A SPATIO-TEMPORAL ANALYSIS ON THE COMPOSITION AND ABUNDANCE OF PHYTOPLANKTON IN SEGARA ANAKAN LAGOON AREA

Rose Dewi 1,3*, Muhammad Zainuri 2,4, Sutrisno Anggoro 3, Tjahjo Winanto 1

1 Fisheries and Marine Science Department, Jenderal Soedirman University
2 Department of Oceanography, Fisheries and Marine Science Department, Diponegoro University
3 Doctoral Program of Coastal Resources Management, Department of Fisheries and Marine Science, Diponegoro University
4 Centre of Excellent Mitigation of Natural Disaster and Coastal Rehabilitation, Diponegoro University
*Corresponding author: rose.83unsoed@gmail.com

Abstract. SegaraAnakan Lagoon (LSA) is a dynamic estuary with humid tropical climate, of which water fluctuates as the result of water hydrodynamics and changes in monsoon. The LSA area is influenced by natural factors (estuary of freshwater flow of Citanduy Watershed and high sedimentation) and various anthropogenic factors. Such conditions may influence the water’s ecological conditions. This research aims at examining such ecological changes as phytoplankton’s biological indicators (composition and abundance), since phytoplankton is able to naturally respond to environmental changes. The method is conducted with spatially in-situ measurement on phytoplankton abundance in the seven areas of SegaraAnakan Lagoon with different characteristics: (1) TPI and Port of Majingklak; (2) Pelawangan Barat LSA bordering the Indian Ocean; (3) Locks of Cikonde and Cimeneng Rivers; (4) Mangrove Forest; (5) Kampung Laut Community Settlement; (6) Conservation Area “Mina Wisata” Ujung Alang; (7) Floating Net Culture. A temporal approach (time series) is then conducted for 1 year based on the representativeness of monsoon: West, Transition I, East and Transition II. Phytoplankton abundance is quantitatively analyzed using Lackey Drop Microtransect Counting method, and for ease of spatio-temporal interpretation, the results are displayed in the form of thematic map using Arc Gis 10.2 software. The analysis results show that spatially, the phytoplankton abundance in the seven areas ranges from 4474.80 ± 3408.25 – 8712.00 ± 6444.89 indv/L. Meanwhile, with the temporal analysis, the highest abundance takes place in the Transition I season of 9956.57 ± 5300.23 indv/L, and the lowest is in West season of 4129.71 ± 3139.88 indv/L. In the whole spatio-temporal period, the phytoplankton composition is dominated by Division Chrysophyta, and then respectively by Divisions Chlorophyta, Cyanophyta, Pyrophyta and Euglenophyta. The composition and abundance of freshwater, estuary and sea phytoplankton are spatio-temporally evenly distributed in the seven areas, which is expectedly resulted from the Flushing Time mechanism from freshwater flow of Citanduy Watershed and the influence of water hydrodynamics of Indian Ocean at Pelawangan Barat entering the lagoon area.

Keywords: Monsoon, Phytoplankton, SegaraAnakan Lagoon, Spatio–Temporal

Introduction

Cilacap Regency covers a coastal area of 225,361 km². According to Act No. 27 of 2007 j.o Act No. 1 of 2014 on the Management of Coastal Area and Small Islands, coast is a transitional area between land and sea ecosystems and is under influence of changes in land and sea. This coast includes the SegaraAnakan Lagoon (LSA) area, which is shielded by Nusa Kambangan Island from Indonesian Ocean Waters and surrounded by river mouths, particularly Citanduy Watershed, thus land’s influence is highly dominant with sedimentation process. Land conversion for various anthropogenic activities in its surrounding causes high process of sedimentation and expansion of mangrove vegetation in the lagoon area. Such conditions cause the depth and size of lagoon water to decrease [1]. Dahuri [2] states that
various anthropogenic activities which cause erosion of an ecosystem, such as land clearing for settlement, agriculture and industry without terracing around the river, may cause sediment on surface flow (surface run off) to increase. Such sediment will enter into the bodies of rivers and go to the lagoon, coastal area and the sea. As reported by [3;4], sediment derived from land use for anthropogenic activities contains organic matter. The contents of Nitrogen (N) and Phosphate (P) organic matter are strongly bound by water molecules, resulting in high concentration in the sediment. There is an ecological change in the quality of water (nutrient loading) or enrichment of organic matter from the perspective of biological indicators, which are the composition and abundance of phytoplankton. The reason is that phytoplankton has the ability to naturally respond to ecological changes [5, 6] and [7] add that phytoplankton may tolerate unstable condition in water, such as a high increase in organic matter, and quickly respond to various forms of pollutant entering body of water, as marked with a change in type dominance, change in community structure, biomass of phytoplankton and fluctuation of chlorophyll content [8; 9].

Moreover, Pintado, et al.,[11] state that weather (rainfall pattern) as the controlling factor in nutrients fluctuation significantly influences organic matter fluctuation. The lagoon area highly depends on closed and open waters and annual (rainy and dry) seasons, which will influence the structure of community and abundance of phytoplankton. Seasons are the cause of variation in primary productivity in the water [5]. The biological parameter serving as the initial indicator directly influenced by such changing season conditions in the water is phytoplankton, which does not only serves an important role in the flow of energy of primary producer, but may also serve as the bio-indicator of fertility level of a water with observation of the composition and abundance of phytoplankton [12; 13]. Therefore, this research aims at studying the ecological change in the LSA area as the biological indicator of phytoplankton (composition and abundance) both spatially, by comparing the difference in characteristics of the research’s station location, and temporally (time series) of the Indonesian Waters influenced by the monsoon pattern.

Materials and Method

The analysis on the composition and abundance of phytoplankton in the LSA Area in this research is conducted in the temporal period (time series) in 2016, in which the measurement is conducted based on monsoon representativeness. Pursuant to the statement of Nontji [14], that based on the data of the Meteorology and Oceanography Body, the Indonesian waters are influenced by monsoon, consisting of: West Season: December – February (Representativeness of sampling in February and December); Transition Season I: March – May; East Season: June - August; Transition Season II: September – November.

Such reference is taken for the time of phytoplankton sampling in-situ with spatial approach in the research’s seven stations with ecological difference in characteristics (Table.1).

- The phytoplankton is sampled vertically using plankton-net 25 µm by screening 100 liters of water on the surface of lagoon water at depth of 0.5 - 1 m (APHA, 2005).
- The samples are preserved using formalin up to 4% [14] for 10 drops and identified using binocular light microscope with 40 times magnification. The sample phytoplankton is observed under microscope having them dropped onto the object glass and covered with cover glass. The calculation is conducted with 20 times of field of vision and repeated 3x. It is then identified using: identifying Marine Phytoplankton, Tomas, C.R [15]; Planktonologi, Sachlan, [16] and Marine Plankton, a practical guide, Newel and Newel [33]. The abundance of phytoplankton is calculated using the formula based on the Lackey Drop Microtransect Counting method [17].

Table. 1 Characteristics of Spatial Approach of Phytoplankton Sampling in Segara Anakan Lagoon Area, Cilacap Regency

| Characteristics | Ordinate                  |
|-----------------|---------------------------|
| 1 TPI and Port of Majingklak | 108°48'02.4"BT 07°40'27.6"LS |
| 2 Gate (Pelawangan Barat) of LSA directly bordering the Indian Ocean | 108°46'56.7"BT 07°41'59.0"LS |
| 3 Locks of Cikonde and Cimeneng Rivers | 108°49'47.9"BT 07°40'34.6"LS |
| 4 Mangrove Forest Area | 108°51'36.5"BT 07°41'44.9"LS |
| 5 Kampung Laut Community Settlement | 108°52'14.0"BT 07°42'19.5"LS |
| 6 Conservation Area “Mina Wisata”UjungAlang, Kampung Laut Subdistrict | 108°52'45.4"BT 07°42'55.4"LS |
| 7 Floating Net Culture Area | 108°48'56.0"BT 07°41'01.0"LS |
The data obtained are displayed in the table and analyzed descriptively and reviewed based on the literature [18]. For ease of spatio-temporal interpretation, the result of calculation of the composition and abundance of phytoplankton is displayed in the form of a thematic map using Arc Gis 10.2 software with output in the form of image format (Jpeg) equipped with a pie chart. The big and small sizes in figure show the quantity of abundance of phytoplankton, while color variation in the pie chart shows the composition (divisions of phytoplankton).

Results and Discussion

The research sampling results in 82 types of phytoplankton from 5 (five) divisions, which are 54 types of Chrysophyta, 13 types of Chlorophyta, 8 types of Cyanophyta, 3 types of Pyrophyta and 4 types of Euglenophyta. The quantity of abundance of phytoplankton with the spatial approach (characteristics of the research’s 7 stations) and temporal approach (monsoon) is presented in (Table 2).

Division Chrysophyta dominate most of the seasons and stations, of class Bacillariophceae (diatom), particularly: Gyrosigmakuetzingii; Cyclotella, sp.; Neidium Affine, Cymbellanaviculiformis; Melosira granulate; Chaetoceros, sp.; Rhizosoleniarobusta; Coscinodiscuslinetus; Thalassiosirarotula, Navicula, sp. and various species of genus Nitzschia. The reason is, according to Basmi [32], that diatoms are an important (adaptive) species in phytoplankton population and are the key to every collection of planktonic algae (identification). The other phytoplankton found in the LSA includes Division Chlorophyta: various species of genus Scenedesmus, Closteriumlunula, Coelastrumastroideum and Pediastrum simplex; Division Cyanophyta: Oscillatoriaprinceps, Lyngbyabarberie, Anabaena hallensi; DivisionPyrophyta (dinoflagellata): Peridinium, sp.; and Division Euglenophyta: Trachelomonas, sp.; Phacus, sp.

Table 2 Measurement of Abundance of Phytoplankton in the Water of Segaran Anakan Lagoon Area with Spatio-Temporal Approach

| Spatial Approach | Abundance of Phytoplankton (indv/L) |
|------------------|-------------------------------------|
| West Season (February) | 8355.60 ± 3049.46 |
| Transition Season I | 4474.80 ± 3408.25 |
| East Season | 6058.80 ± 1860.57 |
| Transition Season II | 8712.00 ± 6444.89 |
| West Season (December) | 7286.40 ± 4137.68 |
|  | 5940.00 ± 4356.00 |
|  | 5742.00 ± 1945.04 |

There is variation of types of freshwater, estuary and sea phytoplankton obtained spatio-temporally throughout the research which, according to Hawkes (1978) in Suryanti [19], is expectedly because of the influence of hydrodynamic factor in the water: direction and speed of flow, which influences the composition and abundance of plankton. Such factors play a role in the process of migration and distribution of plankton as an organism with passive movement.

Abundance of Phytoplankton and spatial approach

The highest abundance of phytoplankton (Table 2) during the research takes place in the mangrove forest area (station 4) of 8712.00 ± 6444.89 indv/L which, according to Riddet al. [20], water around mangrove forest plays a key role in the nutrients cycle since it is rich of nutrients. That the abundance of plankton is high is because the station is known as an area with fertile organic matter producing characteristics. Layborn and Parry [21] add that mangrove ecosystem may potentially generate productive organic matter through leave brown waste. After decomposition process by bacteria and protozoa, the next cycle produces macronutrients (N and P) which are the key to water fertility. The degree of macronutrient contents in the water will then influence the abundance and chlorophyll-a content of phytoplankton [8;9].

Meanwhile, the lowest abundance takes place in (station 2), which is the gate (Pelawangan Barat) of LSA directly bordering the Indian Ocean, of only 4474.80 ± 3408.25 indv/L. The reason is expectedly that the growth of phytoplankton depends on fluctuation of nutrient elements and hydrodynamics in the water [22]. Moreover, Ji [23] states that an estuary area is highly influenced by the tidal dynamics. The hydrodynamic factor in the water of station 2 expectedly causes nutrients in this station to be distributed and enter into the lagoon (other stations) besides runoff of nutrients from Citanduy Watershed into the lagoon. This is supported by Chua’s statement (1970) in Sediadi & Sutomo [24] that in tropical waters, phytoplankton’s cell division process occurs quickly and the quantity is abundant towards
land as the result of nutrients intake from land through river and, on the contrary, tends to decline offshore. This causes the station inside the lagoon to have higher abundance of phytoplankton than station 2.

**Abundance of Phytoplankton and Temporal Approach**

The result of five temporal abundance measurements (monsoon) as outlined in (Table.2) throughout year 2016 shows that the highest abundance of phytoplankton takes place in Transition Season I of 9956.57 ± 5300.23 indv/L with sampling in May. According to Nontji [14], during the transition season, there will be uncertain but generally relatively calm wind power and direction pattern. This transition season will determine the distribution of phytoplankton’s chlorophyll, both spatially and temporally. That the abundance in transition season I is high is expectedly caused by upwelling (increase of water mass), causing nutrients from water’s inner layer to be lifted upwards and fertilize (enrich with nutrients) the surface layer. The upwelling causes primary productivity to increase, as reflected with an increase in abundance and chlorophyll of phytoplankton.

Meanwhile, the lowest abundance takes place in West Season (December) or rainy season of 4129.71 ± 3139.88 indv/L. The reason, according to Panggabean [25], is that in tropical region, eutrophication is likely to occur in rainy season. Eutrophication will occur in the water with weathering of organic matters derived from river mouth by various anthropogenic activities, causing an increase in nutrients entering into coastal water. In eutrophic condition, only certain types of phytoplankton may adapt well and respond quickly with blooming [26]. Besides such factor, the low abundance in West Season in the research is expectedly because of the Flushing Time mechanism derived from the freshwater flow of Citanduy Watershed supported with high rainfall. Based on BMKG’s data, the rainfall in the LSA area in December ranges from 483-958 mm. Dyer [27] further explains that Flushing Time is the time a water needs for replacement of freshwater (flushing) in lagoon area. Such condition causes the abundance of phytoplankton to be distributed towards the sea (Indian Ocean). Pednekar [28] adds that in tropical region, run off influenced by rainy reason will play a role in the spatio-temporal distribution of types of phytoplankton.

![Figure 1: Spatio-Temporal Composition of Phytoplankton in the Segara Anakan Lagoon area in 2016](image-url)

**Figure 1. Spatio-Temporal Composition of Phytoplankton in the Segara Anakan Lagoon area in 2016,** (A) West Season (February); (B) Transition Season 1; (C) East Season; (D) Transition Season 2; (E) West Season (December)

**Composition of Phytoplankton with Spatio-Temporal Approach**
The composition of phytoplankton during the research shows that Division Chrysophyta with abundance of 31957.2 ± 15795.75 indv/L dominates most of the stations (spatial) and season (temporal), particularly with class Bacillariophyceae (diatom). Division Chlorophyta (4831.2 ± 2443.51 indv/L) increases in abundance, particularly in West Season (February) at station (1,2,3,4) and in transition season II (2,6,7), and although found in most of the seasons, but with low abundance. Division Cyanophyta (7603.2 ± 6113.36 indv/L) increases in abundance from transition season I (7), east season to transition season II (at all stations). Division Pyrophyta (673.2 ± 892.09 indv/L) tends to adapt well with an increase of abundance of phytoplankton, particularly in West Season in December (2, 3) and February (1,3,4,5,6,7) until transition I (5), but from east season to transition season II, there is no abundance of Division Pyrophyta found. Division Euglenophyta (1504.8 ± 665.58 indv/L) increases in abundance from east season (1), transition season II (5) to West Season (1), although not in all stations.

Spatio-temporal changes in the composition and abundance of phytoplankton are the form of adaptation to the change in ecological condition in the water, since phytoplankton plays an important role in water that, besides serving as the primary producer, it may also respond to environmental changes [29]. Odum [30] adds that the dynamic of abundance and community structure of phytoplankton are influenced by its form of adaptation to physical and chemical factors in the water, particularly the availability of nutrients and phytoplankton’s ability to utilize them. Phytoplankton community is controlled by dominant species, showing such species’ power against other species. Dominant species and lost species will cause important changes in phytoplankton community ecologically. Some plankton species may be abundant (blooming) in eutrophic water, while the other species are sensitive to organic waste and will be lost. The composition of species of plankton may also mark the quality of water mass [31].

The identification finds some types of phytoplankton are able to produce toxin which may potentially be (HABs) Harmful Algae Blooms in West Season (rainy season) to transition season I, particularly at station around anthropogenic activities. So far, however, there is no clear threshold of quantity of phytoplankton during blooming. Such condition is commonly only marked with a change in domination of type, change in community structure and biomass of phytoplankton [8; 9]. Moreover, Mulyasari, et al. [10] state that phytoplankton blooming condition may occur when the quantity of abundance is higher than the average quantity of phytoplankton annually.

Conclusion and Suggestion

Conclusion

The fluctuation of abundance and composition of phytoplankton in the LSA Area is influenced by difference in ecological characteristics of the research’s stations (spatial) or temporally. The monsoon pattern, supported with hydrodynamic of the water (tide, flow), Upwelling mechanism, Flushing Time and macro nutrients in the water, will spatially influence forming of the research stations’ characteristics. Such condition leads to a change in dominance of type, change in community structure and biomass of phytoplankton as the form of adaptation of the change in the ecological condition of the water, as marked with change in the composition and abundance of phytoplankton.

Suggestion

Based on type identification, with the finding of phytoplankton capable of producing toxin which may potentially be (HABs), the Local Government, related parties and surrounding community need to prepare a lagoon management strategy to maintain ecological stability in the LSA Area, particularly in relation to land conversion for various anthropogenic activities, since they are expected to increase macronutrients which may lead to dominance of HABs type phytoplankton, although will not be easy that there are ecological differences in the lagoon from the upstream (freshwater) to the downstream (seawater). With its geological factors, the lagoon is a very active hydrology zone which is highly sensitive to environmental changes.

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