The Plankton Composition from the Lagoon to the Marine Entrance at the West Part of Segara Anakan Mangrove Ecosystem in Cilacap

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Abstract. There was a unique brackish water ecosystem and affected a chance in the plankton composition at lagoon and riverside in Segara Anakan Cilacap. This study aimed to map phytoplankton and zooplankton composition consisting of freshwater and marine plankton from the lagoon to the marine entrance in the west part of Segara Anakan Cilacap. The survey method was taken with purposive random sampling in fourteen stations and four replicates with new and full moon conditions from March to April 2018 in a wet season. The result showed 52 species of plankton. All species belonged to phylum Cyanophyta (9 species), Chlorophyta (13 species), Chrysophyta (19 species), Euglenozoa (2 species), Rotifera (2 species) and Arthropoda (7 species). Of the 52 species collected in all stations and replicates, phytoplankton has a greater species richness (41 species) than zooplankton (11 species). And also, freshwater plankton (47 species) has a higher species richness than marine plankton (5 species) due to the wet season condition causing freshwater enters brackish water. The largest freshwater of River Citanduy enters the brackish water of Segara Anakan mangrove ecosystem in Cilacap and causing the freshwater phytoplankton abundance, especially Staurastrum sp. in inland waters of Segara Anakan Cilacap.

1. Introduction
Segara Anakan Cilacap is the lagoon and riverine area with mangrove forests located in Cilacap Regency. Nusakambangan Island protects it from direct exposure to the Indian Ocean waves. Mangrove forests play a role as feeding, spawning and nursery ground for many biotas. As for feeding ground, it makes this region rich in planktonic organisms such as phytoplankton and zooplankton, whose existence is influenced by water quality. Phytoplankton also has a characteristic that is sensitive to environmental changes so that it is used as a bioindicator. Segara Anakan Cilacap experienced massive sedimentation originating from various anthropogenic activities and flowed through several major rivers, especially River Citanduy, Cibeureum, Cikonde [1]. Based on another reference [2], River Citanduy accounted for the most sediment by 40 thousand m³.year⁻¹, whereas River Cikonde deposited sediment by 260 thousand m³.year⁻¹. Therefore, there was sediment total at the lagoon by 1 million m³.year⁻¹. Other research also reported the bad condition in water quality [3-6]. It could affect phytoplankton composition, abundance, and temporal variation of polluted brackish waters [7]. In Segara Anakan Cilacap, human activities affected ecological status [8] and plankton [9].
Sedimentation conditions were followed by some rivers such as River Donan and Sapuregel and from the northeast side. In River Donan, sediments were dredged in periodically to overcome this problem [10-11].

The brackish water organism is also affected by the marine entrance at the west and east part of Segara Anakan, coming from the south part of Nusakambangan Island. Based on this background, research was done from lagoon to marine entrance at the west part of Segara Anakan mangrove ecosystem in Cilacap. Therefore, all these conditions affect plankton composition.

The research purpose was to map plankton composition consisting of phytoplankton and zooplankton together with freshwater and marine plankton from the lagoon to the marine entrance in the west part of Segara Anakan Cilacap.

2. Methods

2.1 Study Site

Research locations are in two areas such as lagoon (7°0'–7°35' S and 180°45'-109°3' E) near terrestrial areas and riverine (7°40’–7°41’ S and 180°47’-108°48’ E) near marine areas in West Cilacap. The survey method was taken with purposive random sampling in fourteen stations (Table 1) and four replicates with new and full moon conditions from March to April 2018 in a wet season. All stations were located from the east of the lagoon to the west of the marine entrance areas (Figure 1). The research stations are part of the Science for the Protection Indonesian Marine Coastal Ecosystems, SPICE, research [12].

| No. | Station (SPICE) | Coordinate          | Note                              |
|-----|----------------|---------------------|-----------------------------------|
| 1.  | I (SA-2-22)    | 7°40'35.48" S 108°52'03.32" E | Lagoon (east lagoon)             |
| 2.  | II (SA-2-32)   | 7°39'57.50" S 108°51'49.93" E | Lagoon (in between)              |
| 3.  | III (SA-2-23)  | 7°39'29.04" S 108°51'15.98" E | Lagoon (in between)              |
| 4.  | IV (SA-2-24)   | 7°39'25.04" S 108°50'58.06" E | Lagoon (central lagoon)          |
| 5.  | V (SA-2-34)    | 7°39'30.24" S 108°50'27.56" E | Lagoon (in between)              |
| 6.  | VI (SA-2-19)   | 7°39'50.33" S 108°49'59.52" E | Lagoon (in between)              |
| 7.  | VII (SA-2-18)  | 7°40'19.57" S 108°49'18.62" E | Lagoon (west lagoon)             |
| 8.  | VIII (SA-2-36) | 7°40'34.26" S 108°48'50.62" E | Riverine (creek from lagoon)     |
| 9.  | IX (SA-2-0)    | 7°40'03.34" S 108°48'48.74" E | Riverine (River Cikonde)         |
| 10. | X (SA-1-5)     | 7°40'02.52" S 108°48'20.02" E | Riverine (River Cibeureum)       |
| 11. | XI (SA-1-11)   | 7°40'08.14" S 108°48'03.74" E | Riverine (River Citanduy)        |
| 12. | XII (SA-1-10)  | 7°40'55.77" S 108°48'37.30" E | Riverine (east zone of river crossing) |
| 13. | XIII (SA-1-9)  | 7°40'43.88" S 108°48'10.51" E | Riverine (river crossing)        |
| 14. | XIV (SA-1-8)   | 7°41'20.63" S 108°47'53.52" E | Riverine (marine entrance)       |
2.2 Plankton Sampling and Measurement

Plankton net, mesh size of 60 µ, was placed in a vertical position and their bottle was placed parallel to the waters so that water can enter this plankton net. The water sample was preserved by formaldehyde 40% at a ratio of 9:1 [13]. Plankton identification used a binocular microscope and some books [13–15]. The abundance of plankton was calculated in individual/l according to the below formula [13]:

\[
\text{Abundance} = \frac{\text{Plaktonnet bottle volume} \times \text{Cover glass area} \times \text{Individual number}}{\text{Cover glass sample volume} \times \text{number of visual fields} \times \text{Filtered water volume}}
\]

2.3 Water quality Sampling and Measurement

All water quality samples were taken directly in waters. Temperature, salinity, dissolved oxygen and free carbon dioxide were used as an international standard [16] whereas pH and light penetration using an academic standard [17].

2.4 Data analysis

Plankton and water quality were analyzed as descriptively, especially for water quality using a national standard [18]. The IBM SPSS Statistics Versi 25, 2017 program was used for analyzing their relationship (Spearman’s rank correlation) and the map plankton (dendrogram) [19].

3. Results

The result showed 52 species of plankton. All species belonged to phytoplankton and zooplankton groups. Phytoplankton group consists of Phylum Cyanophyta, Phylum Chlorophyta, Phylum Chrysophyta, whereas the zooplankton group consists of Divisio Euglenozoa, Divisio Rotifera, and Divisio Arthropoda. For grouping their origin, there were freshwater phytoplankton, marine phytoplankton, freshwater zooplankton, and marine zooplankton. In general, the species richness of
freshwater plankton was higher than marine plankton. Freshwater phytoplankton of *Staurastrum* sp. dominated in abundance (Table 2).

**Table 2. Plankton in each station**

| No | Species       | Plankton Abundance |
|----|---------------|---------------------|
|    |               | Station I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | XIII | XIV |
| 1  | *Anabaena* sp.  | 32        | 32 |     |     |   |   |     |     |     |   | 32 |     |     |
| 2  | *Chlorella vulgaris* | 32        | 128 |     |     |   |   |     |     |     |   | 32 |     |     |
| 3  | *Elatobacterium* | 64        | 64 |     |     |   |   |     |     |     |   | 160 |     | 32 |
| 4  | *Oscillatoria limnetica* | 64       | 64 | 224 |     |   |   |     |     |     |   | 96 |     |     |
| 5  | *Oscillatoria limnetica* | 64       | 64 | 192 | 96 | 32 | 192 | 96 | 384 | 32 | 64 | 160 | 96 |
| 6  | *Oscillatoria minutissima* | 64       | 64 |     |     |   |   |     |     |     |   | 32 |     |     |
| 7  | *Oscillatoria sp.* | 576       | 64 |     |     |   |   |     |     |     |   | 32 |     |     |
| 8  | *Pseudanabaena limnetica* | 224      | 384 | 128 | 64 | 160 | 480 | 64 |     |     |   | 64 |     | 32 |
| 9  | *Synura planctonica* | 32        | 32 |     |     |   |   |     |     |     |   | 128 |     | 64 |

**Chloroplastia**

| No | Species       | Plankton Abundance |
|----|---------------|---------------------|
| 1  | *Ahnertia jussieu* | 32        |     |     |     |   |   |     |     |     |   | 32 |     |     |
| 2  | *Chlorella vulgaris* | 544       | 192 | 152 | 480 | 320 | 800 | 128 |     |     |   | 32 |     | 64 |
| 3  | *Chlorella turgidula* | 64        | 64 | 128 | 32 | 96 |     |     |     |     |   | 32 |     | 64 |
| 4  | *Chlorella reinhardti* | 64        | 64 | 128 | 128 | 224 | 160 |     |     |     |   | 32 |     | 64 |
| 5  | *Chlorella kessleri* | 64        | 64 | 128 | 128 | 224 | 160 |     |     |     |   | 32 |     | 64 |
| 6  | *Chlorella salina* | 64        | 64 |     |     |   |   |     |     |     |   | 32 |     |     |
| 7  | *Hydrurus anellus* | 64        |     |     |     |   |   |     |     |     |   | 32 |     |     |
| 8  | *Pseudanabaena limnetica* | 32        |     |     |     |   |   |     |     |     |   | 32 |     | 64 |
| 9  | *Pseudanabaena limnetica* | 32        |     |     |     |   |   |     |     |     |   | 32 |     | 64 |
| 10 | *Somateria quadricula* | 32        | 32 | 32 | 32 | 32 | 32 |     |     |     |   | 32 |     |     |
| 11 | *Somateria quadricula* | 32        | 32 | 32 | 32 | 32 | 32 |     |     |     |   | 32 |     |     |
| 12 | *Synura planctonica* | 32        |     |     |     |   |   |     |     |     |   | 32 |     |     |

**Zooplankton**

| Species               | Plankton Abundance |
|-----------------------|---------------------|
| *Euglena gracilis*    | 64                  |
| *Phacus sp.*          | 32                  |
| *Blastodinium*        | 32                  |
| *Bئ*                 | 32                  |
| *Aphelidium aggregatum* | 64                  |
| *Cyclopes fimbriatus* | 32                  |
| *Cyclopes tenuis*     | 32                  |
| *Cyclopes minute*     | 32                  |
| *Eucyrtidium aequale* | 32                  |

**Zooplankton abundance**

| Species               | Plankton Abundance |
|-----------------------|---------------------|
| *Euglena gracilis*    | 64                  |
| *Phacus sp.*          | 32                  |
| *Blastodinium*        | 32                  |
| *Bئ*                 | 32                  |
| *Aphelidium aggregatum* | 64                  |
| *Cyclopes fimbriatus* | 32                  |
| *Cyclopes tenuis*     | 32                  |
| *Cyclopes minute*     | 32                  |
| *Eucyrtidium aequale* | 32                  |

Where:  
*F* = freshwater  
*M* = marine
All parameters belonged to physical and chemical variables. The physical variable consists of temperature, whereas chemical variables include pH, light penetration, salinity, dissolved oxygen, and free carbon dioxide. From east lagoon to riverine near the marine entrance at the west part of Segara Anakan Cilacap, there were the increasing temperature and salinity values, but pH values were constant. In general, all stations were turbid, especially in River Citanduy, so why their light penetration became low in value (Table 3).

### Table 3. Water quality in each station

| No. | Parameter         | unit | I  | II  | III | IV  | V   | VI  | VII | VIII | IX  | X   | XI  | XII | XIII | XIV |
|-----|------------------|------|----|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|-----|------|-----|
| 1   | Temperature      | °C   | 29.8±0.9 | 29.8±0.6 | 29.3±0.6 | 30.1±0.9 | 30.4±0.5 | 30.6±1.3 | 31.0±0.8 | 30.8±0.9 | 30.8±0.9 | 31.0±0.8 | 30.8±0.9 | 30.8±0.5 | 31.0±0.1 |
| 2   | pH               |       | 7   | 7   | 7   | 7   | 7   | 7   | 7   | 7    | 7    | 7    | 7    | 7    | 7    |
| 3   | Light Penetration| cm   | 45.0±15.8 | 35.0±15.4 | 45.0±15.4 | 45.0±17.3 | 48.8±23.9 | 45.0±22.4 | 35.0±12.3 | 41.3±20.1 | 43.0±21.2 | 31.3±10.0 | 45.0±16.8 | 41.3±20.1 | 38.8±17.5 |
| 4   | Salinity         | %    | 3.3±0.5 | 3.6±0.6 | 3.8±0.6 | 4.0±0.8 | 4.5±0.9 | 4.5±1.3 | 3.1±1.5 | 3.1±1.5 | 3.1±1.5 | 3.1±1.5 | 3.1±1.5 | 3.1±1.5 | 3.1±1.5 |
| 5   | Dissolved Oxygen | mg/l | 6.1±1.1 | 3.0±0.6 | 3.4±1.5 | 3.5±1.6 | 3.5±1.2 | 3.3±1.1 | 3.4±1.1 | 3.4±1.1 | 3.4±1.1 | 3.4±1.1 | 3.4±1.1 | 3.4±1.1 | 3.4±1.1 |
| 6   | Free Carbon Dioxide| mg/l | 4.5±1.2 | 2.8±0.9 | 2.9±1.4 | 3.8±1.4 | 3.1±1.5 | 3.8±1.7 | 3.4±1.7 | 2.8±0.9 | 2.9±1.4 | 2.5±0.8 | 2.9±1.2 | 3.5±0.9 | 2.5±0.6 | 1.8±0.5 |

4. Discussion

A total of 52 species have been collected in all stations and replicates. Species richness of phytoplankton (41 species or 78.9%) was higher than zooplankton (11 species or 21.1%, Figure 2a1) whereas the abundance of phytoplankton (2,066.3 individual/l or 94.4%) was higher than zooplankton (123.4 individual/l or 5.6%, Figure 2b1). Both species richness and abundance of phytoplankton were higher than zooplankton. Another research reported that phytoplankton was higher than zooplankton in the usual sense of a food pyramid [20].

Species richness of Chrysophyta (19 species or 36.5%) was highest and followed by Chlorophyta (13 species or 25%), Cyanophyta (13 species or 25%), Arthropoda (7 species or 13.4%), Rhotifera (2 species or 3.9%) and Euglenozoa (2 species or 3.9%, Figure 2a2) whereas the abundance of Chrysophyta (1,124.6 individual/l or 51.4%) was highest and followed by Chlorophyta (546.3 individual/l or 24.9%), Cyanophyta (395.4 individual/l or 18.1%), Arthropoda (105.1 individual/l or 4.8%), Rhotifera (9.1 individual/l or 0.4%) and Euglenozoa (9.1 individual/l or 0.4%, Figure 2b2). Species richness and abundance of Chrysophyta were higher than others. Other researchers also found this condition [21, 22].

In this research, species richness and abundance of Arthropoda was higher than other zooplankton [23].

Species richness of freshwater phytoplankton (39 species or 75%) was highest and followed by freshwater zooplankton (10 species or 19.2%), marine phytoplankton (2 species or 3.9%), and marine zooplankton (1 species or 1.9%, Figure 2a3) whereas the abundance of freshwater phytoplankton (1,801.1 individual/l or 83.3%) was highest and followed by freshwater zooplankton (118.8 individual/l or 5.4%), marine phytoplankton (265.2 individual/l or 12.1%), and marine zooplankton (4.6 individual/l or 0.2%, Figure 2b3). Both species richness and abundance of freshwater phytoplankton were higher than others. The wet season caused freshwater to enter brackish water. The largest freshwater of River Citanduy enters the brackish waters of Segara Anakan Cilacap and creating the dominant species of phytoplankton, especially freshwater phytoplankton in this area of inland waters. In India, the abundance of freshwater phytoplankton was higher than others also during wet season [24].

Based on class III in Government Regulation Number 82 Year 2001 [18], water quality was in the permissible surface water quality standard at all stations in temperature, pH, and dissolved oxygen (Table 3 and Figure 4a), especially at Station X in River Cibeureum. This river had the highest species richness. Conserve, the coastal environmental profile of Segara Anakan showed that River Citanduy had the highest average flow as much 24.45 million m³/day in the wet season and followed by River Cikonde and Cibeureum as much 1.50 million m³/day and 0.17 million m³/day, respectively. It made a sedimentation process leading to the lagoon became narrow and shallow conditions [25]. This condition was showed that light penetration was the lowest value as much 31.3±0.3 cm (Table 3) and the highest freshwater phytoplankton abundance of *Staurastrum* sp. (Figure 3) as much 2,656 individual/l at Station XI in River Citanduy (Table 2). It means that the decrease of light penetration tends to the increasing in this plankton abundance (p < 0.05; r = -0.454; Figure 4b) because sedimentation and floating materials
Figure 2. The presence of plankton group in (a) species richness (b) abundance were too high in this river. This condition was in bad water quality [4]. Other plankton was no consistent effect of light penetration.

In the same other tendency, salinity was also in the lowest value as much 2.3±0.9 ‰ (Table 3) and the highest plankton abundance (Table 2). It means that the decreasing of salinity tends to the increasing of *Staurastrum* sp. (p < 0.05; r = -0.448). Another research reported that there was a relationship between salinity and plankton in freshwater, brackish water and marine [20]. Otherwise, salinity was in the highest value as much 18.3±0.1 ‰ (Table 3) and no marine phytoplankton abundance of *Skeletonema costatum* abundance in riverine, especially in the marine entrance (Table 2). It means that the increasing of salinity tends to no this marine phytoplankton abundance but the low salinity as much 3.8±0.5 ‰ (Table 3) and the highest this plankton as much 1,120 individual/l between east and central.
lagoon (Table 2). It means that the decreasing of salinity tends to the increasing in this plankton abundance ($p < 0.05; r = -0.463$). *Skeletonema costatum* is marine phytoplankton, but it can survive in freshwater and brackish water [26–28]. Another case of salinity, the highest salinity as much 18.3±0.1 ‰ (Table 3) and the highest marine phytoplankton abundance of *Nitzschia closterium* as much 64 individual/l near the marine entrance (Table 2). It means that the increasing of salinity tends to the increasing of *Nitzschia closterium* ($p < 0.05; r = -0.519$). *Nitzschia closterium* always tends to need a high salinity in the marine entrance as much 18.3±0.1 ‰ or they can live in brackish water salinity of 6–18.3 ‰ at the west part of Segara Anakan (Table 2). Another research showed it live at a wide array in inland saline waters [29–32].

Another parameter of temperature was the lowest value as much 29.8±0.9°C (Table 3) and the highest freshwater zooplankton abundance of *Cyclops fimbriatus* as much 384 individual/l in the east lagoon (Table 2). It means that the decreasing of temperature tends to the increasing of this plankton abundance ($p < 0.05; r = -0.539$). In the same station, the highest freshwater phytoplankton abundance of *Nitzschia longissima* as much 96 individual/l. Another research was also found that it was negatively correlated to water quality [33].

![Figure 3. Staurastrum sp.](image)

Another plankton similarity in (a) species richness (b) abundance [19]

![Figure 4. Dendrogram using Average Linkage (Between Groups)](image)
5. Conclusion
The species richness was dominated by freshwater phytoplankton, especially Chrysophyta, due to their water quality and wet season conditions. In contrast, its abundance was dominated by the freshwater phytoplankton of *Staurastrum* sp. in River Citanduy. This river was high in sedimentation and made the lagoon became narrow and shallow conditions.

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