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SPATIAL DISTRIBUTION AND STRUCTURE OF PHYTOPLANKTON COMMUNITIES THAT HAVE THE POTENTIAL TO CAUSE HARMFUL ALGAE BLOOMS (HABS) IN THE WATERS OF LAIKANG BAY, SOUTH SULAWESI

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ABSTRACT

The presence of nutrients such as nitrate and phosphate can have a positive impact on phytoplankton growth. However, if the nutrient concentration is very high in the waters, it can cause an explosion in the phytoplankton population or Harmful Algae Blooms (HABs) in the waters. Phytoplankton explosions in waters have a negative impact on the surrounding ecosystem, marine biota, and humans. This research aimed to analyze the spatial distribution and structure of phytoplankton communities that can potentially cause HABs in the waters of Laikang Bay, South Sulawesi. This research was conducted in June 2021. The research found 20 species of phytoplankton HABs from 2 classes, namely Bacillariophyceae (8 types) and Dinophyceae (12 species). The Bacillariophyceae class has a higher percentage, 93%, and Dinophyceae at 7%. The abundance status of phytoplankton HABs is classified as not blooming, with the highest abundance found at Station 4 (control), namely 210 ± 80 cells/L. The HABs phytoplankton diversity index (H') is moderate with a value of 1.576 – 2.332, the uniformity index (E) of Station 1 (west) and Station 4 (control) is moderate with a value of 0.568 and 0.582 while Station 2 (north) and Station 3 (south) is classified as high, namely 0.807 and 0.823, the dominance index (D) is classified as low with a value of 0.135 – 0.357. Spatially, phytoplankton HABs based on the station can be divided into five groups. The results of the PCA analysis show that substations 1.A, 1.B, 1.C, 2.A, 2.B, and 2. C are characterized by high temperature and salinity parameters. Substations 3.A, 3.B, and 3.C are characterized by high nitrate and phosphate parameters. Meanwhile, substations 4.A, 4.B, and 4.C are characterized by high parameters of brightness, current speed, and pH and are associated with a high abundance of phytoplankton HABs.

Keywords: Phytoplankton, HABs, Laikang Bay.

INTRODUCTION

Plankton is essential in water as primary producers, and early in the food chain, so plankton is often used to indicate water fertility (Soliha et al., 2016). Plankton is divided into two groups, namely animal plankton (zooplankton) and plant plankton (phytoplankton). Phytoplankton are microscopic organisms floating near the water's surface (Soeprobowati & Suedy, 2011).

Phytoplankton has chlorophyll, which plays an active role in the photosynthesis process to produce organic material and oxygen in water, which is used as the basis of the chain in the marine food cycle (Aunurohim et al., 2008). The abundant presence of nutrients such as nitrate and phosphate in the aquatic environment has a positive impact, namely increasing phytoplankton production and total fish production. These nutrients can negatively impact high concentrations, namely a phytoplankton explosion or a Harmful Algae Bloom (HAB) (Choirun et al., 2015).

Harmful Algae Blooms (HABs) are the growth of phytoplankton in seawater and brackish water, which can emit toxins (Hidayati, 2020). The term HAB refers to the dense growth of phytoplankton in the sea, which can cause mass fish deaths, contaminate marine food (seafood) with toxins produced by phytoplankton and change the ecosystem (LIPI, 2008). The HAB phenomenon is caused by increased water fertility due to industrial activities around the coast, the entry of waste from land into the waters in large quantities, and upwelling (Barokah et al., 2016).

In Indonesia, there have been several fatal cases due to the HAB phenomenon, including in October 1982, when there was a bloom in the waters of Jakarta Bay, which was initially thought to be an oil spill. The next day, the phytoplankton decomposed, resulting in the death of many organisms, namely worms, fish, and other animals, and only the starfish could survive. The blooming in Jakarta Bay is thought to be due to an explosion in the population of Trichodesmium sp. phytoplankton. Another case occurred in the waters of the Lewotobi Strait (Flores) in November 1983; as many as 240 people were sick, and 4 people died after consuming sardine fish and selar fish (Adnan, 1985). From these several cases, we can see that the excessive growth of this algae population is hazardous for marine organisms and humans.

Laikang Bay in Takalar Regency has large marine and fisheries resource potential. The potential includes capture fisheries (small pelagic, crab, snapper, grouper, etc.), aquaculture (seaweed), and marine products (salt and marine tourism) (Zamroni & Istiana, 2017). Ecologically, these waters have an important role for marine biota, and economically, they are a place for people to earn a living through various activities such as seaweed cultivation and cultivation (of fish, shrimp, and lobster) through the floating net cage system. In connection with the function of these waters, every activity carried out in the Laikang Bay area has the potential to pollute the waters. Waste that continues to enter the waters due to fishing activities, household waste, and hot water discharge from the Punagaya Electric Steam Power Plant, which is discharged circularly into the waters, will result in the water quality of Laikang Bay decreasing, which can cause eutrophication and even the HABs phenomenon. The high potential of marine and fisheries resources in Laikang Bay should be supported by information regarding the potential and threats that could disrupt the balance of the ecosystem so that the potential in Laikang Bay can be utilized as best as possible. For this reason, research was conducted on "Spatial Distribution and Community Structure of Phytoplankton which has the Potential to Cause Harmful Algae Blooms (HABs) in the Waters of Laikang Bay, South Sulawesi."

MATERIALS AND METHODS

This research was carried out in June 2021. The sampling location was carried out in Laikang Bay, South Sulawesi. Dissolved oxygen parameters, current velocity, temperature, and water brightness were measured directly in the field. Meanwhile, pH, nitrate, phosphate, and salinity measurements were carried out at the Chemical Oceanographic Laboratory, Department of Marine Sciences, Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar. Phytoplankton identification was carried out at the Marine Microbiology Laboratory, Department of Marine Sciences, Faculty of Marine and Fisheries Sciences, Hasanuddin University, Makassar.

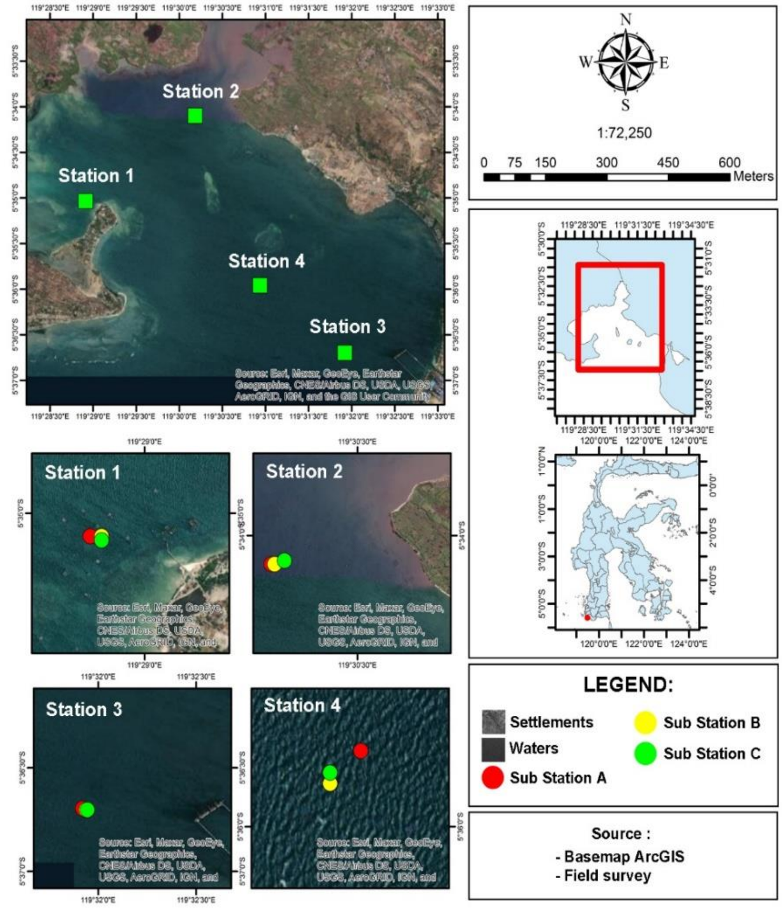

Figure 1. The sampling location at Laikang Bay, South Sulawesi.

Data Analysis

Phytoplankton Abundance

The abundance of phytoplankton in species is stated in the number of cells per liter of water volume. In calculating the phytoplankton abundance, the formula used is the following APHA (1992) :

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

Where:
N: abundance of phytoplankton (cell/L)
n: number of observed phytoplankton cells
Vt: volume of deposited samples (ml)
Vcg: volume of SRC (ml)
Vd: volume of deposited samples (L)

The proportion of Phytoplankton Species is calculated following Boyd (1979),

$$\text{Proportion of Phytoplankton Species (\%)} = \frac{Vt}{Vcg}\, x\ 100\%$$

Diversity Index (H')

The diversity index determines the diversity of species of aquatic organisms. The equation used to calculate this index is the Shannon-Winner equation (Magurran, 1988).

$$H' = -\sum Pi.\ \ln Pi$$

Where:
H': Shanon-Wiener Diversity Index
Pi: ni/N (proportion of plankton taxon)
Ni: number of Individuals in each Species
N: total number of Plankton

Evenness Index (E)

Calculation of uniformity index based on Odum (1993):

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

Where:
E: Evenness index
H': Diversity index

Dominance Index (D)

The Simpson dominance index is used to determine the dominance of certain species with the following equation (Odum, 1993):

$$D = \sum(Pi)^2 = \sum\left(\frac{ni}{N}\right)^2$$

Where:
D: Dominance index
Ni: Number of individuals of species-i (ind/l)
N: Total number of plankton per point (ind/l)

RESULTS AND DISCUSSION

Phytoplankton Community Structure of HABs and Their Abundance Status

Based on the results of phytoplankton identification, 18 species from 2 classes were found to have the potential to cause Harmful Algae Blooms (HABs) in the waters of Laikang Bay. Of the 20 species, are 8 species from the Bacillariophyceae class and 12 from the Dinophyceae class. Species from the Bacillariophyceae class are *Chaetoceros curvisetus* (442 cells/L), *Chaetoceros danicus* (215 cells/L), *Chaetoceros* sp. (2,050 cells/L), *Coscinodiscus* sp. (166 cells/L), *Nitzschia* sp. (56 cells/L), *Pseudonitzschia* sp. (400 cells/L), *Skeletonema* sp. (361 cells/L) and *Thalassiosira* sp. (216 cells/L). Meanwhile, there are 12 species of the Dinophyceae class, namely *Ceratium extensum* (88 cells/L), *Ceratium furca* (208 cells/L), *Ceratium fusus* (70 cells/L), *Ceratium macroceros* (79 cells/L), *Ceratium tripos* (5 cells/L), *Ceratium* sp. (9 cells/L), *Dinophysis acuminata* (13 cells/L), *Dinophysis acuta* (2 cells/L), *Dinophysis caudata* (18 cells/L), *Gonyaulax* sp. (5 cells/L), *Protoperidinium* sp. (177 cells/L) and *Prorocentrum* sp. (14 cells/L). The range (minimum-maximum) and average abundance of phytoplankton HABs at each observation station are shown in Table 1.

Table 1. The abundance (cell/L) and number of phytoplankton HAB species at each station.

Station	Range		Average ± SD	N	Number of types
	Minimum	Maksimum			
1 (West)	92 cell/L	105 cell /L	98 ± 6 cell /L	3	18
2 (North)	137 cell /L	161 cell /L	149 ± 12 cell /L	3	18
3 (South)	44 cell /L	61 cell /L	54 ± 9 cell /L	3	16
4 (Control)	130 cell /L	290 cell /L	210 ± 80 cell /L	3	15

The highest average abundance of phytoplankton was found at Station 3 (south), ranging from 130-290 cells/L with an average of 210 ± 80 cells/L. The high abundance value of phytoplankton HABs at Station 4 (control) is caused by physicochemical parameters that support the growth of the phytoplankton. Apart from that, the high value of current speed due to the station's location bordering the open sea affects the distribution of phytoplankton. This is in line with the statement by Permadi et al. (2015) that currents play a role in biological aspects, namely in the distribution of biota (for those with weak movement abilities, such as phytoplankton). The lowest average abundance value was at Station 3 (south), ranging from 44-61 cells/L with an average value of 54 ± 9 cells/L. The low abundance value at Station 3 (south) is thought to be due to the low current speed value because currents influence the distribution of phytoplankton in the waters. However, this station's nitrate and phosphate concentration has the highest value compared to other stations. According to Latuconsina (2019), excessive phosphorus accompanied by nitrogen can stimulate explosive algae growth in waters (algae bloom). Meanwhile, the research results showed that the abundance of phytoplankton at Station 3 (south) had the lowest value. This proves that the nitrate and phosphate values have not become a limiting factor for phytoplankton growth.

The results of the one-way ANOVA test showed that there were differences in phytoplankton abundance between observation stations. The calculated F value of 27.644 is greater than the table F value, indicated by a sig value <0.05.

A comparison of the proportion of abundance of phytoplankton that have the potential to be HABs and non-HAB phytoplankton can be seen in Figure 2, where non-HAB phytoplankton has a higher percentage, namely 51%, compared to HAB phytoplankton with a percentage of 49%. Mulyani et al. (2012) stated that phytoplankton that has the potential to cause HABs are divided into two groups, namely red tide makers and toxin producers

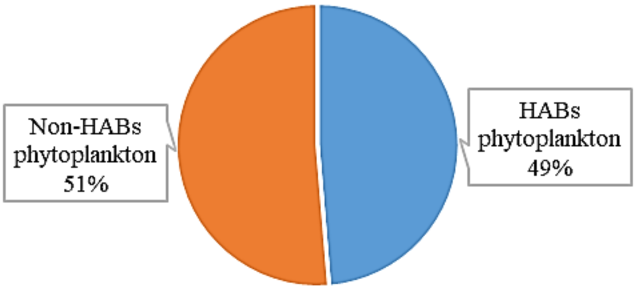

Figure 2. The proportion of HABs and non-HABs phytoplankton abundance in Laikang Bay.

Table 2. Grouping of phytoplankton that has the potential to cause HABs found in Laikang Bay.

No.	Species	Group	Reference
1.	*Ceratium extensum*	*Red tide maker*	Hasani *et al*., 2012
2.	*Ceratium furca*	*Red tide maker*	Hasani *et al*., 2012; Mulyani *et al*., 2012; Tambaru *et al*., 2020
3.	*Ceratium fusus*	*Red tide maker*	Tambaru *et al*., 2020
4.	*Ceratium* sp.	*Red tide maker*	Tambaru *et al*., 2020 and 2021
5.	*Ceratium tripos*	*Red tide maker*	Hasani *et al*., 2012
6.	*Chaetoceros* sp	*Red tide maker*	Mulyani *et al*., 2012; Thoha, 2016
7.	*Coscinodiscus* sp.	*Red tide maker*	Thoha, 2016
8.	*Dinophysis acuminata*	*Toxin producer*	Wiadnyana, 1996
9.	*Dinophysis acuta*	*Toxin producer*	Wiadnyana, 1996
10.	*Dinophysis caudata*	*Toxin producer*	Mulyani *et al*., 2012
11.	*Gonyaulax sp.*	*Red tide maker*	Mulyani *et al*., 2012; Thoha, 2016
12.	*Nitzschia* sp.	*Red tide maker* *Toxin producer*	Mulyani *et al*., 2012; Thoha, 2016
13.	*Prorocentrum* sp.	*Red tide maker* *Toxin producer*	Wiadnyana, 1996; Mulyani *et al*., 2012; Tambaru *et al*., 2021
14.	*Protoperidinium* sp.	*Red tide maker*	Tambaru *et al*., 2020 and 2021
15.	*Pseudonitzschia* sp.	*Toxin producer*	Gurning *et al*., 2020
16.	*Skeletonema* sp.	*Red tide maker*	Mulyani *et al*., 2012
17.	*Thalassiosira* sp.	*Red tide maker*	Mulyani *et al*., 2012

Phytoplankton HABs Ecological Index

The ecological index value of phytoplankton HABs in Laikang Bay can be seen in Table 3. The diversity index values of phytoplankton HABs in the waters of Laikang Bay are 1.642, 2.332, 2.282, and 1.576, respectively. Referring to the diversity index criteria, it can be said that all stations have moderate diversity where the value is 1.5 < H' < 3.5. This explains that phytoplankton are in optimal conditions for growth so that their diversity and stability are moderate. The uniformity index values in Laikang Bay are 0.568, 0.807, 0.823, and 0.582, respectively. Referring to the uniformity index criteria, Station 1 (west) and Station 4 (control) have moderate population uniformity (Harmoko & Sepriyaningsih, 2019). This value shows that the individual uniformity value between species of phytoplankton HABs is quite high, so it is assumed that the distribution of phytoplankton HAB species is even at each station. Then, at Station 2 (north) and Station 3 (south), the uniformity index values are classified as high uniformity. This shows that the community is in a stable state. The phytoplankton dominance index values obtained were 0.357, 0.135, 0.143, and 0.340, respectively. According to Harmoko & Sepriyaningsih (2019), the dominance index value ranges from 1 – 0. The higher the index value, the more visible biota dominates the bottom water substrate. On the other hand, if the number is closer to 0, no biota dominates, which is usually followed by a high uniformity (E) value. This shows that the HABs phytoplankton dominance index value in Laikang Bay is relatively low because it is close to 0. This value shows that no species of HABs phytoplankton dominate at each research station.

The Relationship Between Environmental Factors and the Distribution of Phytoplankton HABs

Several environmental parameters and physiological characteristics strongly influence phytoplankton growth in water. Various chemical and physical factors can influence phytoplankton's growth, survival, and productivity (Asriyana & Yuliana, 2014). The results of measuring the physical and chemical parameters of the waters in Laikang Bay can be seen in Table 4.

Table 3. Phytoplankton ecological index.

Index	Station			
	1 West	2 North	3 South	4 Control
Diversity index (H’)	1.642	2.332	2.282	1.576
Evennes Index (E)	0.568	0.807	0.823	0.582
Dominance Index (D)	0.357	0.135	0.143	0.34

Table 4. Physical and chemical parameters of waters in Laikang Bay.

Parameter	Station				Optimum Phytoplankton	References
	1 (West)	2 (North)	3 (South)	4 (Control)		
Temperature (°C)	30 ± 0	30 ± 0	30 ± 1	30 ± 0	20 - 30	Effendi (2003)
Brightness (m)	3.6 ± 0.3	3.8 ± 0.3	4.6 ± 0.1	5 ± 0.4	< 0.30	Maresi et al (2015)
Current speed (m/s)	0.150 ± 0.041	0.108 ± 0.027	0.047 ± 0.023	0.249 ± 0.054	-	-
DO (mg/L)	5.684 ± 0.033	5.738 ± 0.435	9.397 ± 1.039	6.098 ± 0.383	5	Marlian (2017)
pH	7.80 ± 0.01	7.82 ± 0.01	7.78 ± 0.01	7.85 ± 0	7 – 8.5	KEPMEN LH (2004)
Salinity (ppt)	34 ± 0	34 ± 0	29 ± 1	34 ± 1	10 – 40	Raymont (1980)
Nitrate (mg/L)	0.070 ± 0.038	0.043 ± 0.018	0.209 ± 0.076	0.043 ± 0.023	0.9 – 3.5	Marlian (2017)
Phosphate (mg/L)	0.048 ± 0.011	0.043 ± 0.005	0.099 ± 0.017	0.043 ± 0.006	0.015	KEPMEN LH (2004)

From the results of the PCA analysis, stations 1.A, 1.B, 1.C, 2.A, 2.B, and 2.C are characterized by high temperature and salinity values. Stations 3.A, 3.B and 3.C are characterized by high nitrate and phosphate values. Meanwhile, stations 4.A, 4.B, and 4.C are characterized by high brightness, current speed, and pH and are associated with high values of HABs phytoplankton abundance.

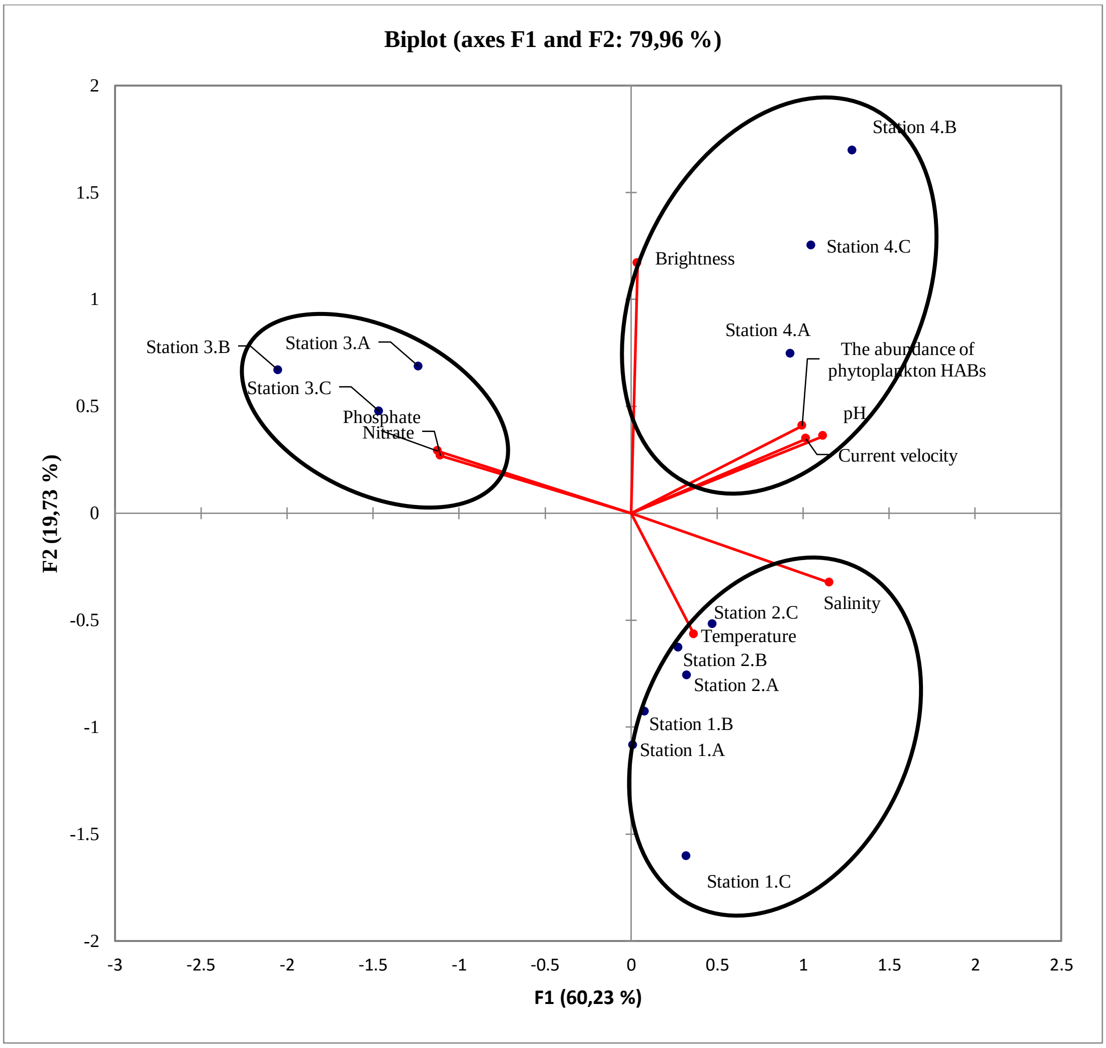

Figure 3. Biplot parameters using principal component analysis (PCA).

Spatial Distribution of Phytoplankton at Each Station

The spatial distribution of phytoplankton at each station was analyzed using the XLSTAT application with correspondence analysis (CA). Based on the results of the CA analysis, there are five groups. The first group consists of Stations 3.A and 3.B with characteristic phytoplankton HABs, namely *Ceratium furca*, *Dinophysis acuminata* and *Prorocentrum* sp. The second group consists of Station 3.B with characteristic phytoplankton HABs, namely *Ceratium tripos*, *Coscinodiscus* sp., and *Pseudonitzschia* sp. The third group consists of Stations 1.A, 1.C, 4.A, 4.B, and 4.C with characteristic phytoplankton HABs, namely *Chaetoceros danicus*, *Chaetoceros* sp., and *Dinophysis acuta*. The fourth group consists of Stations 1.B and 2.B with characteristic phytoplankton HABs, namely *Ceratium macroceros*, *Chaetoceros curvisetus* and *Skeletonema* sp. Then the fifth group consists of Stations 2.A and 2.C with characteristic phytoplankton HABs, namely *Ceratium extensum*, *Ceratium fusus*, *Ceratium* sp., *Dinophysis caudata*, *Gonyaulax* sp., *Nitzschia* sp., *Protoperidinium* sp. and *Thalassiosira* sp. (Figure 4).

Figure 4. Symmetric plot (CA) spatial distribution of phytoplankton HABs at each station.

CONCLUSION

Based on the research results, 20 species were found that have the potential to cause Harmful Algae Blooms (HABs), which fall into 2 categories, namely red tide makers and toxin producers, with abundance values ranging from 44-290 cells/L. The correspondence analysis (CA) results show five spatial groups with different characteristic phytoplankton species.

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