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Bacillariophyceae Distribution and Water Quality in Estuarine-Mangrove Environments: The Commonest Phytoplankton in Musi Estuary, Indonesia

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Abstract: This study reveals the distribution of Bacillariophyceae in estuarine-mangrove which is mainly influenced by the quality of the waters. The main component analysis approach between variables is critical in this study because it determines the environmental characteristics in each estuarine zone. Estuarine-mangrove environments have different physical-chemical dynamics compared to other types of waters, one of which is Musi Estuary, located on the coast of South Sumatra. The aquatic environment of the Musi Estuary is influenced by tidal fluctuations that bring nutrients from inland waters and mangrove litter. This condition is perfect for the phytoplankton habitat, which plays an essential role in the ecological processes of waters as primary producers. This study aims to examine the diversity of Bacillariophyceae phytoplankton in the mangrove estuary environment and its possible role in estuarine ecology. Data were collected at ten observation stations in July, including samples of phytoplankton and water physical-chemical data such as pH, dissolved oxygen, temperature, salinity, water brightness, current speed, nitrates, and phosphates. Quantitative measurement of phytoplankton was performed using an Olympus CX23 light microscope at 100X magnification, while data were analyzed using PCA and Bray-Curtis similarity analysis. Water environment conditions were measured in a stable range in each zone except for salinity and brightness. Furthermore, only Bacillariophyceae were observed in all observation zones dominated by the *Skeletonema* genus. It is a dominant presence, and its abundance determined its role as a significant primary producer in the estuary outer zone near the sea. This study implicitly revealed the existence of *Skeletonema* in influencing ecological processes in estuary mangrove waters.

Keywords: biodiversity, species, Musi Estuary, principal components analysis, phytoplankton.

河口红树林环境中的芽孢杆菌属分布和水质：印度尼西亚穆西河口最常见的浮游植物

摘要：本研究揭示了河口-红树林中硅藻类的分布主要受水质影响。 变量之间的主成分分析方法在本研究中至关重要，因为它决定了每个河口区域的环境特征。 与其他类型的水域相比，河口-红树林环境具有不同的物理化学动力学，其中之一是位于南苏门答腊海岸的穆西河口。穆西河口的水生环境受到潮汐波动的影响，潮汐波动从内陆水域和红树林枯枝落叶中带

来养分。这种条件非常适合浮游植物栖息地，浮游植物在作为初级生产者的水域生态过程中起着至关重要的作用。本研究旨在考察红树林河口环境中硅藻纲浮游植物的多样性及其在河口生态学中的可能作用。7月份在10个观测站采集了数据，包括浮游植物样本和酸碱度值、溶解氧、温度、盐度、水体亮度、流速、硝酸盐和磷酸盐等水体物理化学数据。使用放大100倍的奥林巴斯客户体验23光学显微镜对浮游植物进行定量测量，同时使用主成分分析和布雷柯蒂斯相似性分析对数据进行分析。除盐度和亮度外，各区的水环境条件均在稳定范围内测量。此外，在以骨条藻属为主的所有观察区中仅观察到硅藻纲。它是一个主要的存在，它的丰富性决定了它作为靠近大海的河口外围区域重要初级生产者的作用。这项研究隐含地揭示了骨条藻在影响河口红树林水域生态过程中的存在。

关键词：生物多样性、物种、穆斯河口、主成分分析、浮游植物。

1. Introduction

Tropical estuaries and mangrove forests are among the world's most productive, valuable, and important coastal ecosystems. It has essential natural resources for nutrient recycling, carbon sequestration, and the well-being of humans and other organisms, including the coastal social, economic, and cultural aspects [1]-[2]. This ecosystem, located between the waters of the strait and the longest river, is influenced by the dynamics of tidal fluctuations from two types of waters, namely, fresh and saline waters. This ecosystem facilitates the movement of organic material from land and mangrove litter to the sea from fluvial discharge [3]-[4]. The estuary environment has dynamic and complex rules, influenced by physical-chemical fluctuations of water, which in turn impact the biological community [5]. The existence and task of the structure of biological communities need to be understood in their ecological interactions, especially the phytoplankton community, which plays an essential role in providing the primary food source in the food web in estuary waters. Phytoplankton live in short cycles and respond to environmental changes in estuaries well so that they can act as bioindicators of brackish water ecosystems [6]. However, some species are also found not to have good adaptability. As a result, the population declines significantly and may become extinct in local habitats [7]. These conditions foster the understanding that phytoplankton plays an essential ecological role in estuarine mangrove forests, thus providing an essential value in assessing sustainable aquatic ecosystems.

The Musi Estuary is located on the east coast of South Sumatra. It is a dynamic and complex area influenced by tidal physical-chemical interactions, variations in freshwater entering from upstream Musi, and saline water entering the Bangka Strait [8]-[9]. The entire coast is affected by sedimentation of organic material, so it is rich in nutrient aspects and increases its fishery resources. Estuaries are places where the marine and land environments physical, chemical, and biological systems are exchanged in a short fluctuating time [6], [8], [10]. Based on this, it is expected that the implications of phytoplankton communities are more complex in ecological processes than in aquatic environments.

The general species of phytoplankton in the mangrove waters of the Musi Estuary have not been clearly disclosed, especially at the regional zone level. Previous phytoplankton studies in the Musi estuary area have discussed spatial variability at specific points and daily temporals [9], [11]. A general species study at a site is needed to assess the adaptive environmental characteristics of some common phytoplankton species.

The general species of phytoplankton in the mangrove estuary waters of the Musi estuary have not been studied further, so there needs to be a study of community structure to assess the most common phytoplankton species. This study will be closely related to its function as the primary producer of mangrove estuary waters. Based on this, we studied the structure and ways in which the phytoplankton community interacted with the mangrove-estuarine environment. Is there a dominance caused by the adaptability of each species to changes in the physical and chemical environment and the ability to compete better than other species in using nutrient sources in the estuary.

2. Materials and Methods

2.1. Study Site

The Musi Estuary is located on the east coast of South Sumatra and has the number one largest mangrove vegetation zone in western Indonesia. This area was dominated by the mangrove plants *Avicennia* *marina*, *Avicennia alba*, *Sonneratia caseolaris*, *Sonneratia alba*, *Rhizophora mucronata*, and *Nypa fruticans* [8]-[9], [12]. Due to high sedimentation, this estuary area has the characteristics of deep mud. Moreover, environmental conditions were strongly influenced by tides. This area was a transportation route for residents and domestic and industrial ship transportation. Additionally, organic material from domestic, agricultural, and industrial anthropogenic activities accumulated in the estuary area.

This research was conducted in July 2020. Phytoplankton sampling and water quality measurements were carried out at ten observation stations on mid tide, determination of five stations based on the assumption that it was influenced by freshwater. Stations 6 and 7 were based on the central area of the estuary, while stations 8, 9, and 10 were affected by seawater (Figure 1).

Fig. 1 Location of the study area

2.2. Data Collection

The water quality data were collected simultaneously with phytoplankton retrieval at each station. Each physical and chemical parameter was measured in situ, pH, dissolved oxygen, and temperature, using Multiparameter Hanna Hi 98194, salinity using a hand refractometer, water brightness using a Secchi disk, current speed using current meter FP111 Global Flow Probe. The 100-L water sample for phytoplankton was filtered using a 25 μm plankton net. The water volume filtered was 250 mL with 4% formalin solution. Furthermore, water sampling for nitrate and phosphate measurements was done using a 250 mL dark bottle. Samples were carried in cooler box during the trip to the laboratory [13].

Nitrate analysis used the cadmium reduction method measured at a wavelength of 543 nm spectrophotometer UV-vis while phosphate analysis used the ascorbic acid reduction method with absorbance measurement of 880 nm spectrophotometer UV-vis [14].

2.3. Quantitative Phytoplankton Analysis

Quantitative analysis of phytoplankton used an Olympus CX23 light microscope at 100X magnification equipped with a Sedgwick Rafter Counter Cell (SRCC) [11], [15]. Identification was based on morphology and the number of cells counted to analyze abundance and biodiversity. Species identification referred to the reference [16].

2.4. Data Analysis

The abundance of phytoplankton was expressed in cell/L, the volume of filtered water was 100 L and the volume of water was taken to be 250 mL [11], [13]. Phytoplankton diversity (H') and dominance (D) were calculated using the Shannon-Wiener diversity index and Simpson dominance index [17].

The interactions correlation between the physical-chemical parameters (salinity, dissolved oxygen, temperature, pH, water brightness, current, nitrates, and phosphates) with the biodiversity and abundance were analyzed using Principal Component Analysis with XLSTAT 2021 and cluster dissimilarity analysis using the Bray-Curtis dissimilarity with PAST3 software [9], [14].

3. Results

3.1. Physical-Chemical Parameters in Estuarine-Mangrove

A spatial description of the environmental conditions at 10 stations is presented in Figure 2. Temperature, salinity, dissolved oxygen, pH, water brightness, current velocity, nitrates, and phosphates differed in the study sites. Each parameter at each station had a measurement pattern based on the spatial size. The spatial similarity of each parameter is shown in the dendrogram of Figure 3. Spatial multivariable similarities with the highest correlation value were salinity and pH (0.986), temperature, and brightness (0.921).

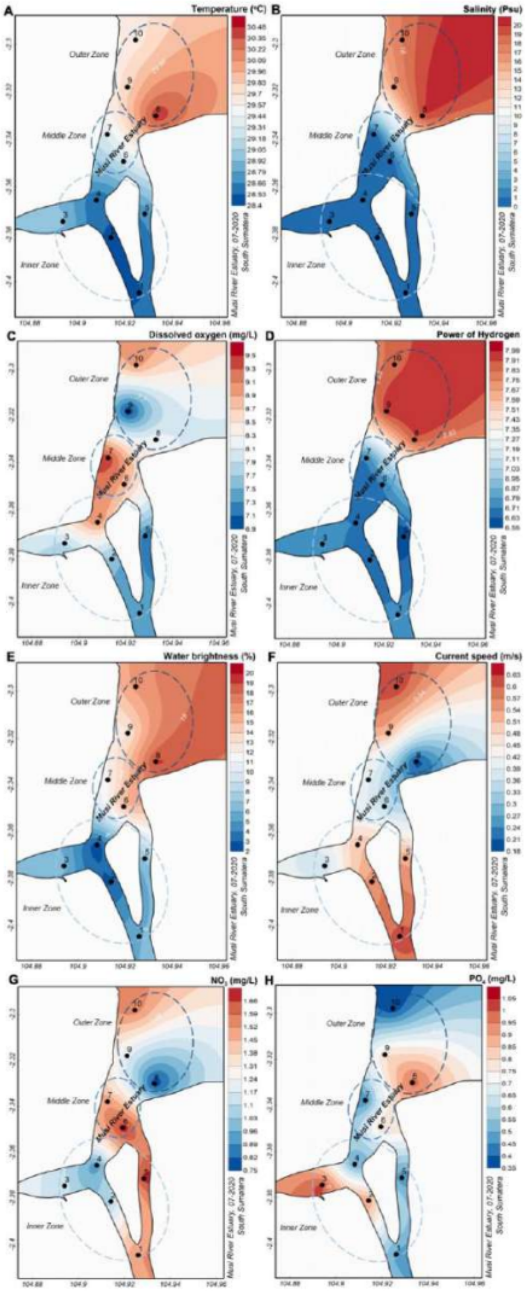

Fig. 2 Water quality parameters in Musi Estuary

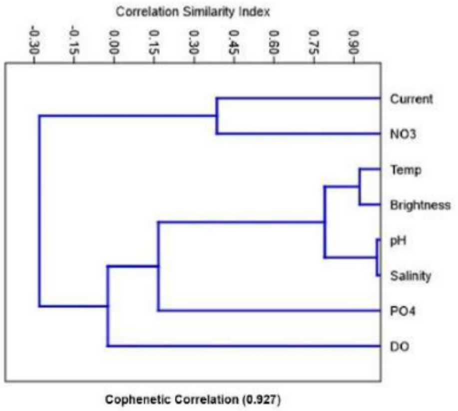

Fig. 3 Cluster of the water quality using a correlation similarity index

Measurements of physical-chemical parameters obtained consecutively resulted ranging from 28.24 °C-30.46 °C (temperature), 0 Psu – 20 Psu (salinity), 6.87 mg/L-9.46 mg/L (DO), 6.56-7.96 (pH), 2.3 %-19.2 % (brightness water), 0.19 m/s-0.63 m/s (current speed), 0.755 mg/L-1.716 mg/L (NO_3), 0.354 mg/L-1.015 mg/L (PO_4). The water temperature range was quite close due to tropical weather factors, which tended to be stable throughout the day. The salinity values described the geographical differences in the study locations. Among the ten locations, there were only three locations where the influence of seawater was quite strong. The dissolved oxygen tended to be higher at heavier locations in the interior of the river. More high alkaline level in estuary (more than 7 as neutral) also tended to be higher near the sea.

3.2. Community Structure of Bacillariophyceae

Nineteen were genera identified from the class Bacillariophyceae (Figure 4). The major genera that were found in frequency at all stations in these waters were *Amphora*, *Leptocylindrus*, *Skeletonema*, and *Thalassiosira*. However, the genus which is considered minor, is found in frequency less than three stations, namely, *Cymbella*, *Coscinodiscus*, *Cylindrotheca*, *Eucampia*, *Hemiaulus*, *Planktoniella*, and *Rhizoselenia*. Several genera were found in large and small numbers. The percentage of the genus *Skeletonema* (72.16%) was the highest, while *Coscinodiscus* (0.06%) was the lowest (Figure 5). The existence of all genera can be seen in Table 1.

The *Skeletonema* genus was found at all the study sites. It also contributed a lot to the density of the phytoplankton community in the Musi estuary waters. It was believed to have a better adaptability to the physical-chemical dynamics of the estuary.

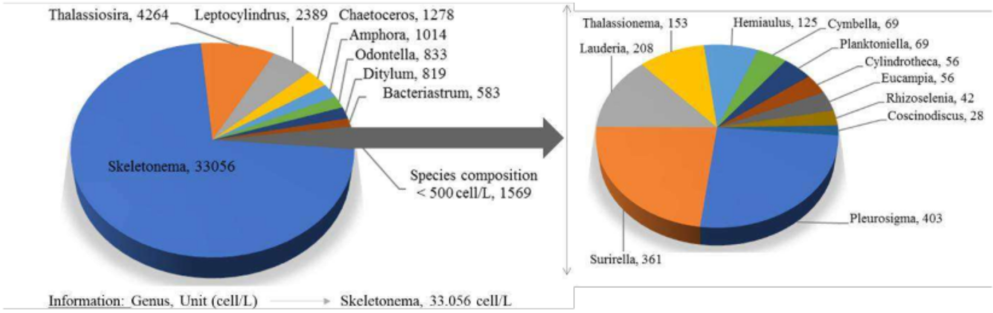

Fig. 4 Composition and density of Bacillariophyceae in total

Table 1 Occurrence and cell density of Bacillariophyceae at observation stations

Genus	**Station Location in Estuary**									
	Inner Zone					**Middle Zone**		**Outer Zone**		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Amphora	+	+	+	+	+	+	+	+	+	+
Bacteriastrum	-	-	-	-	-	+	+	+	+	+
Cymbella	-	-	-	-	-	-	-	+	+	-
Chaetoceros	+	-	-	-	-	+	+	+	+	+
Coscinodiscus	-	-	-	-	-	-	+	+	-	-
Cylindrotheca	+	+	-	-	-	-	-	-	-	-
Ditylum	-	-	+	+	-	-	+	+	+	+
Escambia	-	-	-	-	-	-	-	-	+	-
Hemiaulus	-	-	-	-	-	-	-	-	+	+
Lauder	-	-	-	-	-	+	+	+	+	+
Leptocylindrus	+	+	+	+	+	+	+	+	+	+
Odontella	+	-	-	-	-	+	-	+	+	+
Planktoniella	-	-	-	-	-	-	-	+	-	-
Pleurosigma	+	+	+	+	+	+	+	-	-	-
Rhizoselenia	-	-	-	-	-	+	-	-	-	-
Skeletonema	+	+	++	+	+++	++++	++++	++++	*	++++
Surirella	-	-	-	-	-	+	+	+	+	+
Thalassionema	-	-	-	-	-	+	+	+	+	+
Thalassiosira	+	+	+	+	+	+	+	++	+	+
Total density (cell/L)	105	73	163	97	265	437	441	547	620	550

Note: (-) Not found, (+) 1 to 100 cell/L, (++) 101 to 200 cell/L, (+++) 201 to 300 cell/L, (++++) 301 to 400 cell/L, (*) > 400 cell/L

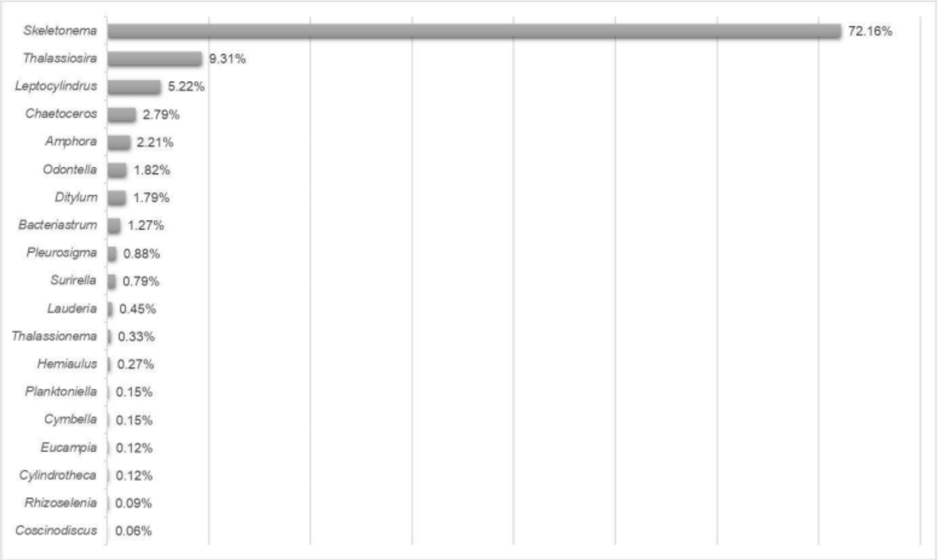

Fig. 5 Genus percentage of Bacillariophyceae

3.3. Abundance and Biodiversity of Bacillariophyceae

The distribution of phytoplankton was higher in the outer estuary near the sea than in the interior. As previously determined, stations 8, 9, 10 were more influenced by salinity water and became the area with the highest abundance of Bacillariophyceae. Stations located in rivers tended to be influenced by freshwater to be areas of lower abundance. Based on this, the stations used as objects of observation had linear characteristics with their location in the estuary.

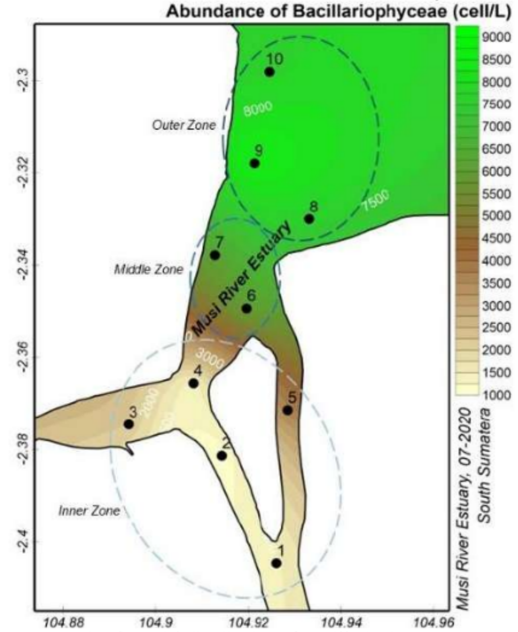

Fig. 6 Spatial distribution of Bacillariophyceae

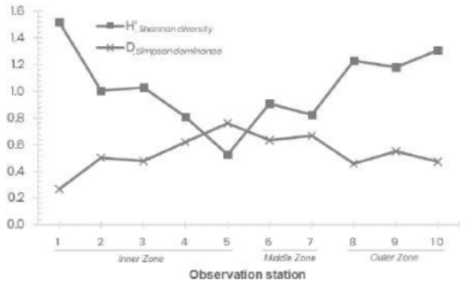

Fig. 7 Biodiversity index of Bacillariophyceae

The Shannon H' (0.526 – 1.519) and Simpson D (0.267 – 0.762) were analyzed to explain the level of biodiversity. The lowest H' index level was station 5, and the highest was station 1. The lowest Simpson D level was at station 1, and the highest was at station 5. The two formulas, Shannon H' and Simpson D curves, intersected each other, as shown in Figure 7.

3.4. Correlation of the Bacillariophyceae Abundance and Biodiversity with the Estuarine-Mangrove Environments

Based on principal component analysis, cumulative eigenvalues were 65.60%, and only two clusters were found. Both were formed by the linkage between the F1 and F2 axes.

As shown in Figure 8A, the first cluster was formed on the positive F1 axis with active variables including brightness, temperature, salinity, and pH, which characterize observations at stations 9 and 8. Furthermore, the second cluster was spread on the positive F2 axis, including the active variables uniformity and species diversity observations at stations 1 and 2. The negative axis F2 included the active variable of species dominance observations at stations 6 and 7.

The Bray-Curtis similarity index was calculated to analyze the similarity of locations based on the physical-chemical conditions of the environment and the structure of the phytoplankton community of Bacillariophyceae. The ten study sites were grouped into three clusters based on the dendrogram (Figure 8B). The mean percentage of the Cophenetic correlation was 92.8%. The first cluster included stations 1, 2, 3, 4, and 5, the second cluster included stations 6 and 7, the third cluster included stations 8, 9, and 10. The three clusters showed the closeness between areas spread out in estuarine-mangrove environments in the Musi Estuary.

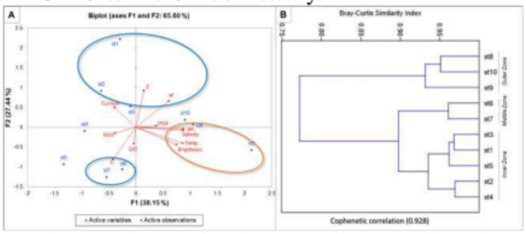

Fig. 8 Correlations of the interaction of water quality and biodiversity index at each station: A) Principal component analysis (PCA); B) Bray-Curtis similarity index

4. Discussion

Estuarine-mangrove environments in the estuary tended to change according to tidal conditions. However, the variables of salinity and water clarity had significant differences when measured spatially in all parts of the estuary at mid-tide. Both variables depend on geographic location. Stations in deep estuaries had lower salinity because they were heavily influenced by fresh water. In contrast, stations near the sea tended to have higher salinity [18]-[19]. Additionally, the brightness obtained was based on the current conditions concerning lifting and stirring the suspended material [19]. Significantly different values of these environmental variables were also observed in other water areas, such as the San Francisco Bay [20], Chesapeake Bay, and the Baltic Sea [21]. Variables of depth and type of water substrate impact the brightness level of other currents. However, both measurements were not a priority for assessing environmental aspects in this study because they were outside the study. Meanwhile, the assessment of the aquatic environment for phytoplankton was at the optimum level for life except in areas known to have been polluted due to various local human activities [22].

The phytoplankton found in this study only came from the class Bacillariophyceae. The existence of the Bacillariophyceae group raised the suspicion that the environmental conditions in the Musi estuary were not suitable for developing groups from other classes. However, research on finding the level of dominance of Bacillariophyceae in waters is not the first to be reported, previously at the Mediterranean Coast [23], Osaka, and Tokyo Bays [24]. The latest in Vancouver Island waters, Canada [25], got the same dominance species as research in Musi Estuary. A cause for developing Bacillariophyceae was the stable and warm temperature conditions so that they were often found in tropical waters [26] and only seen during one summer period in higher latitude regions [27]. In addition, the *Skeletonema* genus of the same class had an extremely great adaptability to brackish waters [28]. All of these abilities were supported by the excellent level of nutrient fertility in each area. Here, the concentration of net primary production was accumulated in the water [29]. The semi-enclosed geography of estuaries supports the creation of a fertile aquatic environment, deposits organic material from river flows consisting of various kinds of organic waste disposal. Organic material from litter in mangrove ecosystems and dead organisms create excess nutrient abundance in tropical estuaries [30].

Eutrophication in the estuary benefited *the Skeletonema* of the Bacillariophyceae class. Studies of its behavior indicated that *Skeletonema* could become a species that could bloom in waters. Several areas have been reported to have bloomed algae from the genus *Skeletonema* in the waters of Masan-Chinhae Bay, South Korea [31], East China Sea [32], Ariake Sea, Japan [33], and Yangtze Estuary, China [34]. The ability to bloom due to eutrophication of waters also often occurred in other genera of the Bacillariophyceae class, including *Pseudo-nitzschia cuspidata* in the waters of Marina Bay, Malaysia Borneo [35], *Asterionellopsis glacialis* in the waters of Bengal Bay [36], and *Thalassiosira angulata* in the waters of White Sea [37].

Skeletonema has a complex involvement in ecological processes in estuaries. As happened in this study, high abundance in the waters indicated its essential role in the food web as a primary producer of water. The trophic level one level above depended strongly on the existence of *Skeletonema* as a food source [38]. This phytoplankton has good biochemical content and is not a toxic genus to other organisms [39]. The existence of *Skeletonema* in the Musi estuary food web greatly regulates the life cycle of other organisms in the waters. *Skeletonema* abundance increased at observation locations near the sea. Based on the instincts of an organism, it was suspected that many trophic predators approached that location to look for food sources, one of which was fish [40]. The implications of phytoplankton in the environmental ecosystem of the Musi estuary are very complex. Through an assessment of its community structure, it was essential ecologically for the sustainable use of the potential of brackish waters on the coast of South Sumatra.

5. Conclusion

We found that the dominance of Bacillariophyceae was due to the contribution of *Skeletonema sp*. This contribution was due to water quality factors in the Musi Estuary, which influenced the distribution of phytoplankton in each estuary zone. The outer zone, middle zone, and inner zone were the zones that had the highest to lowest abundance of phytoplankton. Several locations showed a high presence of Bacillariophyceae causing blooming events such as those that occurred in Masan-Chinhae Bay, East China Sea, Ariake Sea, and Yangtze Estuary. The *Skeletonema* genus was the main contributor to the blooming event. Phytoplankton blooming in semi-enclosed aquatic ecosystems would cause a longer-term lack of dissolved oxygen and threaten the lives of other aquatic organisms. However, the zoning system of this study can represent estuaries in other parts of the world by showing that the outer zone of the estuary is more prone to experiencing blooming events. Based on this study, the *Skeletonema* species were the main species in the Musi Estuary waters with the support of their aquatic characteristics. It is hoped that the next study will be able to analyze the impact of a species that is blooming on aquatic organisms, because there is an assumption that each species has different implications.

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References

[1] GROENEVELD JC, HOGUANE AM, KUGURU B, et al. Estuarize-WIO: A socio-ecological assessment of small-scale fisheries in estuaries of the Western Indian Ocean. *Western Indian Ocean Journal of Marine Science*, 2021, (1/2021): 1–15. https://doi.org/10.4314/wiojms.si2021.1.1.

[2] GU Xiaoxuan, ZHAO Hewei, PENG Congjiao, *et al*. The

mangrove blue carbon sink potential: Evidence from three net primary production assessment methods. *Forest Ecology and Management*, 2022, 504: 119848. https://doi.org/10.1016/j.foreco.2021.119848.

[3] XIA Shaopan, SONG Zhaoliang, LI Qiang, *et al*. Distribution, sources, and decomposition of soil organic matter along a salinity gradient in estuarine wetlands characterized by C: N ratio, δ13C- δ15N, and lignin biomarker. *Global Change Biology*, 2021, 27(2): 417–34. ttps://doi.org/10.1111/gcb.15403.

[4] CHEN Hui, FENG Jianxiang, ZHANG Yihui, *et al*. Significant but short time assimilation of organic matter from decomposed exotic Spartina alterniflora leaf litter by mangrove polychaetes. *Estuarine, Coastal and Shelf Science*, 2021, 259: 107436. https://doi.org/10.1016/j.ecss.2021.107436.

[5] TAKARINA ND, NURLIANSYAH W, and WARDHANA W. Relationship between environmental parameters and the plankton community of the Batuhideung Fishing Grounds. *Biodiversitas Journal of Biological Diversity*, 2019, 20(1): 171–80. https://doi.org/10.13057/biodiv/d200120.

[6] WANG Chao, JIA Huijuan, WEI Jingxin, *et al*. Phytoplankton functional groups as ecological indicators in a subtropical estuarine river delta system. *Ecological Indicators*, 2021, 126: 107651. https://doi.org/10.1016/j.ecolind.2021.107651.

[7] ZHAO Qiuyue, LIU Shutang, and NIU Xinglong. Effect of water temperature on the dynamic behavior of phytoplankton–zooplankton model. *Applied Mathematics and Computation*, 2020, 378: 125211. https://doi.org/10.1016/j.amc.2020.125211.

[8] ROZIRWAN, MELKI, APRI R, *et al*. Assessment the macrobenthic diversity and community structure in the Musi Estuary, South Sumatra, Indonesia. *Acta Ecologica Sinica*, 2021, 41(4): 346–350. https://doi.org/10.1016/j.chnaes.2021.02.015.

[9] ROZIRWAN, MELKI, APRI R, *et al*. Assessment of phytoplankton community structure in Musi Estuary, South Sumatra, Indonesia. *AACL Bioflux*, 2021, 14: 1451–1463.

[10] ROZIRWAN, NUGROHO RY, HENDRI M, et al. Phytochemical profile and toxicity of extracts from the leaf of Avicennia marina (Forssk.) Vierh. collected in mangrove areas affected by port activities. *South African Journal of Botany*, 2022, 150: 903–19. https://doi.org/10.1016/j.sajb.2022.08.037.

[11] ROZIRWAN, FAUZIYAH, WULANDARI PI, et al. Assessment distribution of the phytoplankton community structure at the fishing ground, Banyuasin estuary, Indonesia. *Acta Ecologica Sinica*, 2022, 42: 670–678. https://doi.org/10.1016/j.chnaes.2022.02.006.

[12] ROZIRWAN, FAUZIYAH, NUGROHO RY, *et al*. An ecological assessment of crab's diversity among habitats of migratory birds at Berbak-Sembilang national park, Indonesia. *International Journal of Conservation Science*, 2022, 13(3): 961–972.

[13] ROZIRWAN, ISKANDAR I, HENDRI M, *et al*. Distribution of phytoplankton diversity and abundance in Maspari island waters, South Sumatera, Indonesia. *IOP Conference Series: Journal of Physics*, 2019, 1282: 012105.

[14] ROZIRWAN, SUGEHA HY, FITRIYA N, *et al*. Correlation Between the Phytoplankton Distribution with the Oceanographic Parameters of the Deep-Sea Surface of Sangihe-Talaud, North Sulawesi, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 2021, 789(1): 12007. https://doi.org/10.1088/1755-1315/789/1/012007.

[15] HARTLEY B. *An atlas of British diatoms*. Balogh Scientific Books; 1996.

[16] TOMAS CR. *Identifying Marine Phytoplankton*. St. Petersburg: Academic Press; 1997.

[17] ODUM EP. and BARRETT GW. *Fundamentals of ecology*. vol. 3. Saunders Philadelphia; 1971.

[18] MACCREADY P, GEYER WR, and BURCHARD H. Estuarine exchange flow is related to mixing through the salinity variance budget. *Journal of Physical Oceanography*, 2018, 48(6): 1375–84. https://doi.org/10.1175/JPO-D-17-0266.1.

[19] ALMANIAR S, ROZIRWAN, and HERPANDI. Abundance and diversity of macrobenthos at Tanjung Api-Api waters, South Sumatra, Indonesia. *AACL Bioflux*, 2021, 14: 1486–97.

[20] TOMPERI J, ISOKANGAS A, TUUTTILA T, *et al*. Functionality of turbidity measurement under changing water quality and environmental conditions. *Environmental Technology*, 2020: 1–9. https://doi.org/10.1080/09593330.2020.1815860.

[21] CLOERN JE, JASSBY AD, SCHRAGA TS, *et al*. Ecosystem variability along the estuarine salinity gradient: Examples from long- term study of San Francisco Bay. *Limnology and Oceanography*, 2017, 62(S1): S272–91. https://doi.org/10.1002/lno.10537.

[22] OLLI K, PTACNIK R, KLAIS R, *et al*. Phytoplankton species richness along coastal and estuarine salinity continua. *The American Naturalist*, 2019, 194(2): E41–51. https://doi.org/10.1086/703657.

[23] QUIGG A, PARSONS M, BARGU S, *et al*. Marine phytoplankton responses to oil and dispersant exposures: Knowledge gained since the Deepwater Horizon Oil Spill. *Marine Pollution Bulletin*, 2021, 164: 112074. https://doi.org/10.1016/j.marpolbul.2021.112074.

[24] QUIJANO-SCHEGGIA S, GARCÉS E, SAMPEDRO N, *et al*. Identification and characterisation of the dominant Pseudo-nitzschia species (Bacillariophyceae) along the NE Spanish coast (Catalonia, NW Mediterranean). *Scientia Marina*, 2008, 72(2): 343–59. https://doi.org/10.3989/scimar.2008.72n2343.

[25] YAMADA M, OTSUBO M, KODAMA M, *et al*. Species composition of *Skeletonema* (Bacillariophyceae) in planktonic and resting-stage cells in Osaka and Tokyo Bays. *Plankton and Benthos Research*, 2014, 9(3): 168–175. https://doi.org/10.3800/pbr.9.168.

[26] SAWAI Y, TANIGAWA K, SHINOZAKI T, *et al*. Diatom (Bacillariophyceae) assemblages in tidal environments of Vancouver Island, British Columbia, Canada. *Phycological Research*, 2022, 70(1): 3–21. https://doi.org/10.1111/pre.12470.

[27] BHARATHI MD, SARMA V, and RAMANESWARI K. Intra-annual variations in phytoplankton biomass and its composition in the tropical estuary: Influence of river discharge. *Marine Pollution Bulletin*, 2018, 129(1): 14–25. https://doi.org/10.1016/j.marpolbul.2018.02.007.

[28] HILALUDDIN F, YUSOFF FM, and TODA T. Shifts in diatom dominance associated with seasonal changes in an estuarine-mangrove phytoplankton community. *Journal of Marine Science and Engineering*, 2020, 8(7): 528. https://doi.org/10.3390/jmse8070528.

[29] OGURA A, AKIZUKI Y, IMODA H, *et al*. Comparative genome and transcriptome analysis of diatom, *Skeletonema costatum*, reveals evolution of genes for harmful algal bloom. *BMC Genomics*, 2018, 19(1): 1–12.

[30] BEAMUD SG, BAFFICO G, REID B, *et al*. Photosynthetic performance associated with phosphorus availability in mats of *Didymosphenia geminata* (Bacillariophyceae) from Patagonia (Argentina and Chile). *Phycologia*, 2016, 55(2): 118–125. https://doi.org/10.2216/15-83.1.

[31] OGAWA Y, OKAMOTO Y, SADABA RB, *et al*. Sediment organic matter source estimation and ecological classification in the semi-enclosed Batan Bay Estuary, Philippines. *International Journal of Sediment Research*, 2021, 36(1): 110–9. https://doi.org/10.1016/j.ijsrc.2020.05.007.

[32] LEE C. and LIM W. Variation of harmful algal blooms in Masan-Chinhae Bay. *Science Asia*, 2006, 32(Supplement 1): 51–6. 10.2306/scienceasia1513-1874.2006.32(s1).051.

[33] SHEHATA N, MEEHAN K, and LEBER DE. Oceanography of *Skeletonema costatum* harmful algal blooms in the East China Sea using MODIS and QuickSCAT satellite data. *Journal of Applied Remote Sensing*, 2012, 6(1): 63529. https://doi.org/10.1117/1.JRS.6.063529.

[34] FENG C, ISHIZAKA J, SAITOH K, *et al*. A Novel Method Based on Backscattering for Discriminating Summer Blooms of the Raphidophyte (*Chattonella* spp.) and the Diatom (*Skeletonema* spp.) Using MODIS Images in Ariake Sea, Japan. *Remote Sensing*, 2020, 12(9): 1504. https://doi.org/10.3390/rs12091504.

[35] TIAN Rongxiang, LIN Qun, LI Dewang, *et al*. Atmospheric transport of nutrients during a harmful algal bloom event. *Regional Studies in Marine Science*, 2020, 34: 101007. https://doi.org/10.1016/j.rsma.2019.101007.

[36] TENG ST, ABDULLAH N, HANIFAH AH, *et al*. Toxic bloom of Pseudo-nitzschia cuspidata (Bacillariophyceae) and domoic acid contamination of bivalve molluscs in Malaysia Borneo. *Toxicon*, 2021, 202: 132–141.

[37] SAHU G, MOHANTY AK, SARANGI RK, *et al*. *Asterionellopsis glacialis* (Family: Fragilariaceae, Class: Bacillariophyceae, Phylum: Ochrophyta) bloom and its impact on plankton dynamics at Kalpakkam (Bay of Bengal, Southeast coast of India). *Oceanologia*, 2022, 64(1): 145–159.

[38] RADCHENKO IG, SHEVCHENKO VP, KRAVCHISHINA MD, *et al*. The first record of *Thalassiosira angulata* (Bacillariophyceae) bloom in the White Sea: spatial distribution and associated species. *Moscow University Biological Sciences Bulletin*, 2018, 73(4): 217–221.

[39] ROZIRWAN, APRI R, and ISKANDAR I. Distribution of zooplankton abundance and diversity in the vicinity of Maspari Island, Bangka Strait, South Sumatra, Indonesia. *EurAsian Journal of BioSciences*, 2020, 14(2): 3571–3579.

[40] SAPUTRA A, NUGROHO RY, ISNAINI R, *et al*. A review: The potential of microalgae as a marine food alternative in Banyuasin Estuary, South Sumatra, Indonesia. *Egyptian Journal of Aquatic Biology and Fisheries*, 2021, 59: 1053–1065. https://doi.org/10.21608/EJABF.2021.170654.

[41] NAIR PG, JOSEPH S, PILLAI N, *et al*. Trophic significance of microzooplankton to commercially important small pelagic fishes along the southwest coast of India. *Environmental Science and Pollution Research*, 2021, 28(45): 64394–64406. https://doi.org/10.1007/s11356-021-15452-7.

参考文:

[1] GROENEVELD JC、HOGUANE AM、KUGURU B 等。河口化-世界信息组织：对西印度洋河口小规模渔业的社会生态评估。西印度洋海洋科学杂志，2021，(1/2021)：1–15。https://doi.org/10.4314/wiojms.si2021.1.1.

[2] GU Xiaoxuan, ZHAO Hewei, PENG Congjiao，等．红树林蓝色碳汇潜力：来自三种净初级生产评估方法的证据。森林生态与管理，2022，504：119848。https://doi.org/10.1016/j.foreco.2021.119848。

[3] XIA Shaopan, SONG Zhaoliang, LI Qiang,，等．以 C:否比、δ13C-δ15N 和木质素生物标志物为特征的河口湿地土壤有机质沿盐度梯度的分布、来源和分解。全球变化生物学，2021，27(2)：417–34。https://doi.org/10.1111/gcb.15403。

[4] CHEN Hui, FENG Jianxiang, ZHANG Yihui，等．红树林多毛类动物对腐烂的外来互花米草叶凋落物中有机物的显着但短时间同化作用。河口、海岸和大陆架科学，2021，259：107436。https://doi.org/10.1016/j.ecss.2021.107436。

[5] TAKARINA ND、NURLIANSYAH W 和 WARDHANA W. 巴图希登渔场环境参数与浮游生物群落的关系。生物多样性生物多样性杂志, 2019, 20(1): 171–80. https://doi.org/10.13057/biodiv/d200120。

[6] WANG Chao, JIA Huijuan, WEI Jingxin，等．浮游植物功能群作为亚热带河口河流三角洲系统的生态指标。生态指标，2021，126：107651。https://doi.org/10.1016/j.ecolind.2021.107651。

[7] ZHAO Qiuyue, LIU Shutang, 和 NIU Xinglong. 水温对浮游植物-浮游动物模型动态行为的影响。应用数学与计算，2020，378：125211。https://doi.org/10.1016/j.amc.2020.125211。

[8] ROZIRWAN、MELKI、APRI R 等。评估印度尼西亚南苏门答腊穆西河口的大型底栖生物多样性和群落结构。生态学报，2021, 41(4): 346–350. https://doi.org/10.1016/j.chnaes.2021.02.015。

[9] ROZIRWAN、MELKI、APRI R 等。印度尼西亚南苏门答腊穆西河口浮游植物群落结构评估。AACL 生物通量，2021，14：1451–1463。

[10] ROZIRWAN、NUGROHO RY、HENDRI M 等。白骨海棠(福斯克。) 维尔赫叶提取物的植物化学特征和毒性。 在受港口活动影响的红树林地区收集。 南非植物学杂志，2022，150：903–19。https://doi.org/10.1016/j.sajb.2022.08.037。

[11] ROZIRWAN、FAUZIYAH、WULANDARI PI 等。印度尼西亚班纽阿辛河口渔场浮游植物群落结构的评估分布。生态学报，2022, 42: 670–678. https://doi.org/10.1016/j.chnaes.2022.02.006。

[12] ROZIRWAN、FAUZIYAH、NUGROHO RY 等。 印度尼西亚贝尔巴克-森美兰国家公园候鸟栖息地螃蟹多样性的生态评估。国际保护科学杂志, 2022, 13(3): 961–972.

[13] ROZIRWAN、ISKANDAR I、HENDRI M 等。印度尼西亚南苏门答腊马斯帕里岛水域浮游植物多样性和丰度分布。眼压会议系列：物理学杂志，2019，1282：012105。

[14] ROZIRWAN、SUGEHA HY、FITRIYA N 等。浮游植物分布与印度尼西亚北苏拉威西省桑吉河塔劳德深海表面海洋学参数的相关性。眼压会议系列：地球与环境科学，2021，789(1)：12007。https://doi.org/10.1088/1755-1315/789/1/012007。

[15] HARTLEY B. 英国硅藻图集。巴洛格科学书籍；1996.

[16] TOMAS CR。识别海洋浮游植物。圣彼得堡：学术出版社； 1997.

[17] ODUM EP。和 BARRETT GW。生态学基础。卷。3.费城桑德斯；1971.

[18] MACCREADY P、GEYER WR 和 BURCHARD H。河口交换流量与盐度差异预算的混合有关。物理海洋学杂志, 2018, 48(6): 1375–84. https://doi.org/10.1175/JPO-D-17-0266.1。

[19] ALMANIAR S、ROZIRWAN 和 HERPANDI。印度尼西亚南苏门答腊丹绒阿比阿比水域大型底栖动物的丰度和多样性。AACL 生物通量，2021，14：1486–1497。

[20] TOMPERI J、ISOKANGAS A、TUUTTILA T 等。在不断变化的水质和环境条件下测量浊度的功能。环境技术，2020：1-9。https://doi.org/10.1080/09593330.2020.1815860。

[21] CLOERN JE、JASSBY AD、SCHRAGA TS 等。沿河口盐度梯度的生态系统变异性：来自旧金山湾长期研究的例子。湖沼学与海洋学, 2017, 62(小号 1): S272–91. https://doi.org/10.1002/lno.10537。

[22] OLLI K、PTACNIK R、KLAIS R 等。沿海和河口盐度连续体的浮游植物物种丰富度。美国博物学家，2019，194(2)：E41-51。https://doi.org/10.1086/703657。

[23] QUIGG A、PARSONS M、BARGU S 等。海洋浮游植物对石油和分散剂暴露的反应：自深水地平线漏油事件以来获得的知识。海洋污染公报，2021，164：112074。https://doi.org/10.1016/j.marpolbul.2021.112074。

[24] QUIJANO-SCHEGGIA S、GARCÉS E、SAMPEDRO N 等。西班牙东北部海岸（加泰罗尼亚、西北地中海）的主要拟菱形藻属（硅藻科）的鉴定和特征。科学码头，2008, 72(2): 343–359. https://doi.org/10.3989/scimar.2008.72n2343。

[25] YAMADA M、OTSUBO M、KODAMA M 等。大阪湾和东京湾浮游和静止期细胞中骨条藻（硅藻纲）的物种组成。浮游生物和底栖生物研究，2014，9(3)：168–175。https://doi.org/10.3800/pbr.9.168。

[26] SAWAI Y、TANIGAWA K、SHINOZAKI T 等。加拿大不列颠哥伦比亚省温哥华岛潮汐环境中的硅藻（硅藻纲）组合。藻类研究，2022, 70(1): 3–21. https://doi.org/10.1111/pre.12470。

[27] BHARATHI MD、SARMA V 和 RAMANESWARI K. 热带河口浮游植物生物量及其组成的年内变化：河流流量的影响。海洋污染公报，2018, 129(1): 14–25. https://doi.org/10.1016/j.marpolbul.2018.02.007。

[28] HILALUDDIN F、YUSOFF FM 和 TODA T。与河口-红树林浮游植物群落的季节性变化相关的硅藻优势的变化。海洋科学与工程杂志，2020, 8(7): 528. https://doi.org/10.3390/jmse8070528。

[29] OGURA A、AKIZUKI Y、IMODA H 等。硅藻中肋骨条藻的比较基因组和转录组分析揭示了有害藻华基因的进化。BMC 基因组学，2018，19(1)：1-12。

[30] BEAMUD SG、BAFFICO G、REID B 等。光合性能与来自巴塔哥尼亚（阿根廷和智利）的双翅目（硅藻科）垫中的磷有效性相关。藻类, 2016, 55(2): 118–125. https://doi.org/10.2216/15-83.1。

[31] OGAWA Y、OKAMOTO Y、SADABA RB 等。菲律宾半封闭巴丹湾河口沉积物有机质来源估算和生态分类。国际沉积物研究杂志，2021, 36(1): 110–9. https://doi.org/10.1016/j.ijsrc.2020.05.007。

[32] LEE C. 和 LIM W. 马三是图片湾有害藻华的变化。亚洲科学，2006, 32(补充 1): 51–6. 10.2306/scienceasia1513-1874.2006.32(s1).051。

[33] SHEHATA N、MEEHAN K 和 LEBER DE。使用 MODIS 和快速 SCAT 卫星数据的东海中肋骨条藻有害藻华的海洋学。应用遥感学报，2012，6(1)：63529。https://doi.org/10.1117/1.JRS.6.063529。

[34] FENG C, ISHIZAKA J, SAITOH K, 等。一种基于反向散射的新方法，用于在日本有明海使用 MODIS 图像鉴别针叶藻（查通氏菌属.）和硅藻（骨条藻属.）的夏季水华。遥感，2020, 12(9): 1504. https://doi.org/10.3390/rs12091504。

[35] IAN Rongxiang, LIN Qun, LI Dewang, , 等 . 有害藻华事件期间营养物质的大气输送。海洋科学区域研究，2020，34：101007。https://doi.org/10.1016/j.rsma.2019.101007。

[36] TENG ST、ABDULLAH N、HANIFAH AH 等。马来西亚婆罗洲假菱形藻（硅藻科）的毒华和双壳类软体动物的软骨藻酸污染。毒药，2021，202：132–141。

[37] SAHU G、MOHANTY AK、SARANGI RK 等。冰

星星藻（科：脆科，纲：杆菌科，门：褐藻门）在卡尔帕卡姆（孟加拉湾，印度东南海岸）开花及其对浮游生物动态的影响。海洋学，2022，64(1)：145–159。

[38] RADCHENKO IG、SHEVCHENKO 副总裁、KRAVCHISHINA 医学博士等。角海链藻(杆菌科)在白海开花的首次记录：空间分布和相关物种。莫斯科大学生物科学通报，2018，73（4）：217-221。

[39] ROZIRWAN、APRI R 和 ISKANDAR I. 印度尼西亚南苏门答腊邦加海峡马斯帕里岛附近浮游动物丰度和多样性的分布。欧亚生物科学杂志, 2020, 14(2): 3571–3579.

[40] SAPUTRA A、NUGROHO RY、ISNAINI R 等。评论：微藻作为印度尼西亚南苏门答腊班纽阿辛河口海洋食品替代品的潜力。 埃及水生生物学和渔业杂志，2021，59：1053–1065。https://doi.org/10.21608/EJABF.2021.170654。

[41] NAIR PG、JOSEPH S、PILLAI N 等。微型浮游动物对印度西南海岸具有重要商业价值的小型远洋鱼类的营养意义。环境科学与污染研究, 2021, 28(45): 64394–64406. https://doi.org/10.1007/s11356-021-15452-7。

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