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Phytoplankton in Eutrophic Waters of Hurun Bay: An Examination of Composition Patterns, Structure, and Impacts on Aquatic Ecosystems

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***Abstract*— Ecological conditions are shifting due to increased anthropogenic activities along coastal areas. These activities are affecting the life cycle of aquatic organisms, especially phytoplankton. This study, conducted in the unique ecosystem of Hurun Bay Lampung, aims to analyze the composition and structure of phytoplankton communities in eutrophic waters and water quality conditions. Sampling was conducted in two different months, August and October, by vertical hauling from a depth of 5 meters to the surface. The results revealed a rich diversity of phytoplankton, with 72 genera, 48 families, and 6 classes identified in August, and 55 genera, 42 families, and 6 classes identified in October. The diatom group was the most prevalent, accounting for over 90% of the total, with the highest abundance found in *Skeletonema* and *Chaetoceros*. The diversity, uniformity, and dominance indices were all in the low to medium category, indicating a balanced ecosystem.**

Keywords— *Anthropogenic, Nutrient, Hurun Bay*

I. INTRODUCTION

H Hurun Bay, located on the coast of Lampung, Indonesia, is one of the water areas that has experienced significant eutrophication due to increased human activities, such as agriculture, settlements, and industry [1]. Eutrophication, a pressing global issue, is characterized by a buildup of nutrients, especially nitrogen and phosphorus, in waters, which then changes the ecological conditions of the seas [2][3][4]. This condition can affect water quality, ecosystem health, and overall environmental function, primarily by triggering excessive phytoplankton growth [5]. We must address this issue with urgency.

Phytoplankton is a significant component in the aquatic food chain and plays a crucial role in photosynthesis processes, nutrient cycling, and marine ecosystem dynamics [6][7][8]. Elevated nutrient levels and unpredictable seasonal patterns can lead to Harmful Algae Blooms (HABs) dominance in eutrophic regions, raising the risk of fish deaths in aquaculture zones [9]. Given the vital role of phytoplankton in aquatic ecosystems and the negative impacts that may arise from eutrophication, therefore, an understanding of the composition, pattern, and structure of phytoplankton communities in eutrophic waters is essential. Consequently, it is crucial to understand the composition and structure of phytoplankton communities as an initial step in preventing and mitigating risks to aquatic ecosystems.

This study, which aims to assess the pattern of phytoplankton community composition and structure in the eutrophic waters of Hurun Bay, holds the potential to provide valuable insights. By gaining a deeper understanding of phytoplankton dynamics in the context of environmental change, it is hoped that this research will pave the way for more effective management and conservation strategies, offering hope for the future of Hurun Bay.

II. METHOD

A. Time and Place of Research

This research, conducted in August and October of 2023, revealed significant findings about the abundance, diversity, uniformity, and dominance of phytoplankton in Hurun Bay, Lampung Province. Phytoplankton were identified and observed at the Fish and Environmental Health Laboratory, while environmental parameters were analyzed at the Lampung Marine Aquaculture Center (BBPBL) water quality laboratory. The research location map can be seen in Figure 1.

B. Data Collection Methods

Collecting research data is carried out through field observation and laboratory analysis. Apart from that, scientific literature review activities are also carried out to enrich the research results.

a. Phytoplankton Sampling

The phytoplankton sampling process was meticulously carried out. It involved vertical hauling by lowering a plankton net with a precise mesh size of 25 µm at a depth of 5 m, which was then slowly pulled to the surface. The filtered samples were carefully preserved in 100 ml sample bottles with the addition of 4% Lugol. Each sample was observed twice using the identification book The Marine Plankton of Japan [10] and Monograph on Marine Plankton of East Coast of India a Cruise Report [11]

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b. Measurement of Aquatic Parameters

Measurement of water quality parameters in situ (directly in the field) includes temperature, brightness, depth, Dissolved Oxygen (DO), and salinity. Meanwhile, ex-situ measurements include current direction pattern, pH, Total Organic Matter (TOM), phosphate (PO4), nitrate (NO3), and ammonia (NH3).

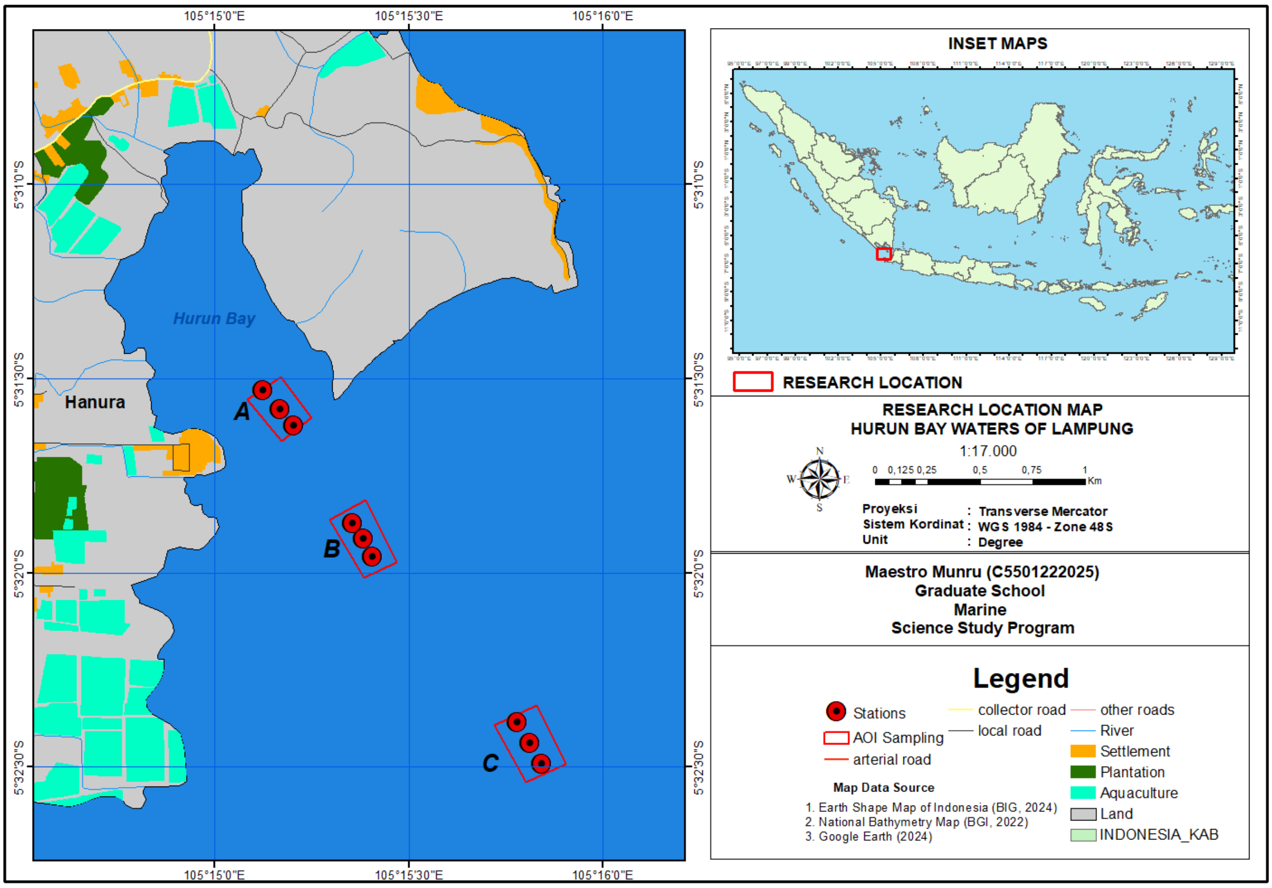

Figure 1. Map of the research location of Hurun Bay waters

C. Research Data Analysis

a. Phytoplankton abundance

Phytoplankton abundance was calculated by referring to [12] as follows:

$$N = n \frac{Vt}{Vcg} x \frac{1}{Vd}$$

N is the abundance of species (cells/l), Vcg is the volume of Sedgewick rafter (ml), Vt is the volume of filtered sample water (l), Vd represents the volume of filtered sample water (ml), and n is the number of enumerated cells.

b. Ecological index

The diversity index in each research zone was

Where E is the uniformity index, H' represents the Shannon-Wiener diversity index, H max is the natural logarithm of S, and S denotes the total number of species.

The dominance index is calculated based on the formula referring to Odum [13]:

$$C = \sum_{i:1}^{s} \left(\frac{ni}{n}\right)^2$$

analyzed based on the Shannon-Wienner theory

$$H' = - \Sigma Pi \ In\ (Pi) \text{ or } Pi = ni/N$$

H' represents the Shannon-Wiener diversity index, Pi refers to the number of individuals of the i-th species, and N is the overall count of individuals. Diversity is classified into three categories: low diversity ($H' < 1$), medium diversity ($1 \leq H' \leq 3$), and high diversity ($H' > 3$).

The uniformity index was analyzed using a formula based on Odum [13]:

$$E = \frac{H'}{H\ Max}$$

C represents the dominance index; Pi denotes the count of individuals of the i-th species, ni indicates the number of individuals of the i-th species, and n refers to the total number of individuals across all species.

c. Water quality

The results of water quality measurements are discussed descriptively by comparing the results with quality standards and literature.

d. Normality and significance of data

The results of phytoplankton abundance data were tested for normality to see whether the data were normally distributed. After that, further analysis was conducted to see significant differences between each observation station.

III. RESULTS AND DISCUSSION

A. Water Quality Parameters

As revealed by our study, the water quality conditions in Hurun Bay can be summarized by several critical environmental parameters, as detailed in Table 1.

TABLE 1.
WATER QUALITY PARAMETER VALUES IN AUGUST AND OCTOBER

Parameters	Research station									water quality standard
	23-Aug			27-Aug			30-Aug			
	A	B	C	A	B	C	A	B	C	
Brightness (m)	5,00	5,00	4,00	9,00	8,00	10,00	12,00	7,00	10,00	>5
Depth (m)	13,50	12,50	13,80	15,30	19,10	20,50	21,00	20,80	21,20	>7
Temperature (^{O}C)	29,40	29,50	29,40	29,10	29,10	29,30	29,10	29,10	29,30	25-32
Salinity (ppt)	31,00	32,00	31,00	32,00	32,00	32,00	32,00	33,00	32,00	28-33
DO (mg/l)	5,11	5,33	5,40	5,69	5,57	5,53	5,99	5,49	5,69	>5
pH	8,32	8,33	8,33	8,33	8,33	8,33	8,34	8,33	8,32	7-8,5
Phosphate (mg/l)	1,08	1,00	0,94	1,46	0,89	0,86	1,04	1,12	0,88	0,015
Nitrate (mg/l)	0,23	0,03	0,09	0,33	0,09	0,17	0,43	0,15	0,26	0,008
Ammonia (mg/l)	0,19	0,23	0,12	0,20	0,24	0,12	0,16	0,22	0,13	0,3
N:P	2,25	1,91	2,07	2,26	2,94	2,89	1,87	2,02	2,00	-
TOM (mg/l)	30,34	33,50	35,39	14,54	15,80	16,43	12,01	20,86	12,64	-

Parameters	Research station									water quality standard
	04-Oct			11-Oct			18-Oct			
	A	B	C	A	B	C	A	B	C	
Brightness (m)	4,00	5,00	4,00	11,00	14,00	10,00	10,00	16,00	10,00	>5
Depth (m)	10,90	10,40	11,50	18,50	20,00	20,40	21,60	22,30	21,00	>7
Temperature (^{O}C)	28,70	30,00	29,90	29,10	29,50	29,60	28,40	29,20	29,50	25-32
Salinity (ppt)	32,00	32,00	33,00	33,00	32,00	33,00	33,00	33,00	33,00	28-33
DO (mg/l)	5,77	5,36	5,63	5,89	5,56	5,86	6,10	5,64	6,00	>5
pH	8,35	8,38	8,32	8,36	8,37	8,33	8,33	8,37	8,33	7-8,5
Phosphate (mg/l)	0,92	0,33	0,76	0,98	0,33	0,69	0,59	0,33	0,68	0,015
Nitrate (mg/l)	0,10	0,13	0,10	0,12	0,18	0,27	0,14	0,10	0,05	0,008
Ammonia (mg/l)	0,11	0,35	0,38	0,33	0,33	0,33	0,30	0,33	0,32	0,3
N:P	1,68	1,50	4,23	13,62	13,77	13,67	6,33	7,35	6,77	-
TOM (mg/l)	19,59	18,33	15,80	21,49	12,01	8,22	26,54	34,76	24,65	-

(Note: A, B, and C are codes for the three observation stations. Water quality standard based on [14])

The temperature of the waters in Hurun Bay ranges from 28-30 oC; this temperature range shows that the waters of Hurun Bay are in average condition for the survival of biota [15]. Salinity in the waters in Hurun Bay is in the range of 31-33 ppt; the value of this range, according to [15], is the same as in coastal waters in general, which ranges from 28-33 ppt. Dissolved Oxygen (DO) is obtained in the range of 5.11-6.10 mg/l, describing waters with excellent oxygen availability in towards Lampung Bay, similar to the results obtained [17].

The TOM obtained ranged from 8.22-35.39 mg/l; the value obtained is relatively high, which illustrates that supporting the survival of organisms. [16] stated that waters with DO> 5 mg/l are optimal conditions for various biota to carry out their life cycle. The pH measurement results were very stable during the observation, which was 8.32-8.37. This study did not measure the current parameters directly but used data from satellite images taken from Marine Copernicus; the results obtained showed the pattern of the current direction in Hurun Bay as a whole directed outward the waters of Hurun Bay receive significant inputs of organic matter from the surrounding environment, raising concerns about potential environmental impact. Nitrate obtained during the study time ranged from 0.03-

0.43 mg/l; these results indicate that the nitrate concentration at the study site is also in the high enough category, according to [18], with a concentration of >0.2 mg/l, indicating that the waters have experienced eutrophication.

The phosphate concentration in the waters of Hurun Bay during the observation time was obtained in the range of 0.33-1.46 mg/l; the phosphate concentration was also very volatile in the two months of observation, but if seen in August, the concentration obtained was very high, namely more than one mg/l. The ammonia concentration obtained is in the range of 0.11-0.38 mg/l, a relatively stable value compared to the quality standards the government sets.

B. Phytoplankton Composition

The percentage of phytoplankton based on their constituent groups is presented in Figure 2.

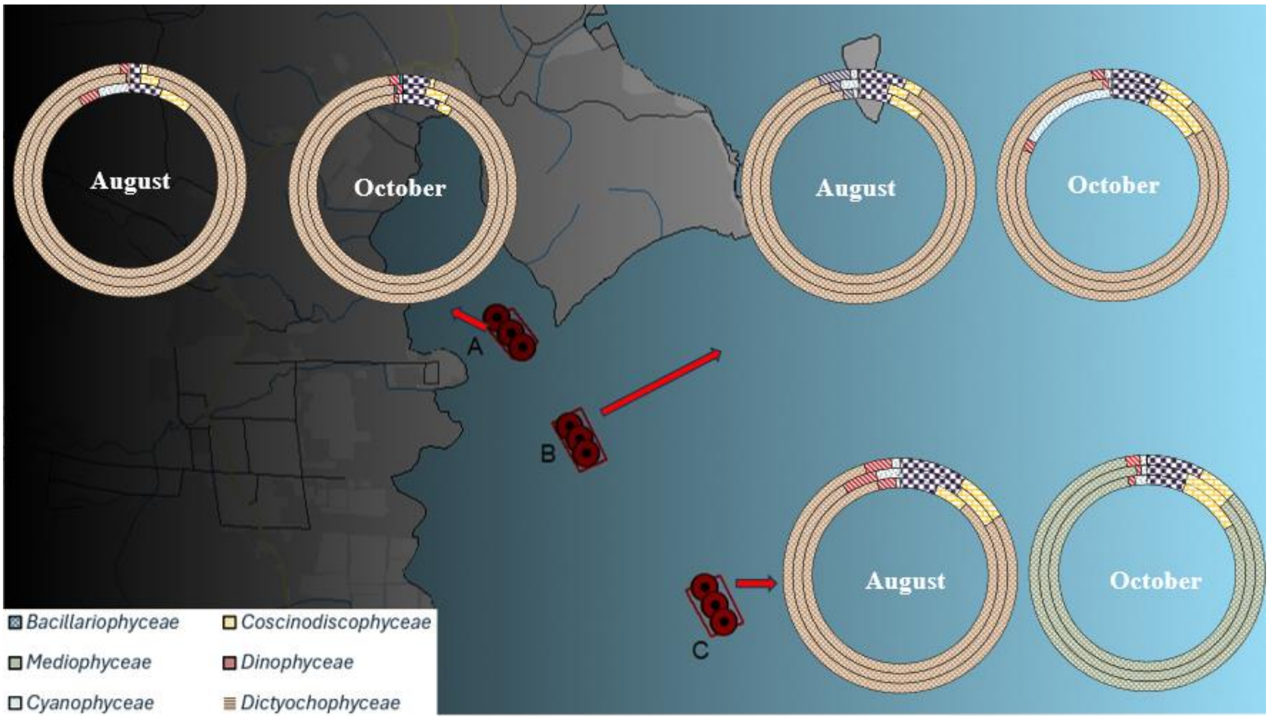

Figure 2. Percentage abundance of phytoplankton classes in August and October.

In August and October, phytoplankton from the diatom group was the most dominant species, and then phytoplankton from the dinoflagellate group occupied the second-highest abundance. The phytoplankton of the diatom group includes the *Bacillariophyceae, Mediophyceae*, and *Coscinodiscophyceae* classes. The percentage of diatom groups is >90%, with the *Mediophyceae* class as the leading pioneer. This phytoplankton overgrows to dominate the waters, with the ability to absorb nutrients and high adaptation, allowing diatom groups to survive and reproduce better than other phytoplankton groups [19] [20]. These diatom groups (*Bacillariophyceae, Mediophyceae,* and *Coscinodiscophyceae*.) have a relatively shorter life span than *Dinophyceae* or dinoflagellates so that after a period of diatom dominance the species composition will be dominated by dinoflagellate groups. Due to its ability to migrate vertically, some experts assume that the dinoflagellate class can utilize nutrient sources in deeper waters [21]. *Dinophyceae* is considered the most HABs-contributing phytoplankton group, so it often causes problems in aquatic ecosystems to trigger diseases that affect humans through bioaccumulation mechanisms from fish/shellfish consumed by humans [22].

C. Phytoplankton Abundance

72 genera from 48 families were identified at all observation stations in August. In contrast, observations in October experienced a decrease in the number of species to only 55 genera and 42 families. Differences in the composition of a body of water, especially at different times, are widespread in an ecosystem. Phytoplankton abundance in an ecosystem area cannot be separated from the physical and chemical factors of the environment [23]. However, the ability of phytoplankton to assess the appropriate environment is also a significant factor, causing compositional differences to be prevalent. Phytoplankton growth triggered by suitable environmental conditions will eventually decline until it is replaced by populations of other species or groups [24]. A graph of phytoplankton abundance can be seen in Figure 3.

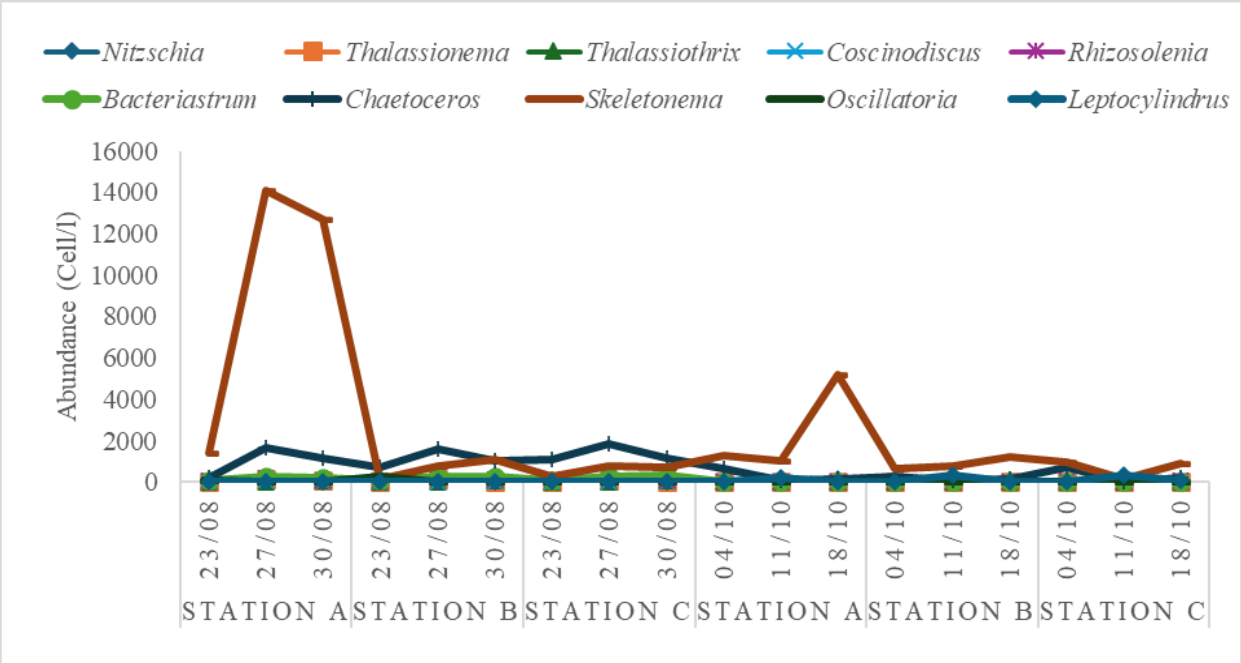

Figure 3. Phytoplankton abundance in August and October

Changes in the composition of the phytoplankton community are widespread, following changes in aquatic environmental conditions. When nutrients in the water column decrease, the composition of phytoplankton shifts [25]. In general, the abundance was dominated by Skeletonema and Chaetoceros in August and October. The abundance of these two phytoplankton was very high compared to the others, with abundance ranging from 153-14116 cells/l for August and 121-5178 cells/l in October, while Chaetoceros ranged from 238-1856 cells/l in August and 48-695 cells/l in October. The rapid ability and broad resistance to changes in aquatic environmental conditions are why Skeletonema and Chaetoceros are more common [26][27]. Water's chemical and physical characteristics affect and control life in aquatic habitats, causing the appearance and disappearance of certain types of biotas in the ecosystem [28]. Phytoplankton abundance during the observed study time was still in good condition and did not indicate blooming.

D. Ecological Index of Phytoplankton

The objective data on diversity, uniformity, and dominance indices in August and October, as presented in Figure 4, provides a clear picture of the ecological balance in Hurun Bay.

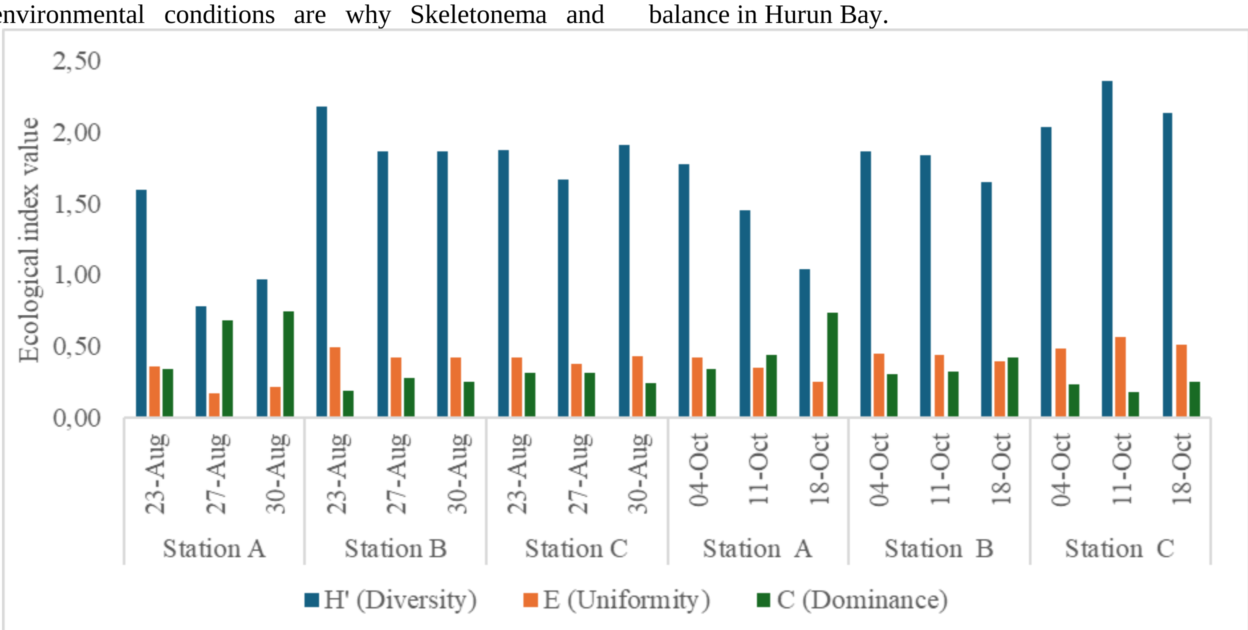

Figure 4. Diversity, uniformity, and dominance indices of Hurun Bay phytoplankton August and October.

In August, the diversity index value ranged from 0.78-2.18; in October, it was 1.04-2.35. The fact that the average diversity is categorized as moderate is significant, as it indicates a balanced diversity in the community; only a few fall into the low category. The value of the diversity of organisms in a community is primarily determined by the number of species and the number of compositions observed. Phytoplankton uniformity in August ranged from 0.18-0.49, while in October ranged from 0.25-0.57 in the low to medium category. The dominance index in August ranged from 0.19 to 0.74, while in October, it ranged from 0.18 to 0.73. The dominance category was high at station A, especially the observations of August 27, 30 and October 18, while the other stations were in the low to moderate category.

E. Normality and significance of data

The data normality test was conducted to determine whether the data were typically distributed during the study. If the data is usually distributed, Anova analysis is carried out. Still, if it is not normally distributed, the Kruskal Wallis test is carried out to see if there is a significant difference between observation stations. The results of the normality test can be seen in Table 3.

TABLE 2
NORMALITY TEST

	August			October		
Stastion	*Shapiro-Wilk*			*Shapiro-Wilk*		
	Statistic	df	sig.	Statistic	df	Sig.
A	.122	2	.000	.160	55	.000
B	.244	2	.000	.212	55	.000
C	.218	2	.000	.306	55	.000

The results of data normality show that the data are not generally distributed because if the Shapiro-Wilk sig value <0.05, then the data does not usually spread. So, proceed with the Kruskal Wallis test. The results of the Kruskal Wallis test can be seen in Table 4.

TABLE 3
SIGNIFICANCE TEST

	August			October		
	A	B	C	A	B	C
Chi-Square	7.732	4.434	2.369	6.000	3.200	3.600
df	2	2	2	2	2	2
Asymp. Sig.	.021	.109	.306	.050	.202	.165

Asymp. There is no significant difference in the sig (P-Value) value > 0.05, while if the Asymp.sig (P-Value) value < 0.05, then there is a considerable difference. The results of the Kruskal Wallis test show that the data are similar between the three observation stations.

CONCLUSION

The composition and structure of the phytoplankton community in the waters of Hurun Bay found 72 genera, 48 families, and 6 classes identified at all observation stations in August. A decrease in species occurred in October to only 55 genera, 42 families, and 6 classes. *Skeletonema* dominated phytoplankton abundance from the diatom group. There is no significant value difference between stations in the two months of observation. However, the waters were still in good condition and did not bloom, with high uniformity, diversity, and dominance indices at locations near land. Water conditions are generally suitable for marine organisms' survival and aquaculture activities, but nutrient conditions in the waters have exceeded normal limits, indicating eutrophication.

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