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# Macroalgae diversity in the Pari Island Cluster, Seribu Islands District, Jakarta, Indonesia

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**Abstract.** *Handayani S, Widhiono I, Widyartini DS. 2023. Macroalgae diversity in the Pari Island Cluster, Seribu Islands District, Jakarta, Indonesia. Biodiversitas 24: 1659-1667.* Macroalgae are primary producers of the ocean that support the life of other organisms at higher trophic levels in aquatic ecosystems. This study aimed to determine the diversity of macroalgae in the Pari Island cluster and the diversity of water quality. The research method used is the survey method, with the quadratic transect method. Ecological index analysis using PAST 4.0 software. The relationship between diversity correlation and water quality using PCA software. The results of the study found 22 species of macroalgae consisting of 3 divisions, namely Chlorophyta (11 species), Phaeophyta (4 species), and Rhodophyta (7 species). Diversity of Pari Island (H'=2.314, E=0.594, D=0.121) and Kongsi Island (H'=1.191, E=0.481, D=0.211). The largest species are *Acanthophora spicifera* (M.Vahl) Børgesen (Rhodophyta), with 396 individuals; *Caulerpa racemosa* (Forssk.) J.Agardh (Chlorophyta), with 343 individuals; and *Padina australis* Hauck (Phaeophyta), with an individual number of 130. Macroalgae diversity in the Pari Island Cluster belongs to the moderate category. The diversity of macroalgae in the Pari Island Cluster is influenced by physical factors of temperature, salinity, brightness, depth, and current speed, as well as chemical factors of nitrate, orthophosphate, dissolved oxygen, heavy metal levels of Pb, Cu, and pH.

**Keywords:** *Acanthophora spicifera*, aquatic ecosystem, *Caulerpa racemosa*, indicators, *Padina australis*

## INTRODUCTION

Macroalgae are widespread in almost all regions of Indonesia since Indonesia is an archipelagic country and has the longest coastline. Macroalgae are important primary producers of the ocean. They support the life of other organisms at the trophic level in marine ecosystems, which are found in the intertidal zone to the subtidal zone (Satheesh and Wesley 2012; Umanzor et al. 2017). The presence and diversity of macroalgae in an area are, among other things, determined by the structure of the habitat or substrate type (Duran et al. 2018) since each macroalga occupies a habitat tightly attached to different substrates. In addition to substrate types, other physical factors also influence the species diversity of macroalgae, such as temperature, brightness, current, and chemical factors, e.g., salinity, acidity (pH), nitrates, and phosphates (Martínez et al. 2012; Cleary et al. 2016; Zhao et al. 2016) also, biological factors such as competition between types of macroalgae, predation by marine animals such as sea urchins, sea cucumbers, starfish and herbivorous animals that can damage macroalgae thallus by eating them so that it will reduce the number of spores and inhibit the spread of macroalgae (Fox et al. 2012; Macusi and Deepananda 2013; Anggadiredja 2017; Cordeiro et al. 2020; Budzałek et al. 2021)

The economic benefits of macroalgae are as raw materials for several industries, such as the carrageenan and agar industry, and food supplements and additives (Khan et al. 2016). On the other hand, macroalga is an excellent commodity to be developed because of its chemical content. Thus macroalgae can be used as a source of foods and medicinals (Roohinejad et al. 2017; Afonso et al. 2019; Peñalver et al. 2020). Macroalgae also have the potential as bio accumulators, bioremediation, bioindicators, and biomonitoring on water heavy metals. (Duran et al. 2018; Flouty and Estephane 2012; Chakraborty et al. 2014; Shams El-Din 2014; Henriques et al. 2015; Ihsan et al. 2015; Seoane et al. 2020; Zeraatkar et al. 2016; Bonanno and Orlando-Bonaca 2018). Macroalgae have an ecological role as habitats for other small marine life such as crustaceans, mollusks, and echinoderms (Chen et al. 2020; Umanzor et al. 2017), the nurturing area (Chaves et al. 2013; Giakoumi et al. 2012; shelters (Amsler et al. 2015), spawning grounds, and food sources for marine life (Filbee-Dexter and Scheibling 2014; Mauffrey et al. 2020), as well as playing a role in the blue carbon system (Chung et al. 2011; Chung et al. 2013; Sondak et al. 2017). So the existence and diversity of macroalgae need to be managed and preserved.

Pari Island and Kongsi Island are among the Pari Island Cluster, a marine tourist destination in the southern Seribu Islands and adjacent to Jakarta Bay; The Pari Island Cluster waters cannot be separated from anthropogenic pressure. This will impact the macroalgae diversity of both islands (Khrisnamurti et al. 2016; Zulpikar et al. 2020). Moreover, studies related to macroalgae diversity with water quality in the Pari Island Cluster are very important, can be used as a database related to macroalgae-type information, and can be used as indicators of water quality. Therefore, this research aimed to determine the diversity of macroalgae in the Pari Island Cluster and the relationship of macroalgae diversity with water quality.

## MATERIALS AND METHODS

### Study area and period

This research was conducted in September 2022 in the intertidal zone in the Pari Island Cluster. This study has two stations: Kongsi Island and Pari Island (Figure 1).

### Procedure

The data collection on macroalgae with a survey using the square transects method. First, on each sampling station, three transects of line 50 m long perpendicular to the coast to the tubing with a distance between transects of 20 m are made. Next, the observations were made by placing squared transects measuring 1x1 m at a distance of 5 m from the coastline. Then, subsequent placement of the square plot at a distance of 10 m from the first laying, and so on to 50 m (Figure 2).

The types of macroalgae, substrates, and environmental parameters were observed. The measurements include temperature, Salinity, Brightness, Current, TDS, Depth, Substrate, pH, DO, Nitrate and orthophosphate (APHA 2017), Hg, Pb, and Cu (Li et al. 2020). In addition, environmental parameters such as substrate, temperature, salinity, brightness, current, TDS, depth, pH, and DO are measured in the field. At the same time, chemical parameters such as Nitrate, Orthophosphate, Hg, Pb, and Cu are analyzed at the Productivity and Aquatic Environment Laboratory IPB-Bogor (Table 1).

Data analysis includes the Shannon-Wiener diversity index, the index to equal, and the dominance index using PAST 4.0 software. In addition, the linkages between parameters were tested using Principal Component Analysis (PCA).

The identification of macroalgae species found was determined using the identification book and journals (Lima et al. 2017; Lim et al. 2017; Joshi 2022; Hurtado-Poncec et al. 1992; Atmadja et al. 1996; Trono 1997; Bolton et al. 2007; Ni-Ni-Win et al. 2013; Subagio et al. 2019; Widyartini et al. 2023). In addition, the identification also uses macroalgae scientific nomenclature that is in international force today.

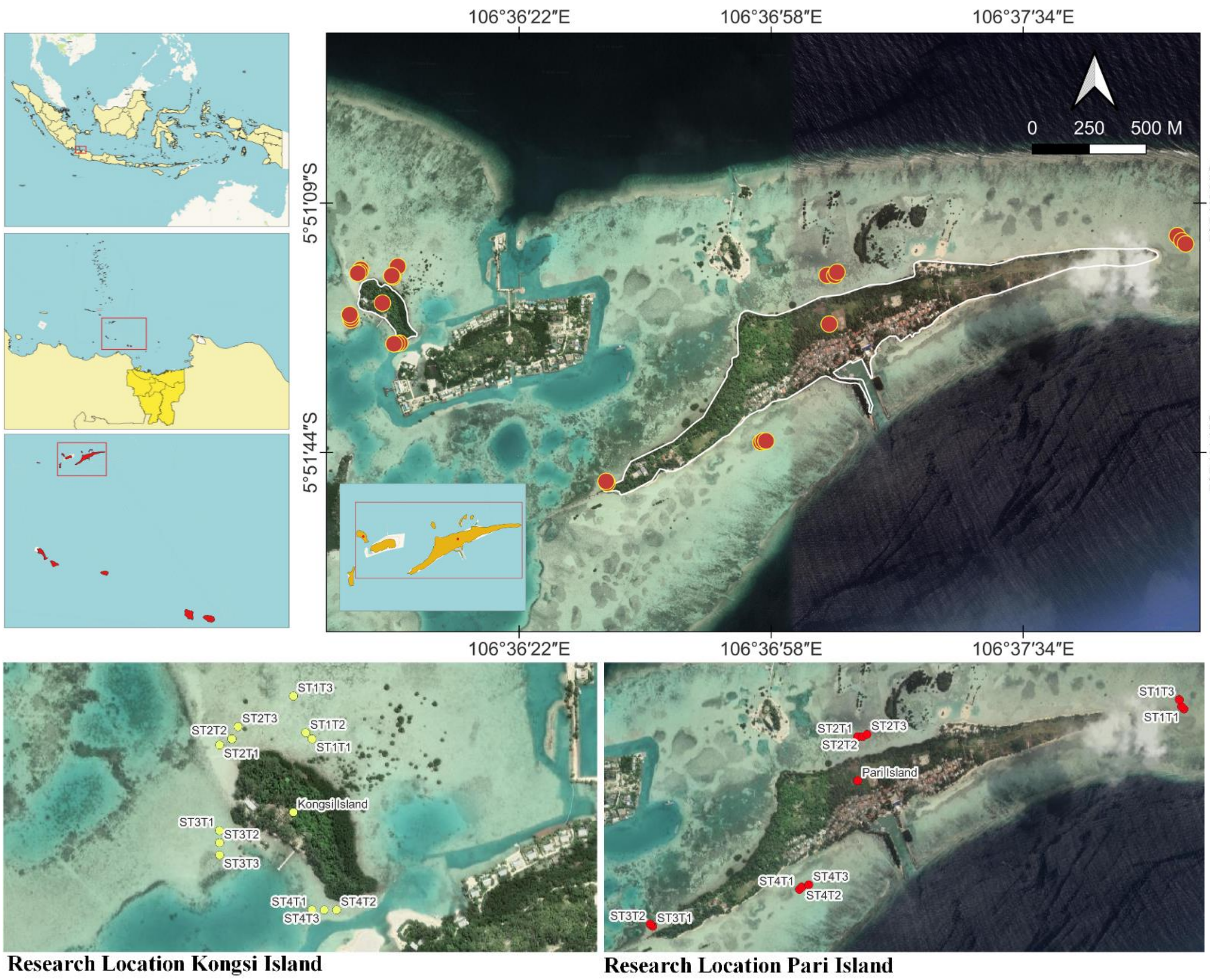


**Figure 1**. The research sampling location in the Kongsi and Pari Islands at Pari Cluster, Seribu Islands District, Jakarta, Indonesia (https://map.google.co.id)

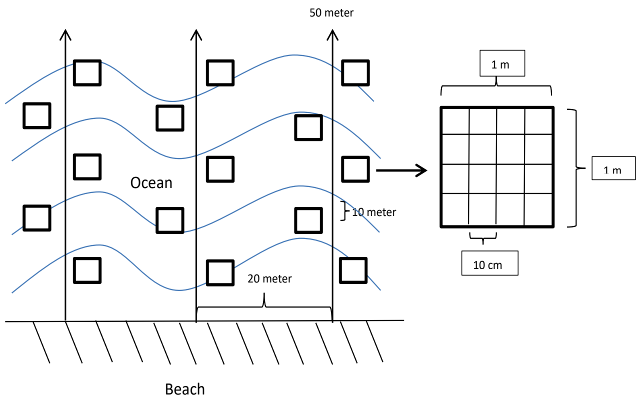


**Figure 2.** Design of plots by the method of transect squared

**Table 1.** Measurement of aquatic environmental parameters

| Parameter | Unit | Method/tools | Measurement |
|---|---|---|---|
| Temperature | °/C | Lutron T 017219 series | In situ |
| Brigtnees | m | Secchi disc | |
| Salinity | °/oo | Lutron TF 06213 | In situ |
| Current velocity | m/s | Floating droudge | In situ |
| Depth | m | Regular stick | In situ |
| pH | | Lutron seri TP 07 | In situ |
| DO | mg/L | Lutron Seri WAC-2019CP | In situ |
| Orthophosphate | mg/L | APHA, 23rd Edition, 4500-NO3-E, 2017 | Laboratory |
| Nitrate | mg/L | APHA, 23rd Edition, 4500-P-E, 2017 | Laboratory |
| Hg | mg/L | IK-LAB-logam-04 (Cold Vapor) | Laboratory |
| Pb | mg/L | IK-LAB-logam-11 (Ekstraksi-GFAAS) | Laboratory |
| Cc | mg/L | IK-LAB-logam-11 (Ekstraksi-GFAAS) | Laboratory |

## RESULTS AND DISCUSSION

### Macroalgae composition

The results of macroalgae identification at the study site in the Pari Island cluster were grouped into three divisions, namely Chlorophyta, Phaeophyta (Ochrophyta), and Rhodophyta, with 22 macroalgae species. The proportion of each division is 11 of Chlorophyta (50%), including *Halimeda macroloba* Dcainsne, *Halimeda opuntia* (L.) J. V. Lamouroux, *Halimeda gracillis* Harv. ex J.Agardh, *Halimeda micronesia*, *Caulerpa sertularoides* (S. G. Gmelin) M. Howe, *Caulerpa racemosa* (Forsskal) J. Agardh, *Caulerpa racemosa* var. *uvifera* (C. Agardh) J. Agardh, *Caulerpa serrulata* (Forsskal) J. Agardh, *Caulerpa* sp., *Dictyospaera* sp., *Boergensenia forbesii* (Harvey) Feldmann. Then, four species of Phaeophyta (Ochrophyta) (18%), covering *Padina tetrastromatica* Hauck, *Padina australis* Hauck, *Sargassum* sp., *Dictyota bartayresiana* J. V. Lamouroux. Finally, seven species of Rhodophyta (32%), including *Hypnea asperi* Bory, *Corallina* sp., *Eucheuma denticulatum*, *Amphiroa fragilissima* (L.) J. V. Lamouroux, *Acathophora specifera* (M. Vahl) Borgeson, *Galaxaura rugosa* (J. Ellis & Solander) J. V. Lamouroux, *Laurencia nidifica* J. V. Lamouroux. The diversity of macroalgae species at the research station in Kongsi and Pari Island is seen in Figure 3.

Overall, the macroalgae community in the waters of the Pari Island Cluster is dominated by Chlorophyta, which has a larger species composition and several species, followed by Rhodophyta and Phaeophyta. The presence of Chlorophyta is 50 %, with 11 species dominated by *Caulerpa* and *Dictyosphaera*, while *Padina* dominates Phaeophyta, and *Achanthopora* and *Galaxaura* dominate Rhodophyta. The high Chlorophyta in the waters of the Pari Island Cluster is thought to be due to the substrate type at the study site filled with sandy sand and mud, which is a suitable growing place for Chlorophyta macroalgae. Chlorophyta has a filamentous, sheet, and cylindrical thallus with overlapping dense tissues (stolons) and creates a sea-based green network that allows horizontal expansion. In contrast, stolons stick to substrates such as those of the *Caulerpa*. Chlorophyta can inhabit various substrates of subtidal (sand, mud, rock, layers of dead seagrasses, from a depth of 0-50 m) and has the potential to expand its range along the coastline (Mushlihah et al. 2021). Macroalgae from Chlorophyta generally respond quickly to nutrient enrichment and tend to dominate in shallow aquatic environments. Chlorophyta is suitable for growing on sand substrates in the intertidal zone and tolerates lower salinity (Isham et al. 2018; Abdullah et al. 2020). Sand substrates are a less stable medium, easily blown away by large waves, even though certain species, such as Chlorophyta, can grow (Ferawati et al. 2014). Anggadiredja (2017) mentions that *Chlorophyta* macroalgae prefer to grow on sandy beaches and tolerate lower salinity.

Phaeophyta (Ochrophyta) presents 24.3% of the sample with four species. Phaeophyta contains chlorophyll pigments and phycocyanin, so this macroalgae's color is brown, has holdfast, thallus shaped like a fan, sheets, and there are radial concentric lines like in the *Padina* clan. Some are cylindrical, while the leaf morphology resembles a trumpet with jagged edges like the *Turbinaria*. In addition, thallus resembles Cormophyta plants with the characteristic presence of air bubbles between the leaves, such as the *Sargassum clan*, *Cystoceira*.

The presence of Rhodophyta was 32% of the sample with seven species. Rhodophytes contain chlorophyll and phycoerythrin pigments, so the thallus is red and has holdfast. Various thallus there are cylindrical, tightly prickly, and intermittent branching, as in *Euchema*, *Hypnea*, *Achantophora*, *Laurencia*, and *Gracillaria*, with a cartilaginous, herbaceous texture.


**Figure 3.** Diversity macroalgae Pari Island Cluster, Seribu Islands District, Jakarta, Indonesia

**Macroalgae ecological index in the Pari Island Cluster**

Diversity is a very important parameter and can be used to compare different communities of marine life, especially to determine the influence of water quality. Analysis of the diversity index, equality index, and dominance index in the two islands in the Pari Island Cluster is presented in Table 2.

The diversity index on the two islands belongs to the moderate category, i.e., the range of the diversity index is greater than 1 and smaller than 3. The diversity index of a community can describe its level of stability. The moderate diversity index is due to the still fairly stable environmental conditions and many macroalgae species found. Krebs (2014) stated that the value of the diversity index between 1<H'<3, including moderate species diversity and the environment's carrying capacity to the community, is still quite good.

According to Farito et al. (2018), the difference in macroalgae diversity index values is influenced by the number of individuals of each species and the total number of entire species. The fewer the number of species individuals of each species, the smaller the value of the diversity index. This is also reinforced by Kepel et al. (2019) that species diversity is related to species richness and distribution within a community. The low diversity value illustrates the small number of macroalgae present in these waters and also indicates the presence of a dominating species. Low levels of diversity can also be caused by habitat complexity due to substrate damage or high waves (Ferawati et al. 2014). Macroalgae in the intertidal and subtidal zones globally experience physical disturbances of both currents and waves (Kregting et al. 2016; Millar et al. 2020). Another factor that causes low diversity is excessive anthropogenic activity since macroalgae are organisms susceptible to environmental changes (Richmond et al. 2018). Handayani (2019) explained that macroalgae diversity is influenced by the substrate and how it attaches itself to the substrate. Herlinawati et el. (2017) state that diverse substrate types can affect the diversity of more diverse macroalgae.

The macroalgae dominance index obtained in the waters of the Pari Island Cluster is included in the low category. The dominance is centered on several species, so no one macroalgae dominate greatly. The low dominance value of a community species is due to the evenness of the number of individuals in each species (Krebs 2014). The evenness index (E) in the Pari Island Cluster is less than 1; generally, the evenness index between research stations is not too different. Therefore, it is suspected that species distribution tends to be heterogeneous, and a large number of macroalgae species strongly influences the number of species. Therefore, this similarity index shows that environmental conditions are still quite stable.

**Environmental quality of Pari Island Cluster waters**

Physical and chemical aquatic conditions influence the existence and diversity of macroalgae. The measurement results of several water parameters, including temperature, salinity, current, pH, turbidity, nitrates, phosphates, heavy metals, and substrates (Table 3), each provide an important role in the presence and diversity of macroalgae in water.

The quality of water and substrates have a very important role in macroalgae life in shallow marine waters. Environmental factors that influence the presence and diversity of macroalgae, such as temperature, are among the most important factors in regulating the metabolism and distribution of organisms. The temperature measurements results in the Pari island Cluster waters are 31.3°C. These temperatures are still within the normal range that macroalgae can tolerate. According to Charan (2017), the optimum temperature for macroalgae growth ranges from 28-30°C. Therefore, high water temperatures can have a bad impact on macroalgae growth.

The salinity of seawater also affects the distribution, abundance, and growth of macroalgae in coastal waters. The Pari Island Cluster's seawater salinity measurement results range from 30.79-31.3 ppt. These conditions still favor macroalgae growth as per the statement of Duran et al. (2018), that the optimum salinity range for macroalgae growth is between 26-41 ppt. Organisms in the intertidal zone generally tolerate a wide range of salinity and temperature (Roleda and Hurd 2019; Tsutsui et al. 2015). Some Chlorophyta species living in intertidal environments have varying salinity levels, such as *Chaetomorpha* sp. have a broader tolerance to salinity (Tsutsui *et al.* 2015).

The degree of acidity or pH also affects the growth of macroalgae. The results of measuring the degree of acidity (pH) in the waters of the Pari Island Cluster range from 8.10-8.13. The degree of acidity (pH) is good for macroalgae growth in the pH range of 6.8-9.6 (Anggadireja et al. 2017), and optimum pH conditions for macroalgae growth range from 6.8-8.2 (Young and Gobler 2016). So, the pH in the Pari Island Cluster is still quite ideal for macroalgae growth.

**Table 2.** The value of the diversity index, evenness index, and dominance index at the research site

| Parameters | Pari | Kongsi |
|---|---|---|
| Shanon-Wiener (H') | 2.31 | 1.907 |
| Evenness (E) | 0.594 | 0.481 |
| Simpson (D) | 0.121 | 0.211 |

**Table 3.** Water quality in the Pari Island Cluster, Seribu Islands District, Jakarta, Indonesia

| Parameters | Station | |
|---|---|---|
| | Kongsi Island | Pari Island |
| **Physics** | | |
| Temperature (°C) | 31.3 | 31.3 |
| Salinity (ppt) | 30.78 | 31.3 |
| Current ($m.s^{-1}$) | 5.33 | 4.14 |
| Depth (m) | 0.69 | 0.74 |
| Substrate | Sand, muddy sand | Sand, muddy sand |
| **Chemistry** | | |
| pH | 8.10 | 8.13 |
| DO ($mg.L^{-1}$) | 6.38 | 6.38 |
| Phosphate ($mg.L^{-1}$) | 0.039 | 0.021 |
| Nitrate ($mg.L^{-1}$) | 0.234 | 0.230 |
| **Heavy metals** | | |
| Hg ($mg\ L^{-1}$) | 0.001 | 0.001 |
| Pb ($mg.L^{-1}$) | 0.020 | 0.02 |
| Cu ($mg.L^{-1}$) | 0.021 | 0.21 |

Depth observations in the waters of the Pari island Cluster on sand substrates ranged from 33-58 cm at the lowest tidal. According to Farito et al. 2018, macroalgae in Indonesia grows well at a depth of 20-30 cm because, generally, sunlight penetration is still good and reaches that depth. On the other hand, waters that are too shallow will inhibit the growth of macroalgae because the bottom of the water is easily stirred, causing turbidity and disrupting the process of photosynthesis. In addition, macroalgae will be easily reached by predators such as sea turtles and sea urchins (Oliveira 2012; Marinho-Soriano 2012).

A suitable current for macroalgae growth is between 20-40 $cm.s^{-1}$. The measurement result of current velocity on a sand substrate of 4.14-5.33 $cm.s^{-1}$. Based on this range, the current speed in the Pari island Cluster during the study was below the optimal current speed. Anggadireja et al. (2017) state that waves or waves with relatively strong pressure cause macroalgae thallus to be damaged, but some macroalgae can survive even on large waves.

Nitrate is a chemical compound that serves as a nutrient in seawater. Nitrate levels in the waters of the Pari Island Cluster range from 0.230-0.234 $mg.L^{-1}$. The KLH (2004) sets a quality standard for nitrate compounds for marine life of 0.008 $mg.L^{-1}$. However, the range of nitrate content in the waters of the Pari Island Cluster is above the standard quality threshold for marine life. This is thought to be because the sampling time was carried out in September in the Eastern season, so there was a movement of currents from the Java Sea through the Seribu Islands which brought contamination from Jakarta Bay which is located opposite the Pari Island Cluster.

Phosphate is one of the nutrients needed and affects the growth and development of macroalgae. The measurements of phosphate levels in the Pari Island Cluster range from 0.002-0.039 mg/L, which is still within safe limits for marine life. The KLH (2004) set the standard quality for phosphate compounds for marine life at 0.015 $mg.L^{-1}$.

Heavy metal measurements are used to determine metal contamination in water. The measurement results of heavy metals in the Pari Island Cluster for Hg ranged from 0.0005-0.001 $mg.L^{-1}$, Pb ranged from 0.005-0.02 $mg.L^{-1}$, and Cu ranged from 0.005-0.21 $mg.L^{-1}$. The range of Hg levels is still within safe limits for marine life. The KLH (2004) set the standard quality for Hg compounds for marine life at 0.001 $mg.L^{-1}$. The high Pb, and Cu content in the Pari Island Cluster, above the safe limit for marine life, is thought to be because sampling was carried out in September or the Eastern season. The current in the waters of the Pari Island Cluster in the Eastern season (May to September) moves from the Java Sea through the waters of the Seribu Islands. These conditions allow water masses rom the Java Sea, especially Jakarta Bay, to be carried to the waters of the Pari Island Cluster. Jakarta Bay's sources of pollutants or pollutants are relatively large because it is located in an area of high industrial and anthropogenic activities. Furthermore, the activities of cruise and traditional ships used as a means of transportation and recreation, as well as industrial activities in the waters of the Seribu Islands, can affect the value of Pb and Cu metal content (Cordova and Muhtadi 2017; Sachoemar 2018).

## The relationship of water quality to macroalgae diversity

The results of the PCA analysis (Figure 4) show that Pari Island has a fairly good environmental quality. Biplot axes F1 and F2 of 51.36% mean that environmental characteristics influence the entire observation station by 51.36%. On Pari Island, the $S_4T_2$ and $S_4T_3$ stations are characterized by an environment with a high Hg and Cu content; other environmental factors such as temperature, brightness, depth, and TDS are also high. Stations $S_4T_2$ and $S_4T_1$ are characterized by environmental characteristics of orthophosphate content, heavy metal content Pb and high current speed. In addition, stations $S_1T_1$, $S_1T_2$, $S_1T_3$, and $S_2T_2$ are characterized by environmental characteristics with high nitrate levels, dissolved oxygen, and salinity and acidity (pH).

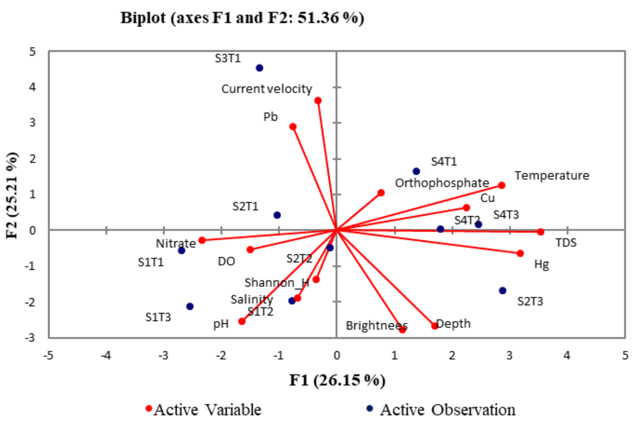


**Figure 4.** The relationship of the diversity index with the quality of Pari Island waters, Seribu Islands District, Jakarta

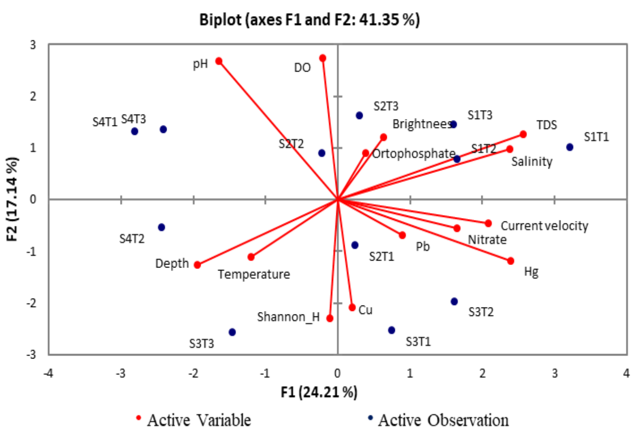


**Figure 5.** The relationship of the diversity index with the quality of Kongsi island waters, Seribu Islands District, Jakarta

The results of the PCA analysis (Figure 5) show that Kongsi Island has poor environmental quality. Biplot axes $F_1$ and $F_2$ of 41.35% mean that environmental characteristics influence the entire observation station at 41.35%. Environmental characteristics with high levels of nitrate, orthophosphate, Hg, Pb, Cu, and Cu, physical factors such as salinity, current speed, and high TDS characterize stations $S_1T_1$, $S_1T_2$, $S_1T_3$, and $S_2T_2$. Stations $S_2T_2$, $S_2T_3$, and $S_3T_1$ are characterized by environmental characteristics that have high levels of dissolved oxygen, high pH, and factors of high brightness physics. Stations $S_3T_2$, $S_3T_3$, $S_4T_1$, $S_4T_2$, and $S_4T_3$ are not characterized by environmental characteristics or values; the environmental characteristics are low.

Chemical factors, especially nitrate, orthophosphate, Hg, Pb, and Cu greatly affect macroalgae diversity, because Hg, PB, and Cu can be toxic to macroalgae at high concentrations, likewise the physical factors such as water salinity, current speed, and TDS. Physicochemical factors are a very influential determinant of macroalga diversity. This result was in line with the result of research by Melsasail et al. (2018) which has been done at Nusa Laut, Central Sulawesi, and Mushlihah et al. (2021) at Makasar Bay, South Sulawesi.

In conclusion, based on the results of data analysis and discussion it can be concluded that the macroalga diversity between Pari Island and Kongsi Island is different from the number of species and the number of individuals is higher on Pari Island. This difference is caused by differences in physical factors which include Hg, Pb, Cu, Orthophospat, water currents, brightness, salinity and TDS. There are 22 species of macroalgae found in the Pari Island cluster, consisting of *H. macroloba*, *H. opuntia*, *H. gracillis*, *H. micronesia*, *C. sertularoides*, *C. racemosa*, *C. racemosa var. uvifera*, *C. serrulata*, *Caulerpa sp.*, *Dictyospaera* sp., *B. forbesii*, *P. tetrastromatica*, *P. australis*, *Sargassum* sp., *D. bartayresiana*, *H. asperi*, *Corallina* sp., *E. denticulatum*, *A. fragilissima*, *A. specifera*, *G. rugosa*, and *L. nidifica*.

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