Bacteriastrum furcatum*	0.08 ± 0.02	*	*
6	*Bacteriastrum* sp. 1	6.67 ± 2.70	5.75 ± 3.59	2.72 ± 1.11
7	*Bacteriastrum* sp2	*	0.17 ± 0.26	*
8	*Chaetoceros constrictus*	*	0.08 ± 0.01	5.81 ± 2.37
9	*Chaetoceros curvisetus*	27.08 ± 5.07	7.50 ± 5.16	8.80 ± 3.59
10	*Chaetoceros* sp2	5.33 ± 3.75	*	2.42 ± 0.99
11	*Climacodium frauenfeldianum*	2.50 ± 0.63	0.92 ± 1.11	1.28 ± 0.52
12	*Coscinodiscus radiatus*	*	*	0.58 ± 0.24
13	*Coscinodiscus* sp1	1.33 ± 0.17	1.58 ± 1.11	1.21 ± 0.49
14	*Coscinodiscus* sp2	0.17 ± 0.10	0.25 ± 0.61	0.82 ± 0.33
15	*Cossoneis placentula*	0.08 ± 0.10	*	*
16	*Cyclotella meneghiniana*	0.08 ± 0.10	0.08 ± 0.20	0.20 ± 0.08
17	*Cymbella* sp	0.50 ± 0.20	0.33 ± 0.61	0.61 v 0.25
18	*Diploneis* sp	0.25 ± 0.17	*	0.41 ± 0.17
19	*Ditylum brightwellii*	0.08 ± 0.10	*	0.21 v 0.09
Continuation of Table 3				
20	*Eucampia zodiacus*	*	0.33 ± 0.82	*
21	*Eunotia valida*	0.92 ± 0.48	*	*
22	*Frustulia vulgaris*	15.17 ± 1.12	24.92 ± 3.44	3.13 ± 1.28
23	*Fragilaria* sp.	0	1.25 ± 1.75	3.90 ± 1.59
24	*Guinardia delicatula*	7.17 ± 3.15	1.92 ± 3.44	5.57 ± 2.27
25	*Guinardia flaccida*	4.50 ± 0.93	2.92 ± 2.69	4.83 ± 1.97
26	*Guinardia striata*	1.08 ± 1.27	3.67 ± 6.91	4.89 ± 1.99
27	*Gyrosigma scalproides*	*	0.17 ± 0.41	0.20 ± 0.08
28	*Gyrosigma sp.*	*	*	0.87 ± 0.27
29	*Navicula radiosa*	*	0.25 ± 0.03	*
30	*Navicula peticolasii*	*	0.08 ± 0.03	*
31	*Nitzshia longissima*	*	0.08 ± 0.02	0.20 ± 0.08
32	*Nitzschia epithemoides*	0.75 ± 0.12	0.17 ± 0.41	*
33	*Odontella sinensis*	*	*	0.42 ± 0.17
34	*Pinnularia* sp1	0.50 ± 0.10	1.00 ± 0.88	*

DOI:https//doi.org/10.22452/mjs.vol45no1.3
Malaysian Journal of Science 45(1): 17-26 (March 2026)

35	*Pinnularia* sp2	1.08 ± 0.88	*	*
36	*Pleurosigma directum*	0.08 ± 0.10	0.08 ± 0.03	*
37	*Pleurosigma elongatum*	*	0.33 ± 0.16	*
38	*Pleurosigma* sp	*	*	1.21 ± 0.49
39	*Rhizosolenia alata*	*	*	1.02 ± 0.42
40	*Rhizosolenia imrbicata*	0.83 ± 0.48	*	1.87 ± 0.27
41	*Rhizosolenia striata*	5.08 ± 0.40	1.08 ± 0.08	0.66 ± 0.27
42	*Skeletonema* sp	0.33 ± 0.10	*	0.66 ± 0.27
43	*Strauroneis producta*	*	*	0.49 ± 0.20
44	*Synedra ulna*	*	6.75 ± 1.72	2.09 ± 0.85
45	*Triceratium favus*	0.58 ± 0.58	0.08 ± 0.01	0.42 ± 0.17
46	*Zygoceros atlanticus*	0.75 ± 0.15	*	*
	Division Chlorophyta			
47	*Closterium* sp	*	*	0.20 ± 0.08
48	*Mougetia* sp	7.50 ± 1.34	10.00 ± 2.61	5.21 ± 2.13
48	*Pleurococcus miniatus*	7.83 ± 3.11	17.00 ± 3.12	4.77 ± 1.95
50	*Ulothrix* sp	0.50 ± 0.10	5.42 ± 1.30	4.46 ± 1.82
	Division Dinophyta			
51	*Ceratium* sp	0.08 ± 0.02	0.33 ± 0.10	0.41 ± 0.17
52	*Dinophysis caudata*	0.08 ± 0.10	*	0.41 ± 0.17
53	*Protoperidinium depressum*	0.42 ± 0.11	0.08 ± 0.01	0.80 ± 0.33
54	*Protoperidium* sp1	0.08 ± 0.02	*	0.42 ± 0.17
55	*Alexandrium* sp2	0.17 ± 0.20	0.25 ± 0.02	0.52 ± 0.21
	Division Cyanophyta			
56	*Oscillatoria tenuis*	*	4.83 ± 0.51	2.80 ± 1.14

* indicates not recorded

Figure 1. Light microscopy plate of; a. Eight cells of *Chaetoceros curvisetus* in a chain, b. *Frustulia vulgaris* and; c. Single cell of genus *Guinardia*, the *Guinardia striata.*

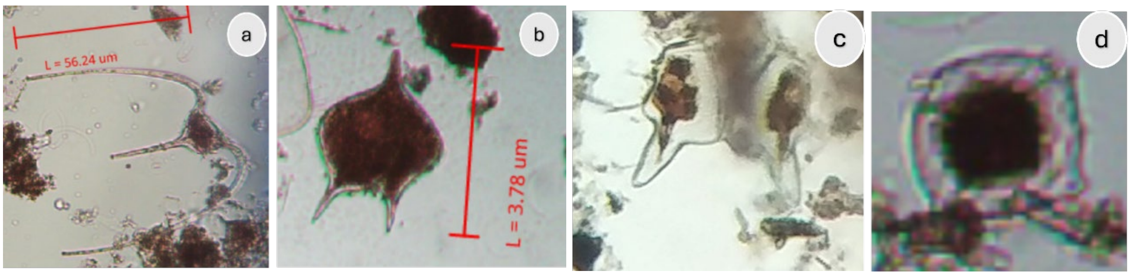

Figure 2. a. *Ceratium* sp., b. *Protoperidinium depressum*, c. *Dinophysis caudata* and d. *Alexandrium* sp. Four out of the five Dinoflagellate species recorded at chosen sites of Kerteh River.

DOI:https//doi.org/10.22452/mjs.vol45no1.3
Malaysian Journal of Science 45(1): 17-26 (March 2026)

Spatial Variability of Phytoplankton Diversity

Diversity-wise, Station 3, located further away from the main outlet to the South China Sea, had the highest species richness (S). There were 42 species recorded at Station 3, followed by Station 1 and Station 2, with 36 and 34 species, respectively. The high species richness at Station 3 potentially contributed to its relatively higher diversity value (H') (2.96)(Magurran, 2004; Supriatna, 2018) than the other two stations, Station 1 (2.697) and Station 2 (2.669), in addition, the H' value of Station 3 was also at high potential to be attributed by the station's small species relative abundance range of 0.2 – 8.80 % (Table 3). The range was the lowest range between the 3 stations and further confirmed by Station 3's Equitability (J) index score of 0.792, followed by Station 2 and 1 with the values of 0.7569 and 0.7526, respectively (Table 3). A positive relationship between the diversity indices scores and both the species richness and species equal abundance (evenness) was confirmed in a comprehensive analysis on measuring biodiversity by Magurran (2004).

Table 2. Diversity scores based on phytoplankton species composition and abundance at the three stations.

	Station 2	Station 3	Station 4
Taxa (S)	36	34	42
Shannon (H')	2.697	2.669	2.96
Equitability (J)	0.7526	0.7569	0.792

4. Conclusion

Although the Kerteh River is facing rapid urbanization from adjacent terrestrial areas, the abundance of the phytoplankton species suggested that the ecosystem is still in a 'not alarming ecosystem' condition. However, preliminary results of this study indicated that the phytoplankton species *Chaetoceros curvisetus* is the species that needs to be monitored in future biomonitoring projects. The presence of some species of bloom-forming and harmful dinoflagellates is also an important concern that needs attention. Biomonitoring or comprehensive temporal studies on phytoplankton abundance and diversity should be initiated immediately as a precaution to ensure no threat to phytoplankton diversity imbalance in the Kerteh River. Phytoplankton, although small, collectively, if in bloom, could potentially lead to the collapse of ecosystems, causing economic loss as well as biodiversity loss.

5. Acknowledgement

The authors would like to express their sincere gratitude to the Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, and Eco-Care, MNS for providing funding, facilities, and continuous support.

7. References

Ajibare, A. O., P. O. Ayeku, J. O. Akinola, and A. H. Adewale. (2019). Plankton Composition in Relation to Water Quality in the Coastal Waters of Nigeria. *Asian Journal of Fisheries and Aquatic Research* 5 (2):1-9. https://doi.org/10.9734/ajfar/2019/v5i230070.

Alvarez Dalinger, F. S., Claudia Nidia, B., Lozano, V. L., Moraña, L. B., & Salusso, M. M. (2024). Bloom-forming cyanobacteria and dinoflagellates in five Argentinian reservoirs: Multi-year sampling. *Water Biology and Security*, 3(1). https://doi.org/10.1016/j.watbs.2023.100232

Anne E Magurran. ([s.d.]). Measuring_Biological_Diversity (3).

Arsenieff, L., Simon, N., Rigaut-Jalabert, F., Le Gall, F., Chaffron, S., Corre, E., Com, E., Bigeard, E., & Baudoux, A. C. (2019). First viruses infecting the marine diatom *Guinardia delicatula*. *Frontiers in Microbiology*, 10 (JAN). https://doi.org/10.3389/fmicb.2018.03235

Azaman, F., Juahir, H., Yunus, K., Azid, A., Khalit, S. I., Mustafa, A. D., & Yusri, M. A. M. (2017). Metal concentration at surface water using multivariate analysis and human health risk assessment. *Journal of Fundamental and Applied Sciences*, 9(2S), 217-237.

Begum, M., Sahu, B. K., Das, A. K., Vinithkumar, N. V., & Kirubagaran, R. (2015). Extensive *Chaetoceros curvisetus* bloom in relation to water quality in Port Blair Bay, Andaman Islands. *Environmental Monitoring and Assessment* 187(5), 1–14. https://doi.org/10.1007/s10661-015-4461-2

Bellinger, E. G., & Sigee, D. C. (2010). Algae as Bioindicators. Em Freshwater Algae (p. 99–136). John Wiley & Sons, Ltd. https://doi.org/10.1002/9780470689554.ch3

Bosak, S., Godrijan, J., & Šilović, T. (2016). Dynamics of the marine planktonic diatom family Chaetocerotaceae in a Mediterranean coastal zone. *Estuarine, Coastal and Shelf Science* 180: 69–81. https://doi.org/10.1016/j.ecss.2016.06.026

Canini, N. D., Metillo, E. B., & Azanza, R. V. (2013). Monsoon-influenced phytoplankton community structure in a Philippine mangrove estuary. *Tropical Ecology,* 54(3): 331–343.

Chowdhury, A.J., Mohamed, A.A., John, A., & Yunus, K.B. (2011). Spatial Variation and Community Composition of Phytoplankton along the Pahang Estuary, Malaysia. *Asian Journal of Biological Sciences, 4*, 468-476.

C.K., H., Hardikar, R., Thomas, J., Pradhan, U. K., T.A., A., P.S., R., M.A., V., Sahu, B., & Rafeeq, M. (2022). Bloom report of *Noctiluca scintillans, Gymnodinium wulfii* and *Guinardia delicatula* from Shastri Estuary, West Coast of India. *Regional Studies in Marine Science* 56: 102689. https://doi.org/10.1016/j.rsma.2022.102689

Essien, T. P., S. P. Antai & N. U. Benson. 2007. Microalgae biodiversity and biomass status in Qua Iboe Estuary Mangrove Swamp, Nigeria. *Aquatic Ecology* 42: 71-81.

Ettoubi, E., Akif, F., Blaghen, M., & Genten, F. (2020). Marine Biotoxins: Origins, Effects, Distribution, Prevention and Treatment. In *International Journal of Innovative Science and Research Technology* (Vol. 5, Issue 11). www.ijisrt.com928

Evans JH. 1972. A modified sedimentation system for counting algae with an inverted microscope. *Hydrobiologia* 40: 247-250. DOI: 10.1007/BF00016796

Fang, X., & Sommer, U. (2017). Overwintering effects on the spring bloom dynamics of phytoplankton. *Journal of Plankton Research* 39(5), 772–780. https://doi.org/10.1093/plankt/fbx046

Flynn, R. F., Haraguchi, L., Mcquaid, J., Burger, J. M., Lunga, P. M., Stirnimann, L., Samanta, S., Roychoudhury, A. N., & Fawcett, S. E. (2023). Oceanography Nanoplankton: The dominant vector for carbon export across the Atlantic Southern Ocean in spring. https://oceancolor.gsfc.nasa.gov/l3/

Graham, L. E. & L. W. Wilcox. 2000. Algae. Prentice Hall. New Jersey.

Hammer, Ø., Harper, D.A.T., Ryan, P.D. 2001. PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* 4(1): 9pp.

Haridevi, C.K., Hardikar, R., Thomas, J., Pradhan, U. K., T.A., A., P.S., R., M.A., V., Sahu, B., & Rafeeq, M. (2022). Bloom report of *Noctiluca scintillans*, *Gymnodinium* wulfii and *Guinardia delicatula* from Shastri Estuary, West Coast of India. *Regional Studies in Marine Science* 56: 102689. https://doi.org/10.1016/j.rsma.2022.102689

Hilaluddin, F., Yusoff, F. M., Natrah, F. M. I., & Lim, P. T. (2020). Disturbance of mangrove forests causes alterations in estuarine phytoplankton community structure in Malaysian Matang mangrove forests. *Marine Environmental Research* 158. https://doi.org/10.1016/j.marenvres.2020.104935

Hilaluddin, F., Yusoff, F. M., & Toda, T. (2020). Shifts in diatom dominance associated with seasonal changes in an estuarine-mangrove phytoplankton community. *Journal of Marine Science and Engineering* 8(7). https://doi.org/10.3390/JMSE8070528

Jeslin, I. J., Benny, N., Thomas, L. C., & Padmakumar, K. B. (2021). Short term spatio-temporal variabilities of microphytobenthic assemblages in the mangrove ecosystems along the southwest coast of India. *Wetlands Ecology and Management* 29(5): 689–702. https://doi.org/10.1007/s11273-021-09787-8

Kamal, A. H. M., Idris, M. H., Al-Asif, A., Bhuiyan, M. K. A., Rasdi, N. W., Piah, R. M., Lah, R. A., Musa, N., Wahid, M. E. A., & Abualreesh, M. H. (2022). Phytoplankton Community Structure and Seasonality in a Tropical Mangrove Estuarine and Coastal Waters, South China Sea. *Thalassas*, *38*(1), 511–526. https://doi.org/10.1007/s41208-021-00386-1

Lau, W. L. S, Lawa, I. K., Liow, G. R., Hiia, K. S., Usup, G., Lim, P. T. and Leaw, C. P. (2017). Life-history stages of natural bloom populations and the bloom dynamics of a tropical Asian ribotype of *Alexandrium minutum*. *Harmful Algae,* 70, 52-63

Law, I.K., Hii, K.S., Lau, W.L.S., Leaw, C.P., & Lim, P.T. (2023). Coastal micro-phytoplankton community changes during the toxigenic *Alexandrium minutum* blooms in a semi-enclosed tropical coastal lagoon (Malaysia, South China Sea). *Reg. Stud. Mar. Sci*. 57: 102733

Lim, P. T., Usup, G., & Leaw, C. P. (2012). Harmful algal blooms in Malaysian waters. *Sains Malaysiana* 41: 1509-1515.

Lim, H. C., Leaw, C. P., Tan, T. H., Kon, N. F., Yek, L. H., Hii, K. S., Teng, S. T., Razali, R. M., Usup, G., Iwataki, M., & Lim, P. T. (2014). A bloom of *Karlodinium australe* (Gymnodiniales, Dinophyceae) associated with mass mortality of cage-cultured fishes in West Johor Strait, Malaysia. *Harmful Algae* 40: 51-62.

Liow GR, Lau WLS, Law IK, Hii KS, Mohammad Noor N, Leaw CP, Lim PT (2019) Phytoplankton community changes in Kuantan Port (Malaysia), with emphasis on the paralytic-shellfish toxinproducing dinoflagellate *Alexandrium tamiyavanichii*. Reg Stud Mar Sci 26:100504. https://doi.org/10.1016/j.rsma.2019.100504

Magurran, A. E. (2004). Measuring_Biological_Diversity, pp. 215, Blackwell Publishing Company.

Manna, S., K. Chaudhuri, S. Bhattacharyya & M. Bhattacharyya, 2010. Dynamics of Sundarban estuarine ecosystem: eutrophication induced threat to mangroves. Saline System **6**: 1-16.

Murty, K. N., Sarma, N. S., Pandi, S. R., Chiranjeevulu, G., Kiran, R., & Muralikrishna, R. (2017). Hydrodynamic control of microphytoplankton bloom in a coastal sea. Journal of Earth System Science, 126(6), 82. https://doi.org/10.1007/s12040-017-0867-2

Mohd-Din, M., Hii, K.S., Abdul-Wahab, M.F., Mohamad, S.E., Gu, H., Leaw, C.P., & Lim, P.T. (2022) Spatial-temporal variability of microphytoplankton assemblages including harmful microalgae in a tropical semi-enclosed strait (Johor Strait, Malaysia). *Mar. Environ. Res*. 175: 105589. https://doi.10.1016/j.marenvres.2022.105589

Mohammad-Noor, N., Adam, A., Lim, P. T., Leaw, C. P., Lau, W. L. S., Liow, G. R., Mohammad-Bunnori, N., Hamdan, N. A., Md-Noor, A., Kemat, N., & Muniandi, D. (2018). First report of paralytic shellfish poisoning (PSP) caused by *Alexandrium tamiyavanichii* in Kuantan Port, Pahang, East Coastof Malaysia. *Phycological Research* 66: 37-44

Mohd-Razali R. M., Mustapa N. I., Noordin W. N., Rahim M. A., Hii K. S., Lim P. T., Leaw, C. P., Muhd-Farouk, H., & Ku-Yaacob, K. (2022). Report of a fish kill due to a dinoflagellate bloom in Perak and Penang, Malaysia. *Asian Fish. Sci.* 35: 257–268.

Norhana Noordin, W., Nor Azman Ayub, M., Nor, A., & Mui Hua, L. ([s.d.]). Marine Biotoxins in Malaysia: Occurrence, Toxicity Cases, Analytical Capabilities and Regulatory Limits.

Onitsuka, G., Yoshikawa, Y., Shikata, T., Yufu, K., Abe, K., Tokunaga, T., Kimoto, K., & Matsuno, T. (2018). Development of a thin diatom layer observed in a stratified embayment in Japan. Journal of Oceanography, 74(4), 351–365. https://doi.org/10.1007/s10872-018-0466-0

Odido, M.; Appeltans, W.; BelHassen, M.; Mussai, P.; Nsiangango, S.E.; Vandepitte, L.; Wambiji, N.; Zamouri, N. Jiddou, A.M. (Eds) (2024). African Register of Marine Species. *Frustulia cuspidata* Kutzing,1833.Accessedat:https://www.marinespecies.org/afremas/aphia.php?p=taxdetails&id=163908 on 2024-09-10

Owen, R. B., R. W. Renaut, V. C. Hover, G. M. Ashley & A. M. Muasya. (2004). Swamps, springs and diatoms: wetlands o the semi-arid Bogoria-baringo Rift, Kenya. Hydrobiologia 518: 59-78.

Perumal, N. V., M. Rajkumar, P. Perumal & K. T Rajasekar. (2009). Seasonal variations of plankton diversity in Kaduviyar estuary, Nagapattinam, southeast coast of India. Journal of Environmental Biology **30**: 1035-1046.ES

Rajkumar, M., P. Perumal, V. Ashok Prabu, N. Vengadesh Perumal & K. Thillai Rajasekar. (2009). Phytoplankton diversity in Pichavaram mangrove waters from south-east coast of India. Journal of Environmental Biology **30**: 489-498.

Razali, R. M., Leaw, C. P., Lim, H. C., Nyanti, L., Ishak, I., & Lim, P. T. (2015). Harmful microalgae assemblage in the aquaculture area of Aman Island, Northen Strait of Malacca. Malaysian Journal of Science, 34(1), 20–32.

Razali, R.M., Mustapa, N.I., Yaacob, K.K.K., Yusof, F., Teng, S.T., Hanafiah, A.H., Hii, K.S., Mohd-Din, M., Gu, H., Leaw, C.P., & Lim, P. T. (2022). Diversity of *Heterocapsa* (Dinophyceae) and the algal bloom event in the mariculture areas of Johor Strait, Malaysia. *Plankton Benthos Res*. 17: 290–300.

Redzuan, N. S. (2012). Spatial and temporal distribution of phytoplankton at Carey Island mangrove. University of Malaya.

Redzuan, N. S., & Milow, P. (2021). Monthly chaetocerotales diversity and abundance, and its relationship with water physicochemical parameters and phytoplankton diversity in Carey Island mangrove ecosystem, Malaysia. Biodiversitas, 22(7), 2919–2927. https://doi.org/10.13057/biodiv/d220744

Saifullah, A. S. M., Hena, M. K. A., Idris, M. H., Halimah, A. R., & Johan, I. (2014). Diversity of Phytoplankton from Mangrove Estuaries of Sarawak, Malaysia. 31(5), 915–924. https://doi.org/10.5829/idosi.wasj.2014.31.05.2010

Saifullah, A.S., Kamal, A.H., Idris, M.H., Rajaee, A.H., & Bhuiyan, M.K. (2016). Phytoplankton in tropical mangrove estuaries: role and interdependency. *Forest Science and Technology, 12*, 104 - 113.

Salleh, A., Tajuddin, Z. M. (2006). Phytoplankton of Carey Island. Golden Hope Plantations Berhad and Institute of Biological Sciences (UM). 207 pp.

Saravanakumar, A., Rajkumar, M., Thivakaran, G. A., & Sesh Serebiah, J. (2008). Abundance and seasonal variations of phytoplankton in the creek waters of western mangrove of Kachchh-Gujarat. Journal of Environmental Biology, 29(2), 271–274.

Shao, Q., Zhu, Z., & Zhou, C. (2023). Alteration in Community Dynamics of Chaetoceros curvisetus and Bacterioplankton Communities in Response to Surfactin Exposure. Microorganisms, 11(10). https://doi.org/10.3390/microorganisms11102596

Somsap, N., Gajaseni, N., & Piumsomboon, A. (2015). Physico-Chemical Factors Influencing Blooms of Chaetoceros spp. and Ceratium furca in the Inner Gulf of Thailand. Em Nat. Sci.) (Vol. 49).

Spaulding, S. A., Potapova, M. G., Bishop, I. W., Lee, S. S., Gasperak, T. S., Jovanoska, E., Furey, P. C., & Edlund, M. B. (2021). Diatoms.org: supporting taxonomists, connecting communities. Diatom Research, 36(4), 291–304. https://doi.org/10.1080/0269249X.2021.2006790

DOI:https//doi.org/10.22452/mjs.vol45no1.3
Malaysian Journal of Science 45(1): 17-26 (March 2026)

Stanković, I., Gligora Udovič, M., Žutinić, P., Hanžek, N., & Plenković-Moraj, A. (2024). Is salinity a driving factor for the phytoplankton community structure of a brackish shallow Mediterranean lake? Hydrobiologia, 851(4), 999–1013. https://doi.org/10.1007/s10750-023-05300-9

Supriatna, J. (2018). Biodiversity Indexes: Value and Evaluation Purposes. E3S Web of Conferences, 48. https://doi.org/10.1051/e3sconf/20184801001

Tanaka, K. & P. Choo. 2000. Influences of nutrient outwelling from the mangrove swamp on the distribution of phytoplankton in the Matang Mangrove Estuary, Malaysia. Journal of Oceanography **56**: 69-78

Taucher, J., Arístegui, J., Bach, L. T., Guan, W., Montero, M. F., Nauendorf, A., Achterberg, E. P., & Riebesell, U. (2018). Response of subtropical phytoplankton communities to ocean acidification under oligotrophic conditions and during nutrient fertilization. Frontiers in Marine Science, 5(SEP). https://doi.org/10.3389/fmars.2018.00330

Underwood, G. J. C. (1995). Seasonal and spatial variation in epipelic diatom assemblages in the Severn Estuary. Oceanographic Literature Review, 42(7), 559–560.

United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019, Volume I: Comprehensive Tables (ST/ESA/SER.A/426).

Usup, G., Leaw, C. P., Lim, P. T., & Ahmad, A. (2002). Probable toxin producer responsible for the first occurrence of paralytic shellfish poisoning on the east coast of peninsula Malaysia. *Malaysian Applied Biology* 31(2): 29-35

Utami, F., Hasan, Z., Rizal, A., & Herawati, H. (2019). Spatial distribution of plankton in Cikeruh River, Jatinangor District, West Java Province, Indonesia. Asian Journal of Fisheries and Aquatic Research, 1-9.

Xu, S. J.-L., Chan, S. C.-Y., Wong, B. Y.-K., Zhou, H.-C., Li, F.-L., Tam, N. F.-Y., & Lee, F. W.-F. (2022). Relationship between phytoplankton community and water parameters in planted fringing mangrove area in South China. Science of The Total Environment, 817, 152838. https://doi.org/https://doi.org/10.1016/j.scitotenv.2021.152838

Yaakob, F. K. K., & Zakaria, M. P. (2017). Determination of heavy metals in water samples from Sungai Kerteh and Sungai Paka, Terengganu, Malaysia. Journal of Tropical Resource and Sustainable Science, 5 ,74-78.

Yñiguez, A. T., Lim, P. T., Leaw, C. P., Jipanin, S. J., Iwataki, M., Benico, G. & Azanza, R. V. (2021). Over 30 years of HABs in the Philippines and Malaysia: What have we learned? *Harmful Algae* 102: 101776. https://doi.org/10.1016/j.hal.2020.101776

DOI:https//doi.org/10.22452/mjs.vol45no1.3
Malaysian Journal of Science 45(1): 17-26 (March 2026)