Temporal dynamics of the plankton community structure in Madura Strait: algae bloom study case

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Abstract. In March 2019 there was a phenomenon in the waters around the Suramadu Bridge in the Madura Strait, where surface water appeared in a different color layer. Madura Strait has a surface current with a range of 0.013 - 0.77 m/sec. In the west season to transition I (December-May) surface flows move from West to East and vice versa in the east season to Transition II (June-November) surface currents tend to move from East to West. Madura Strait is a river estuary in the city of Surabaya which tends to have poor / moderate polluted water quality due to the large amount of organic material input into the waters. Both of those causes the Madura Strait tends to have a high concentration of organic matter and primary productivity. Research aims on temporal dynamics in the structure of the plankton community in Madura Straits after blooming algae to analyze the abundance, distribution, diversity, and dominance index with temporal water quality indicators. Water samples were collected using Kitahara net for phytoplankton by filtering from bottom to surface. The density of plankton for each station was measured base on their biovolume bases. Genus of phytoplankton was identified for each station. Phytoplankton community consists of 15-21 species with Chaetoceros sp. as a dominant species. At least five species of Chaetoceros were identified when sea water had a color stratification and declined in subsequent observations. Chaetoceros sp.2 is the dominant species with abundance range 12,018 ind/L - 47,580 ind/L. The diversity index (Shannon Wiener index) shows the waters in poor condition with phytoplankton H' value range 0.2511 - 0.9543, and zooplankton H' value range 1.2566 - 2.0201. The dominance index (D) of phytoplankton 0.5282 - 0.9263 and zooplankton 0.1639 - 0.3882.

1. Introduction
The Madura Strait has an important role in East Java's economy in terms of its resources and contributing to the inter-island transportation sector in East Java and Indonesia. Industrial activity, port and population density on the coast of the Madura Strait contributes pollutants which affect environmental degradation and ecosystem productivity. Settlements and fish farming activities produce a lot of organic material waste which triggers eutrophication. Classically eutrophication was described as the enrichment of a water body leading to enhanced organic production [1].

Eutrophication is an enrichment of water with nutrients, primarily nitrogen and phosphorus, which stimulates primary production. In some cases, that leads to visible blooms and accumulation of submerged and floating organic material in the water [2]. Given the scale, the eutrophication process could be beneficial for the ecosystem, but it could have adverse effects depending on the different characteristics of each ecosystem [3,4]. Eutrophication initially caused an increase in phytoplankton...
biomass, but in terms of composition, the diversity of species making up the phytoplankton community decreased. In highly eutrophicated systems, the trophic chain is lacking higher links, and autotrophic processes exceed heterotrophic, which significantly affects the balance of the system [5,6].

Plankton as the first organism in a trophic structure will immediately be affected by changes in water quality. The composition and abundance of phytoplankton in a water plays a role as natural food at the next tropical level, also acts as a provider of oxygen in the waters.

Spatial and temporal analysis of the abundance and structure of phytoplankton communities in the waters of the Madura Strait is needed because of the dynamic environmental characteristics. The dynamics of the Madura Strait waters create heterogeneous conditions coupled with environmental stresses from anthropogenic activity. This study aims to obtain quantitative data based on the abundance and structure of phytoplankton communities and their relation to environmental factors as an effort to monitor environmental conditions and management of coastal areas in the Madura Strait.

2. Materials and Methods

The study sites are in Madura Strait. This research observation applied three station that randomly showed the difference color of sea water. The observing station was figure out on Figure 1.

![Figure 1. Research station in Madura Strait. A1, A2, A3 = sampling location](image)

Physical and chemical parameters (salinity, temperature, nutrients) were sampled simultaneously with phytoplankton samples to complete ecological characterization of the study area. Primary data was collected consist of biological parameter (phytoplankton) and data supplementary included physical and chemical aquatic. Phytoplankton sample was collected by filtering sea water about 100 liters. Kitahara plankton net was used to filter the seawater with average mesh size 45 micron and preserved the sample with formaldehyde to a final concentration of 2% formaldehyde-sea water solution.

Counting was performed in Sedgwick rafter counting chamber, using a compound microscope with magnification of ×40, and ×100 for different species, depending on their respective sizes. In the case of blooms or a high abundance of some species, counting was done in several randomly selected fields. Phytoplankton identification is purposes to observe the genus identification and compared to Newell and Newell book [7], Costal Marine Zooplankton [8].

Biological parameter phytoplankton was investigated in term of ecological index, types, and abundance. Phytoplankton abundance can be calculated using APHA modified [7].

\[ N = \frac{O_i}{O_p} \times \frac{V_r}{V_o} \times \frac{1}{V_s} \times \frac{n}{p} \]  

Where \( N \) = number of individual per liter; \( O_i \) = the glass area of the preparatory cover (mm\(^2\)); \( O_p \) = area of one field of view (mm\(^2\)); \( V_r \) = filtered water volume (ml); \( V_o \) = observed water volume (ml); \( V_s \) = volume of filtered water (L); \( n \) = the number of plankton on the entry field of view; \( p \) = the number of observed field of view.
Ecological index observation consisted of variance index Shannon-Wiener Index, \( (H') \), and dominate index Simpson's Index \( (D) \). Index calculation used \cite{9}:

\[
H = -\sum_{i=1}^{S} P_i \ln(P_i) \\
D = \sum_{i=1}^{S} P_i^2
\]

Where \( P_i = \frac{N_i}{N} \), \( N_i \) is the number individual of genera \( i \), \( N \) is total number individual of genera, \( S \) is the number of species.

3. Results and Discussions

From the three sampling locations in the two observation periods at least 21 phytoplankton taxa were identified. Based on the phytoplankton sample, this research identified about 18 genus that classified into 11 family (Figure 2) i.e., Biddulphiaceae, Ceratiaceae, Melosiraceae Chaetocerotaceae, Coscinodiscaceae, Dinophysaceae, Lithodesmiaceae, Fragilariaceae, Naviculaceae, Rhizosoleniaceae, Surirellaceae. Phytoplankton species indicated that Chaetoceros, centric diatoms contributed to 94% of phytoplankton population.

![Figure 2. Phytoplankton taxa and family composition in Madura Strait](image)

Phytoplankton from Chaetocerotaceae, Biddulphiaceae, Melosiraceae and Fragilariaceae were grouped in Bacillariophyta phylum (diatom) where the most populated in marine ecosystem. This finding was identically other researcher report that phytoplankton marine ecosystem was diatomic such as (Bacillariophyceae, Fragilariophyceae and Coscinodiscophyceae), Dinoflagellata (Dinophyceae) and blue algae (Cyanophyceae) \cite{8}. The population were calculated Chaetocerotaceae 79035 ind.L\(^{-1}\), Biddulphiaceae 891 ind.L\(^{-1}\), Melosiraceae 1577 ind.L\(^{-1}\) and Fragilariaceae 627 ind.L\(^{-1}\) or 94%, 1%, 2% dan 1%, respectively (Figure 2).

The composition and abundance of the phytoplankton genus at each location are shown in Figure 3. Chaetoceros sp. is one of the diatom species. Diatoms (phyla Heterokontophyta, Bacillariophyta class) is unicellular, though there are various aggregate species which group together and form a colony like a chain. Diatom cells are covered by cell walls made of silicate. Diatoms are efficient producers of photosynthesis, producing much of the food that living things need (the food is the diatom itself), and oxygen \( (O_2) \) as a result of photosynthesis. Diatoms are very important in open water, acting as a major producer in temperate and polar regions \cite{10}.

Diatom dominated in the marine ecosystem due to easily adapt in the environment condition, resist to extreme condition, and highly reproductive \cite{8}. Cell regeneration diatomic depend on environment and species. Generally, cell regeneration come up between 10-12 hours and other species around 18-48 hours.

Biodiversity is one of the primary interests of ecologists but quantifying the species diversity of ecological communities is complicated. In addition to issues of statistical sampling, the rather arbitrary nature of delineating an ecological community, and the difficulty of positively identifying all of the species present, species diversity itself has two separate components: 1. the number of species present
(species richness), shown in Figures 2 and 3. Their relative abundances (termed dominance or evenness), showed in Figure 4. The diversity index ($H'$) of phytoplankton at each of the three locations was 0.84; 0.78 and 0.95 (Figure 4). A diversity index is the measure of species diversity in a given community. The Shannon diversity index value between 0 and 1. Note that lower values indicate more diversity while higher values indicate less diversity. Specifically, an index value of 1 means that all groups have the same frequency. Based on the diversity index values, each research location can be inserted into poor conditions. Lower species diversity and richness accompanied with dominance of fast growing centric diatoms over pennates observed at Madura Strait act as an index for detection of organic pollution and nutrient enrichment.

![Phytoplankton Abundance - period 1](image1)

![Phytoplankton Abundance - period 2](image2)

Figure 3. Phytoplankton composition and abundance in Madura Strait
Figure 4. Plankton diversity and dominance index in Madura Strait

The dominance index indicates a high value which specifies the dominance of certain species in the Madura Strait waters. High species dominance is caused by the high density of one of the species that is found, namely Chaetoceros sp. If the dominance index approaches 1, it indicates that in the community structure there are one or several species that dominate the other types. Conversely, if the dominance index approaches 0, it shows that in the structure of the community there is no species that is extremely in dominating other species [11].

4. Conclusions
This research resumed varieties and phytoplankton abundance in Madura Strait about 21 genus that classified into 18 family and 4 dominant family Chaetocerotaceae, Biddulphiaceae, Melosiraceae and Fragilariaceae. Diatoms were the most represented group of the phytoplankton community in all three locations. Ecology index calculation was classified poor condition Madura Strait, and blooming population of Chaetoceros sp. occurs.

References
[1] Patricia, M.G. (2017). “Eutrophication, harmful algae and biodiversity - challenging paradigms in a world of complex nutrient changes”. Marine Pollution Bulletin 124:591-606.
[2] Vollenweider, R.A. (1976). Advances in Defining Critical Loading Levels for Phosphorus in Lake Eutrophication. Memorie dell'Istituto Italiano di Idrobiologia, Dott. Marco de Marchi Verbania Pallanza.
[3] Crossetti, L.O., Bicudo, D.C., Bicudo, C.E.M. and Bini, L.M. (2008). “Phytoplankton biodiversity changes in a shallow tropical reservoir during the hypertrophication process”. Brazilian J. of Biology 68(4):1061–1067.
[4] Viličić, D. (1989). “Phytoplankton population density and volume as indicators of eutrophication in the eastern part of the Adriatic Sea”. J. of Hydrobiologia 174(2):117–132.
[5] Richardson, K., Nielsen, T.G., Pedersen, F.B., Heilmann, J.P., Lokkegaard, B. and Kaas, H. (1998). “Spatial heterogeneity in the structure of the planktonic food web in the North Sea”. Marine Ecology Progress Series 168:197-211.
[6] Bužančić, M., Gladan, Ž.N., Marasović, I., Kušpilić, G. and Grbec, B. (2016). “Eutrophication influence on phytoplankton community composition in three bays on the Eastern Adriatic Coast”. Oceanologia 58(4):302-31.
[7] Newell, G.E. and Newell, R.C. (1977). Marine Plankton a Practical Guide, 5th ed. Hutchinson Educational Ltd, London.
[8] Todd, C.D., Laverack, M.S. and Boxshall, G. (2003). Coastal Marine Zooplankton, 2nd ed. Cambridge University Press, Great Britain.
[9] APHA (American Public Health Association) (2005). Standard Methods for American Public Health Association. American Public Health Association, Washington DC.
[10] Huber, M.E. and Castro, P. (2007). Marine Biology, 6th ed. The McGraw Hill Companies, Inc, New York.

[11] Pirzan A.M. and Pong-Masak P.R. (2008). “Relationship between phytoplankton diversity and water quality of Bauluang Island in Takalar Regency, South Sulawesi”. J. of Biological Diversity 9(3):217–221.