Plankton Community and Water Quality During Maximum Tidal Range in Segara Anakan Cilacap

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Abstract. Segara Anakan Cilacap waters consist of lagoon and riverine areas with mangrove forests. The mixing of inland and marine waters affects the plankton community. The research objectives were to describe plankton species richness and abundance, water quality during tides, and to analyze the relationship among them. The research method was a survey with a purposive sampling technique. Sampling was taken from five stations, four times in a dry season, on a spring tide when the maximum tidal range occurs. The water quality parameters consisted of temperature, current velocity, light penetration, pH, dissolved oxygen, free carbon dioxide, and salinity. The results showed that plankton species richness was the highest during the new moon at Station 3 near Motean and dominated by sea waters from Division Chrysophyta, such as Chaetoceros decipiens. The next taxa were Phylum Arthropoda, Division Cyanophyta, Division Chlorophyta, Phylum Euglenozoa, and Phylum Cnidaria. The plankton abundance was the highest during the new moon at Station 1 and dominated by sea waters from Division Chrysophyta, such as Chaetoceros. Water quality during the maximum tidal range in the new moon was better than the full moon at Station 1. In general, the highest plankton abundance was related to better water quality at Station 1.

1. Introduction

Segara Anakan is located in the southern part of Cilacap Regency with the coordinate of 8°35’-8°48’S and 108°46’-109°03’E [1]. Nusa Kambangan Island is in south stretches along approximately 30 km in a west-east direction and protects Segara Anakan from Indian Ocean waves. The waters consist of the lagoon and riverine areas with water sources of inland waters from the north side and marine waters from the west and east side of Nusa Kambangan Island. The inland waters are dominated by River Citanduy, Cibeureum, and Cikonde. There are brackish waters such as Kayu Mati, Cikujang, River Kemhang Kuning, Sapuregel, Donan [2].

There are also mangrove forests from River Citanduy to River Donan [3]. Mangrove forests provide a protective habitat for spawning and represent nursery and feeding grounds for a variety of fish, crustaceans, and shellfish due to nutrients [4]. The nutrients in mangrove forests affect the abundance of plankton [5]. Plankton species richness and abundance in the ecosystem are determined by their interaction with physical, chemical, and biological factors. These factors are related to the season and anthropogenic disturbances [6].

The seasonal changes in Segara Anakan involve climate and tidal range. The climate of Segara Anakan Cilacap is tropical and humid, with the southeast monsoon in the dry season and the northwest monsoon in the wet season. Typically, Segara Anakan Cilacap has dry seasons between July and September, whereas the other months are the wet season [1]. Rainfall in Segara Anakan is highly
variable and varies seasonally. Based on Cilacap Meteorology Station from 2000 to 2002, the climate of the Segara Anakan East-swamp Management Areas was as follows. October 2000 to April 2001 was a wet season with precipitation between 190.3 mm and 854.0 mm. May 2001 was the dry season (127.5 mm), and June 2001 was the wet season (302.8 mm). July to September 2001 was a dry season (4.7 - 84.8 mm). October 2001 to January 2002 was a wet season (273.2 - 1,441.2 mm) [7]. There is a tendency for the dry season in May. This condition was in a dry season in May 2009 [8]. It is affected by El Niño that usually followed by rainfall decrease, and air temperature increase [7,9]. The rainfall is responsible for the seasonally varying salinity, temperature, and light penetration. This climate was affected by the inland waters entering the Segara Anakan areas, which caused sedimentation. The sedimentations that occur in Segara Anakan due to a tidal range [10]. The tidal range increases to a maximum level over a week (spring tides) and then decreases to a minimum over the following week (neap tides) due to the monthly orbit of the moon around the earth [11].

The anthropogenic disturbance in Segara Anakan was influenced by settlement, agricultural, and industrial areas. Therefore, the Segara Anakan lagoon became narrower and shallower due to sedimentation on the west part, waters contaminated by pollutants on the east part, and mangrove areas decreased due to illegal logging [10]. The destruction of mangrove areas affects the decreasing of species diversity [12]. Plankton can describe the effect of environmental changes. Based on this background, the objectives of the research were 1) To describe plankton species richness and abundance, as well as water quality during tides. 2) To analyze the relationship between plankton species richness, plankton abundance, and water quality.

2. Methods

2.1 Location and Research Time Period

The sampling stations were in Segara Anakan Cilacap. Identification has been made at The Laboratory of Aquatic Biology, Faculty of Biology, Universitas Jenderal Soedirman. The period of sampling was May 2017 and May 2018 in dry season on spring tide when maximum tidal range occurred due to a new moon phase in 27 May 2017 (at 08.56 am, high 2.1 m) and 16 May 2018 (at 08.32 am, high 2.1 m) then a full moon phase in 13 May 2017 (at 09.10 am, high 1.9 m) and 30 May 2018 (at 08.20 am, high 1.9 m). The new moon phase was detected by the WXTide47 software.

2.2 Sampling Design

2.2.1 Method and Sampling Technique.

This research used a survey method with a purposive sampling technique. There were five stations from the lowest salinity to the highest salinity in the east part of the Segara Anakan Cilacap (Figure 1).

| No. | Station | Coordinate       | Details        |
|-----|---------|------------------|----------------|
| 1   | Station 1 | 07°41′43.7″ S 108°51′35.3″ E | Lowest salinity |
| 2   | Station 2 | 07°42′30.3″ S 108°52′50.9″ E | Low salinity   |
| 3   | Station 3 | 07°42′31.9″ S 108°54′12.9″ E | Middle salinity|
| 4   | Station 4 | 07°42′27.7″ S 108°55′35.9″ E | High salinity  |
| 5   | Station 5 | 07°43′12.1″ S 108°56′48.0″ E | Highest salinity|
2.2.2 Parameter of Research

The main parameters were plankton species richness, plankton abundance, temperature, current velocity, light penetration, pH, dissolved oxygen, free carbon dioxide, and salinity.

2.3 Research Procedures

Water Sampling

The plankton net number 25 was put in a vertical position, and the vial bottle was submerged into waters. As many as 10 l of water was taken bucket for ten times. The water from the vial bottle that attached to the plankton net then detached and poured to the 50-ml sample bottle. The sample was preserved with 40% formalin (ratio of sample and formalin as 9:1), and the bottle was closed immediately [14].

Current Velocity

The current velocity was measured directly by a float method [16]. Based on [17], this method used a bottle. The bottle was filled up with 2/3 water then tied with 10 m rope. The bottle was released to the river flow. The value of the current velocity was obtained as follows:

\[
\text{Current velocity} = \frac{s}{t} \text{ m/sec}
\]

\( s \) = The distance that used, represented by 10 m rope.
\( t \) = The stopwatch value in second shortly after the rope stretched.

Light Penetration

Light penetration (cm) was measured using a Secchi disk method. Secchi disk was submerged into the water body until it was not visible, then measured depth until the intensity of light 0% (x value). Secchi disk was lowered until it was not visible then lifted slowly until it began to visible (y value) [18]. The value of light penetration was obtained by this formula:

\[
\text{Light Penetration} = \frac{x+y}{2} \text{ cm}
\]

\( x \) = First depth to light intensity 0% (cm)
\( y \) = Second depth to light intensity 0% (cm)
**Dissolved Oxygen**

The dissolved oxygen was analyzed by the Winkler method [15]. The water sample was taken by 250 ml Winkler bottle to full (without bubbles inside the bottle), added 1 ml of MnSO4 solution and 1 ml of KOH-KI solution with a pipette in the same size, the bottle was shaken by turning the bottle until homogeneous and continuing by pure H2SO4 solution concentrated 1 ml and the bottle was closed again, the bottle was shaken gently or back and forth until all the sediment dissolved and was in a yellowish-brown color, taken 100 ml using a measuring cup and inserted into the Erlenmeyer, amyllum indicator added 3-5 drops until a dark blue color, titrated with Na2S2O3 0.025 N. solution until clear in color. The titration volume was recorded. The dissolved oxygen content was obtained as follows:

\[
\text{Dissolved Oxygen} = \frac{1000}{100} \times p \times q \times 8 \text{ mg/l}
\]

- \(p\) = the number of Na2S2O3 used in titration (ml)
- \(q\) = the normality of Na2S2O3 0.025 N. solution
- \(8\) = the mass equal in oxygen

**Free Carbon Dioxide**

The free carbon dioxide was also analyzed by the Winkler method [15]. A water sample was added 250 ml Winkler bottle (no bubbles), taken 100 ml with measuring cup and poured into Erlenmeyer flask, added 3-5 drops pp indicator, titrated with Na2CO3 0.0454 N. solution until the color becomes pink. The amount of titrant used was recorded. The free carbon dioxide concentration is obtained as follows:

\[
\text{Free Carbon Dioxide} = \frac{1000}{100} \times p \times q \times 22 \text{ mg/l}
\]

- \(p\) = the number of Na2CO3 used in titration (ml)
- \(q\) = the normality of Na2CO3 0.0454 N. solution
- \(22\) = the mass equal to carbon dioxide

**Plankton Sample Identification**

Water was taken by water sampler, and one drop was put into object-glass, and covered with a cover glass. The object-glass then observed using a microscope [14] and identified based on the books of Planktonologi [14], Illustration of the Marine Plankton of Japan [19], and the Marine and Freshwater Plankton [20].

**2.4 Data Analysis**

**Plankton Species Richness**

Plankton species richness was recorded from the plankton sample identification. Then, data were interpreted descriptively [21].

**Plankton Abundance**

Data were counted by Sachlan’s Formula [14], interpreted in descriptive, analyzed by One-Sample T-Test in XLSTAT software. Sachlan’s Formula as follows:

\[
\text{Plankton Abundance} = \frac{A}{B} \times \frac{C}{D} \times \frac{E}{F} \text{ ind/l}
\]

**Note:**
- \(A\) = Water volume in sample bottle (32 ml)
- \(B\) = Water volume observed (0.05 ml)
- \(C\) = Cover glass width (20x20 mm²)
D = View field number (20 times)
E = Individual plankton number
F = Filtered water volume (100 l)

Water Quality

The temperature, current velocity, light penetration, pH, dissolved oxygen, free carbon dioxide, and salinity were compared with water quality standards from Government Regulation Number 82 in 2001 for class III [22].

The relationship among Plankton Species Richness, Plankton Abundance, and Water Quality

Plankton species richness and water quality were analyzed in a descriptive method. Plankton abundance and water quality analyzed by Spearman’s Rank Correlation on IBM SPSS Statistic software version 23.

3. Results

Plankton species richness was found was 38 species in Segara Anakan during maximum tidal range in the dry season. Plankton species richness was obtained 37 species in new moon and 29 species in the full moon. The One-Sample T-Test result supported this difference that plankton species richness in a new and full moon was different.

Plankton from both phases of the moon was dominated by phytoplankton. The new moon phytoplankton was found 28 species from Divisio Cyanophyta (4 species), Chlorophyta (3 species), and Chrysophyta (21 Species). In contrast, the full moon phytoplankton was 23 species from Divisio Cyanophyta (2 species), Chlorophyta (2 species), and Chrysophyta (19 species). The new moon zooplankton was found 9 species from Phylum Euglenozoa (1 species) and Arthropoda (8 species), whereas the full moon zooplankton was found 6 species from Phylum Cnidaria (1 species) and Arthropoda (5 species).

Phytoplankton was dominated by Divisio Chrysophyta, and zooplankton was dominated by Phylum Arthropoda. Both phytoplankton and zooplankton species were dominated by seawater species. In the new moon condition, there were 22 species of seawater plankton and 15 species of freshwater plankton, whereas there were 17 species of seawater plankton and 12 species of freshwater plankton in full moon condition (Table 2).

| No. | Category                          | New moon                  | Full moon                  |
|-----|-----------------------------------|---------------------------|----------------------------|
| 1   | Total plankton species richness  | 37                        | 29                         |
| 2   | Taxa found                        | Divisio Cyanophyta: 4     | Divisio Cyanophyta: 2      |
|     |                                   | Divisio Chlorophyta: 3    | Divisio Chlorophyta: 2     |
|     |                                   | Divisio Chrysophyta: 21   | Divisio Chrysophyta: 19    |
|     |                                   | Phylum Euglenozoa: 1      | Phylum Cnidaria: 1         |
|     |                                   | Phylum Arthropoda: 8      | Phylum Arthropoda: 5       |
| 3   | Plankton species richness         | Station 1: 18             | Station 1: 12              |
|     | in each station                   | Station 2: 11             | Station 2: 11              |
|     |                                   | Station 3: 21             | Station 3: 16              |
|     |                                   | Station 4: 13             | Station 4: 13              |
|     |                                   | Station 5: 14             | Station 5: 20              |
| 4   | Seawater plankton                 | 22                        | 17                         |
| 5   | Freshwater plankton               | 15                        | 12                         |
| 6   | Species dominance                 | Chaetoceros decipiens     | Chaetoceros decipiens      |
Plankton abundance found in Segara Anakan during maximum tidal range in the dry season was 52,096 ind/l, which are composed by phytoplankton as much 49,536 ind/l and zooplankton as much 2,560 ind/l. Plankton abundance in the new moon was obtained 38,208 ind/l, whereas the full moon was 13,888 ind/l. One-Sample T-Test result has supported this difference because plankton abundance is different in the new and full moon.

During new moon, the plankton abundance in Station 1 obtained 29,888 ind/l, Station 2 was 1,920 ind/l, Station 3 was 2,880 ind/l, Station 4 was 1,728 ind/l, and Station 5 was 1,792 ind/l; whereas full moon at Station 1 obtained 2,560 ind/l, Station 2 was 1,280 ind/l, Station 3 was 2,368 ind/l, Station 4 was 1,280 ind/l, and Station 5 was 6,400 ind/l. The plankton abundance of new or full moon phases occur similarity pattern that is abundant on both ends (Station 1 and 5) and rise back in the middle (Station 3) (Table 3).

| No. | Category                                      | New moon   | Full moon   |
|-----|-----------------------------------------------|------------|-------------|
| 1   | Total plankton abundance                      | 38,208 ind/l | 13,888 ind/l |
| 2   | Taxa found                                    |            |             |
|     | Divisio Cyanophyta: 448 ind/l                |            |             |
|     | Divisio Chlorophyta: 4,096 ind/l             |            |             |
|     | Divisio Chrysophyta: 31,936 ind/l            |            |             |
|     | Phylum Euglenozoa: 128 ind/l                 |            |             |
|     | Phylum Arthropoda: 1,600 ind/l               |            |             |
| 3   | Plankton abundance in each station           |            |             |
|     | Station 1: 29,888 ind/l                      |            |             |
|     | Station 2: 1,920 ind/l                       |            |             |
|     | Station 3: 2,880 ind/l                       |            |             |
|     | Station 4: 1,728 ind/l                       |            |             |
|     | Station 5: 1,792 ind/l                       |            |             |
| 4   | Seawater plankton                            | 20,608 ind/l | 8,636 ind/l |
| 5   | Freshwater plankton                          | 17,600 ind/l | 5,252 ind/l |
| 6   | Species dominant                             | Chaetoceros decipiens | Chaetoceros decipiens |

Water quality was in good quality based on water quality standards. The water quality of the new moon was higher than the full moon (Table 4).

| No. | Parameter                           | Water Quality Standards | New Moon | Full Moon |
|-----|-------------------------------------|-------------------------|----------|-----------|
| 1   | Temperature (°C)                    | ± 3                     | 28.3     | 28.5      |
| 2   | Light penetration (cm)              | -                      | 62.5     | 50.5      |
| 3   | Current velocity (m/s)              | -                      | 19       | 12        |
|     |                                     |                         | 20       | 22.1      |
| 4   | pH                                  | 6.5-9                   | 7.5      | 7         |
| 5   | O₂ (mg/l)                           | ≥3                      | 5.15     | 3.2       |
| 6   | CO₂ (mg/l)                          | -                      | 2.0      | 5.9       |
| 7   | Salinity (ppt)                      | -                      | 16.5     | 21        |

Table 3. Plankton Abundance

Table 4. Water Quality
4. Discussion

4.1. Plankton Species Richness

The highest plankton species richness was from Divisio Chrysophyta during the new moon at Station 1, 2, 3, and 5, but Divisio Chrysophyta had the same number as Phylum Arthropoda at Station 4. During the full moon, the highest plankton species richness at Station 1, 2, 3, 4, and 5 were obtained by Divisio Chrysophyta. The research mentioned that the phytoplankton of brackish waters is dominated by Divisio Chrysophyta [14]. They are dominated in brackish waters were caused by its high availability of inorganic nutrients.

This research showed that species richness in Segara Anakan was high in Divisio Chrysophyta, also Phylum Arthropoda, which composed by Subclass Copepod. [23,24] added that Kembang Kuning River (Station 3, 4, and 5) produced the highest abundance with copepods forming a major part, followed by crab larvae (29%). This is supported by a finding [1] that in East Swamp Managed Areas found 13 species of intertidal crab. [25,24] also added that the highest zooplankton found in Segara Anakan was copepod. Copepods are the primary food source of marine fish larvae in nature [26]. This is supported by a study [27] that there were 24 fish morphotypes in East Plawangan of Segara Anakan.

The dominant of plankton Divisio Chrysophyta in the most all stations in both the moon phase made them belong to cosmopolitan species. [28] added that the cosmopolitan hypothesis predicts that microbes would be present in all environments where they can live due to unrestricted dispersal capabilities. This cosmopolitan species represented by Chaetoceros decipiens from Divisio Chrysophyta and proved that they found in all stations both on the new moon and full moon. This is supported by species reported found in the coastal Kampung Gisi, Bintan Regency, Kepulauan Riau Province [29]. Based on these data Chaetoceros decipiens has a wide distribution due to the waters of Kampung Gisi itself and were still exposed to the Indian Ocean just like the waters of Segara Anakan.

In general, the plankton species richness was higher in the new moon than the full moon. This plankton species richness was dominated by Divisio Chrysophyta followed by Phylum Arthropoda, Divisio Cyanophyta, Divisio Chlorophyta, Phylum Euglenozoa, and Phylum Cnidaria. The dominant species richness from seawater species, Divisio Chrysophyta represented by Chaetoceros decipiens.

4.2. Plankton Abundance

Estuarine systems are highly dynamic in their hydrology, nutrient cycles, and biotic resources. Hydrologically, freshwater runoff interacts with tidal seawater and variable winds, shaped by climatic forcing features such as temperature, rainfall, and winds that vary over time and space scales, strongly influence the chemical and biological characteristics and responses of this ecosystem to environmental changes [30]. The major hazards to estuarine ecosystems as belonging to three categories, such as human activities, global climate change, and extreme events [31]. The environmental changes in Segara Anakan Lagoon are affected by increasing human and climatic pressures, such as dramatic changes in land use, land cover, industrial pollution, and ENSO variations [32]. Major land use of the Segara Anakan area was in agriculture, mainly the cultivation of irrigated rice, which increased by 18% since 1982. Upland crops increased by 25% while the area of forest and plantations decreased by 18% in the same period [10].

The tides and freshwater input govern the hydrology of the lagoon. The lagoon is connected to the Indian Ocean by the western outlet (West Plawangan) and a tidal channel towards Cilacap as an Eastern outlet. It is protected from the open ocean by the rocky mountainous of island Nusa Kambangan. The western part of the lagoon receives a high input of freshwater from Rivers Citanduy, Cibeureum, and Cikonde. In contrast, the eastern part of the lagoon receives a low input of freshwater from short and small freshwater rivers and consists of River Sapuregel and Donan [2].

Station 1 had strongly influenced by western part condition, and Station 5 had strongly influenced by the eastern part condition. The conditions in both parts are different. This was supported by data Physico-biogeochemical Segara Anakan that shown in the western part had a content of nitrate of 11.8 μM, ammonia 3.1 μM, silicate 9-139 μM, dissolve inorganic nutrient (DIN) 16 μM and phosphorous <0.1-0.4 μM; whereas the east one had a nitrate content of 5.6 μM, ammonia 2.4 μM, silicate 10-122
μM, DIN 9 μM and phosporous <0.1-0.8 μM [10,32]. Those nutrients were essential for phytoplankton growth, as well as phosphorous acids for cell membranes and proteins such as enzymes [29]. Based on the statement before was become the reason why on both stations had a high plankton abundance, and the highest plankton abundance was found in Station 1 during the new moon. This was supported by high tide data that the new moon had 2.1 m high of the tide, and the full moon had 1.9 m. The tide spread nutrients, causing sedimentation [10].

Plankton abundance in Station 3 was suspected due to a current meeting. This was reinforced because Station 3 was the area near Motean village, which was the meeting point of the tide coming from the west and east side entering the Segara Anakan areas [25,24]. The areas around Station 3 were also surrounded by the largest mangrove forest from other stations, about 4,905 ha [7]. As a result of meeting the flow of organic waste, including litter from this mangrove forest gathered at Station 3 resulted in the decomposition process. Also, this research was conducted at the time of the highest tide so that the occurrence of water meeting was more likely to occur. This was evidenced by the velocity of the current 0 and looks turbulence, also a lot of litter collecting. Decomposition is a process of degradation of organic material by bacteria inorganic resulted in products that are utilized for their growth and energy requirements. However, others were released as simple inorganic compounds suitable for plant uptake [33]. The inorganic nutrients and organic nutrients accumulated are thought to result in an abundance of plankton at Station 3. For lower plankton abundance at Station 2 and 4 suspected because plankton carried by the current.

The order of plankton abundance from highest to lowest during maximum tidal range was Divisio Chrysophyta (42,688 ind/l), Divisio Chlorophyta (6,080 ind/l), Phylum Arthropoda (2,368 ind/l), Divisio Cyanophyta (769 ind/l), Phylum Euglenozoa (128 ind/l) and the last is Phylum Cnidaria (64 ind/l) (Table 3). This abundance was thought to be related to the nutrient content in each station, the ability of the type of plankton to use the nutrient, and their toxicity to a pollutant. The cosmopolite and highest abundance of Divisio Chrysophyta, especially for Class Bacillariophyceae (Diatom), also derived from their capacity to grow rapidly in turbulent high nutrient environments. Diatom cells were capable of fast growth due to rapid nitrate uptake. Diatoms were well adapted to varying light levels and physical stress characteristics of shallow coastal systems. Diatoms had high species richness due to well adapted to different temperature ranges and the salinity ranges [34]. Diatom also was known to depend heavily on silicate content because it was required to form their cell wall. This silica structures of stomatocysts and scales were used in sediment studies in geology and limnology, often together with pollen analysis, to research the environmental change in the lake [35]. This was supported by why Divisio Chrysophyta had the highest abundance due to high silicate concentration in the Segara Anakan area, can reach 139 μM [32]. Cyanophyta from the Order Chroococcales prefer nitrogen to be present in the form of ammonia, while other Cyanophyta and eukaryotic algae include more readily use nitrate [11].

Based on these results, Segara Anakan during maximum tidal range in the dry season had the highest abundance from Divisio Chrysophyta obtained by Chaetoceros decipiens species. Chaetoceros decipiens was generally shaped like a chain with a cell nucleus in each chain form long chains that can divide into new organisms and allows the intake of nutrients, as well as more as part of the body, can occupy a larger area [29]. Chaetoceros spp. had a tolerance to heavy metals such as Zn, Ni, Cr, Pb, Cd, Ar, Sb, and Se but low in Cu and Hg [36]. Chaetoceros also was known to be harmful to fish. Reviews their spines may lodge in the gills of fish and cause an inflammatory response making them susceptible to infection [29]. This abundance of Chaetoceros decipiens is also suspected to occur because of the many nutrients that accumulate in the waters of Segara Anakan, their toxicity to heavy metal, and lack of predators.

In general, plankton abundance in the new moon is higher than the full moon. The highest abundance was from seawater plankton, Divisio Chrysophyta represented by Chaetoceros decipiens.
4.3. Water Quality

Based on data gradient in the trophic state was observed, the highest DIN concentrations were observed in the western area, mostly in the oligo-/mesotrophic range, occasionally eu-/hypertrophic. In the eastern, DIN was in the oligotrophic range and central area with one exception in the latter in January 2006 when DIN fell in the meso-/eutrophic range [37, 32].

The temperature range of the new moon was 28-28.8°C, and the full moon was 28.5-29.3°C (Table 4). Based on water quality standards from Government Regulation Number 82 in 2001 for class III, this result was not problematic due to below the level considered. The temperature of estuary waters varies significantly because of the incoming influx of both fresh and seawater [38].

The light penetration of the new moon was 46-63 cm, and the full moon was 36-53 cm (Table 4). It is defined that transparency for biota in estuarine is divided into three categories there were good (>50 cm), fair (30-50 cm), and poor (<30 cm) [39]. Based on that light penetration in this research, the new moon of Station 1 was good, Station 2 was fair, Station 3 was good, Station 4 was good, and Station 5 was good. Light penetration of full moon at Station 1 was good, Station 2 was good, Station 3 was fair, Station 4 was fair, and Station 5 was fair. This range was suspected because of the Segara Anakan area that was affected by El Niño. This resulted in a decrease in water volume due to the dry season in the area of Segara Anakan. This silting caused tidal streams that enter the upstream (river) to collide so that the stirring process occurs where the sediment had settled back to the surface, causing the value of the sediment suspension concentration higher at the mouth of the river than others [40]. Sediment stirring was what suspected makes light penetration in the Segara Anakan was only about 36-62.5 cm. The higher the light penetration would be better for the biological activity in the waters because the process of photosynthesis by phytoplankton was not inhibited [38].

The current velocity obtained of the new moon was 0-20.6 m/sec, and the full moon was 0-22.1 m/sec (Table 4). There was a tendency to reduce the current velocity to station 3; the current velocity on the Station 3 was not detected. This is because the effect of the current meeting resulted in the turbulence in that area.

The pH of the new moon was 6.5-7.5, and the full moon was 7 (Table 4). Based on water quality standards from Government Regulation Number 82 in 2001 for class III, the pH range of Segara Anakan was not problematic due to below the level considered. The varying pH values are thought to be due to tidal influences that distribute the mass of freshwater toward the sea [41]. Average pH during the new moon only about 7.2 and full moon relatively neutral suspected due to the effect of El Niño that makes seawater that entering the Segara Anakan area decrease. Then the total suspended solids from the river (freshwater) high affect to make pH increase. Limestone drains can use to increase pH and remove dissolved metals from acidic mine drainage. The factor of limestone contains that carried from the river and also the limestone that contains in Nusa Kambangan Island proved by the establishment of Nusantara Cement Factory now rename as Cibinong Cement and limestone mining sites affect increasing pH in Segara Anakan during El Niño [42]. In this case, water acidification was decreasing pH due to the reaction of carbon dioxide with water produce H2CO3 an acid compound disturbed [43].

The range of concentrations of dissolved oxygen in the new moon was 3-5.15 mg/l, and the full moon was 2.7-4.4 mg/l (Table 4). The new moon of all stations was not problematic due to above the level considered, but the full moon was problematic because Station 4 was below the level considered [22]. This was supported by dissolved oxygen average data that in the new moon was 3.59 mg/l, then in a full moon was 3.34 mg/l. Dissolved oxygen concentration showed a decrease when the water was entering through Station 2,3, and 4 due to a litter collection. The concentration of dissolved oxygen would decrease along with the increase of organic material in waters because dissolved oxygen used by bacteria to degrade organic matter into inorganic materials [44].

The range of free carbon dioxide concentrations of the new moon was 2-5.9 mg/l, and the full moon was 5.5-7 mg/l (Table 4). [45] added that the optimum free carbon dioxide concentration for fisheries in estuarine areas must not exceed 25 mg/l. This was meant that the free carbon dioxide concentrations for fisheries in Segara Anakan were good. This research showed an increased
concentration of free carbon dioxide when water entered Station 2, 3, and 4 due to a litter collection. This is in line with the statement [41] that the increased input of organic material to facilitate the process of decomposition of organic materials caused an increase in carbon dioxide due to the respiration of bacteria.

The range of salinity of the new moon was 16.5-28.5 ppt, and the full moon was 12-22.5 ppt (Table 4). Based on the research [46], the salinity of mangrove waters of Segara Anakan in the rainy season was 0 ppt while in the dry season, it ranges between 20-32 ppt. The salinity range in this research suspected due to the El Niño effect. El Niño affected the dropping of surface water South Java Ocean level between 5-12 cm and distributed lower to Segara Anakan areas [47]. The highest salinity in this research that gets on the new moon also supported by WXTide47 data that the high tide in the new moon reached 2.1 m and full moon only reach 1.9 m.

Generally, the water quality parameters showed problematic at dissolved oxygen in the full moon phase [22]. The dissolved oxygen of Station 4 in the full moon phase was below the level considered.

4.4. The Relationship Among Plankton Species Richness, Plankton Abundance, and Water Quality

Plankton species richness is higher in the new moon due to reach 37 species than full moon only 29 species. Plankton abundance was also higher in the new moon than the full moon. The new moon was obtained 38,208 ind/l while the full moon was 13,888 ind/l. The high plankton species richness and plankton abundance in the new moon indicate succession occurs. Succession was proposed by Clements (1916) that succession was the process as an orderly series of plant assemblages from the point of initiation through to the climax, a stable state [48].

There was a tendency of increasing dissolved oxygen and an increase of plankton abundance (p<0.05; r = 0.695) (Table 5). This is proved that there was a higher plankton abundance in the new moon than the full moon was related to their dissolved oxygen concentration. Decreasing dissolved oxygen concentration had decreasing biodiversity [49]. This was indicated that the dissolved oxygen concentration also was related to plankton species diversity. This proved the condition in Cilacap.

In deeply, the tendency of increasing dissolved oxygen was related to the increase of phytoplankton (p<0.01; r = 0.796). This was proved it because the tendency of increase of dissolved oxygen was related to increasing Chlorella vulgaris (p<0.01; r = 0.765), increasing Chaetoceros lorenzianus (p<0.01; r = 0.784), and increasing Pleurosigma angulatum (p<0.05; r = 0.711). [11] added that one factor that affects the concentration of oxygen in waters was the photosynthesis of phytoplankton.

The tendency of decreasing light penetration was related to increasing CO2 data (p<0.05; r = -0.647). CO2 concentration increase means that increasing litter or other suspended material that reduces light penetration. This CO2 increased due to the increasing litter or other suspended material decomposition by bacteria [33].

The tendency of increasing CO2 of water was related to increasing temperature (p<0.05; r = 0.709), increasing Melosira malayensis (p<0.01; r = 0.801), and decreasing Nitzschia longissima (p<0.05; r = -0.729). In station 3, the litter increased; this increase means that the decomposition process increased. [33] stated that the decomposition process would increase CO2 concentration due to bacteria respiration. This loss of some of the energy input showed the changing into heat and entropy, causing a temperature increase. The increasing Melosira malayensis was supported also by a study [33] reporting that phytoflagellates and algae operated in a pond by utilizing the inorganic salts and provided CO2 by the bacterial decomposition. The decreasing Nitzschia longissima was supported by finding [50] that increasing CO2 affected the decreasing growth rate of Nitzschia species due to decreasing silica ratio. This was shown that Nitzschia longissima abundance decreased at station 3 that litter was clumped and produced CO2 due to the decomposition process.

The tendency of increasing temperature was related to increasing Oscillatoria brevis (p<0.01; r = 0.814) and Melosira malayensis (p<0.01; r = 0.848). The increasing Melosira malayensis due to the area with high temperature and indicated that it was rich in CO2 needed by this species for growth.
The increasing Oscillatoria brevis was supported due to belonging thermal algae, the algae that grow in warm water springs about 70°C and were called as thermal algae [51].

The increasing current velocity was related to increasing Oscillatoria brevis (p<0.05; r = 0.719), increasing Nitzchia longissima (p<0.05; r = 0.658), increasing Coscinodiscus wailesii (p<0.05; r = 0.677), decreasing Coscinodiscus asteromphalus (p<0.05; r = 0.653) and decreasing Melosira malayensis (p<0.05; r = -0.730). Salinity has a positive correlation with Coscinodiscus wailesii, Nitzchia longissima, and Tigriopus japonicus because they belonged to seawater plankton species. The decreasing Melosira malayensis due to belonging to freshwater species. The decreasing Coscinodiscus asteromphalus was supported by a study [52], that this species was abundant in brackish waters. This was suspected that Coscinodiscus asteromphalus was spreading widely and already adapted to salinity stress.

The increasing current velocity was related to increasing of Oscillatoria brevis (p<0.01; r = 0.975) and decreasing Tigriopus japonicus (p<0.05; r = -0.709). The increasing Oscillatoria brevis was supported by research [53], that Divisio Cyanophyta found in River Llobregat Spain had the highest abundance by the genus Oscillatoria with free-floating mat treatment. The decreasing Tigriopus japonicus was supported by research [54] that zooplankton dislikes a lot of water movement because it can provoke predators, zooplankton swims only need to feed, and for relocating, they do propulsion to minimize the fluid disturbance that they generate.

The tendency of increasing pH was related to the increasing of Microcystis aeruginosa (p<0.05; r = 0.651). The highest growth rate of Microcystis aeruginosa was at a pH of 9 and lower pH values; they grew more slowly [55].

In general, the dissolved oxygen concentration was related to plankton species richness and plankton abundance. The higher plankton species richness and plankton abundance in the new moon than the full moon was related to the higher dissolved oxygen concentration in the new moon than the full moon.

5. Conclusion

It can be concluded that:
1. Plankton species richness was highest in the new moon condition at Station 3 near Motean and dominated by sea waters from Divisio Chrysophyta. This divisio was a cosmopolitan species and represented by Chaetoceros decipiens. The next taxa were followed by Phylum Arthropoda, Divisio Cyanophyta, Divisio Chlorophyta, Phylum Euglenozoa, and Phylum Cnidaria. The plankton abundance was highest in the new moon condition at Station 1 near West Plawangan and dominated by sea waters from Divisio Chrysophyta. This divisio was represented by Chaetoceros decipiens. Water quality during the maximum tidal range in the new moon condition was better than the full moon at Station 1.
2. The highest plankton abundance in the new moon condition at station 1 was related to better water quality in the new moon than the full moon.

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