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# Exploration of Microalgal Role as Bioindicator to Evaluate Water Quality in the Waters of Desa Sungai Nibung West Kalimantan

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**Abstract:** The coastal area of Desa Sungai Nibung is a conservation area with high biodiversity. This area has been used for various activities, such as capture and aquaculture fisheries, shipping traffic, and tourism. These activities could affect the waters, ecosystems, and biodiversity condition. Water quality is determined by several parameters, which one of the bioindicators is microalgae. The presence of certain microalgae contributes to the change in the color of the water which indicates the presence of HABS phenomenon. Therefore, this study aimed to determine the composition of microalgae in the waters of Desa Sungai Nibung. Water samples were taken by purposive sampling method in 5 stations with different environmental characteristics. Each station was taken surface water using a plankton net. Microalgae in the samples were then observed with a microscope and their abundance was calculated. The composition of microalgae consisted of 22 genera, belonging to Bacillariophyceae (14 genera), Dinophyceae (7 genera), and Chlorophyceae (1 genus). The Bacillariophyceae dominated the waters with a percentage of 63.66%. Microalgae abundance ranged from 3.94-7,329.25 ind/L with oligotrophic and mesotrophic categories. The diversity index was low to medium (0.74-1.78), Evenness index was low to medium (0.31-0.66), and dominance index was low to high (0.24-0.74).

**Keywords:** Bacillariophyceae; *Chlamydomonas*; Estuary; Microalgae

## Introduction

The coastal area of Desa Sungai Nibung has been reported to have high biodiversity which supports the designation of the area as a conservation area in Kubu Raya Regency, West Kalimantan based on West Kalimantan Provincial Regulation Number 1 of 2019 and Decree of the Minister of Marine Affairs and Fisheries Number 92/Kepmen-KP /2020. The coastal ecosystem in Desa Sungai Nibung plays an important ecological and economical role in maintaining global climate stability, as a habitat for various types of aquatic fauna, such as fish, crabs, shrimp, shellfish and various types of mangrove snails (Safitri et al., 2023a; Safitri et al., 2023b; Thasya et al., 2023) with important economic value that support the community's economy. Apart from that, the coastal area of Desa Sungai Nibung also provides services for various purposes, such as settlement, capture and cultivation fisheries, ship traffic, and tourism. However, the high intensity of these activities often contributes to the release of waste, garbage and the presence of nutrients which have negative impacts, one of which is drastically reducing water quality conditions. Santis et al. (2023) stated that human activities, both individually and in communities, are very vulnerable to posing significant threats to ecosystems and their biodiversity. Pollution and eutrophication are the main problems that generally occur in coastal areas due to waste discharge from land.

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Excessive concentrations of nutrients, lead various negative impacts on ecosystems causing a decrease in water quality (Bai et al., 2022; Akinnawo, 2023).

Water monitoring is considered very important to determine the quality of an environment, whether there are pressures or not that affect the balance of the ecosystem. This assessment can be carried out using various methods, such as analysis of physical, chemical and biological parameters. The use of living organism as biological indicators is able to provide comprehensive information because their existence in direct contact with environmental changes that occur around (El-Din et al., 2022). Organism that can be used as a bioindicator is microalgae. Microalgae are eukaryotic organisms, autotrophs (Ruiz et al., 2022) which can produce their own food through the process of photosynthesis, and are primary producers in the food chain. As cosmopolitan organisms, microalgae are widely distributed, and can be found in various types of waters (Mahmudi et al., 2023; Arsad et al., 2024).

Several previous studies used microalgae as bioindicators of aquatic health (Apriansyah et al., 2021; Santos et al., 2023) because they have high sensitivity and fast response to fluctuating environmental conditions (Khalil et al., 2021). Microalgae community structure is used as an indicator of the health of intensive *Litopenaeus vannamei* shrimp ponds in Probolinggo Regency. The composition of microalgae in healthy ponds is more stable than in contaminated ponds (Musa et al., 2024). In addition, Samudra et al. (2022) also reported that microalgae can be used as an indicator of the level of pollution in waters. The appearance of certain types of microalgae that cause changes in water color can indicate the presence of the Harmful Algal Blooms (HABs) phenomenon. Some microalgae produce potent toxins that are transferred through the food web (Díaz & Álvarez, 2023), which are harmful to the environment and other organisms. Knowledge about the composition of microalgae species in the waters of Desa Sungai Nibung is not only used as a database, but can also be used to develop steps in managing coastal ecosystems. Therefore, this research aims to analyze the microalgae community in the waters of Desa Sungai Nibung, West Kalimantan.

## Method

*Sampling Location*

Water sampling for microalgae community was carried out in August 2023 in the waters of Desa Sungai Nibung, Kubu Raya Regency. A total of 5 (five) station points were determined using the purposive sampling method with different environmental characteristics. Stations I and II are waters close to the sea, station III is an estuary, stations IV and V are river waters (Figure 1).

*Microalgae Sampling*

A total of ± 100 L of surface water samples with three repetitions was filtered using a plankton net with a length of 1 m, a mouth of 30 cm, and a mesh size of 30 µm. The filtered water sample was put into a 30 mL bottle, then 3-4 drops of 4% formalin solution were added (Edler & Elbrachter, 2010) for sample preservation. After that, the microalgae samples were placed in a cooling box to avoid direct exposure to sunlight (Aryawati et al., 2017).

*Microalgae Identification*

Observations and calculation of microalgae samples were carried out at the Marine Science Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Tanjungpura using an XSZ 107BN Smartcare binocular LED microscope with a magnification of 10 x 10. The genera of microalgae found were identified using an identification book according to Vuuren et al. (2006) and Yamaji (1984), as well as database information at https://www.algaebase.org/.

*Data Analysis*

*Species Abundance and Relative Abundance*

Species abundance provides information on the number of microalgae found in a certain unit volume. Abundance (K) can be calculated quantitatively with the following equation:

$$K = \frac{Q_1}{Q_2} \times \frac{Vr}{Vo} \times \frac{1}{p} \times \frac{1}{V} \times ni \quad (1)$$

where K is abundance of microalgae species (ind/L), $Q_1$ is cover glass area (mm), $Q_2$ is field of view area (mm), Vr is volume of filtered sample (30 mL), Vo is volume of sample drop (1 mL), p is number of visual fields, V is volume of filtered water (100 L), and ni is the individual amounts of microalgae (ind).

Relative abundance (KR) is a percentage comparison between the abundance of a type of microalgae and the total abundance in the population. Relative abundance can be calculated using the following formula:

$$KR = \frac{K_{type}}{K_{total}} \times 100\% \quad (2)$$

*Biological Index of Microalgae*

The microalgae diversity index can be calculated using the Shannon-Wienner formula, such as (Shannon & Wiener, 1969):

$$H' = -\sum_{k=0}^{n} pi \ln pi \tag{3}$$

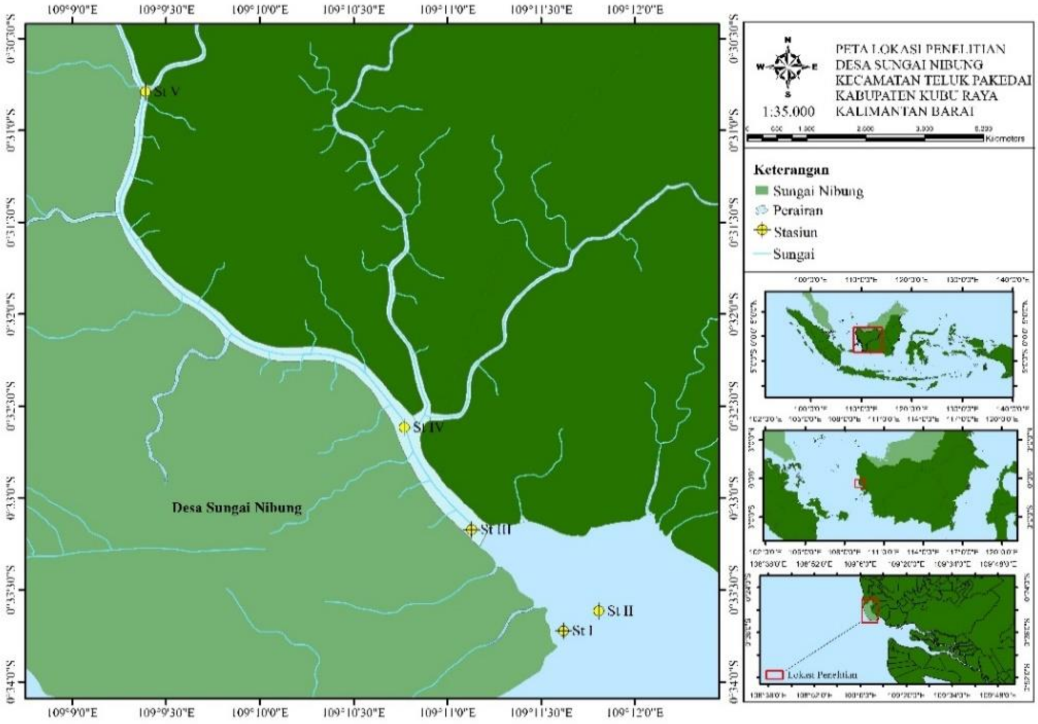


**Figure 1.** Microalgae sampling location in the waters of Desa Sungai Nibung, West Kalimantan

where H' is microalgae diversity index, pi is ni/N, ni is number of individuals type (ind), and N is total number of individuals (ind).

**Table 1.** Diversity index criteria

| Value | Criteria |
|---|---|
| $H' < 1$ | low level of diversity |
| $1 < H' < 3$ | moderate level of diversity |
| $H' > 3$ | high level of diversity |

Furthermore, the microalgae diversity index value can express the condition of water quality, where $H' < 1$ describe that waters are experiencing pollution, value of $1 < H' > 3$ indicate that waters in the moderate level of pollution, while $H' > 3$ exhibit that waters are not experiencing pollution (Begon et al., 1986).

The calculation of the Evenness index (E) provides information about the distribution of microalgae in a particular group. The Evenness index can be calculated using the equation (Odum, 1993), as follows as:

$$E = \frac{H'}{\ln S} \tag{4}$$

**Table 2.** Evenness index criteria

| Value | Category |
|---|---|
| $0.00 < E < 0.50$ | low level of uniformity |
| $0.50 < E < 0.75$ | moderate level of diversity |
| $0.75 < E < 1.00$ | high level of diversity |

The species dominance index (C) can be used to determine the presence of certain genus/species of microalgae that dominate in a population, calculated using the following equation (Odum, 1993):

$$C = \sum \left(\frac{ni}{N}\right)^2 \tag{5}$$

where C is dominance index, ni is number of individuals of spesies (ind), and N is total number of individuals in population (ind).

**Table 3.** Dominance index criteria

| Value | Category |
|---|---|
| $C < 0.50$ | dominance in low level category |
| $0.50 < C < 0.75$ | dominance in low moderate category |
| $C > 0.75$ | dominance in high level category |

## Result and Discussion

*Composition of Microalgae in the Waters of Desa Sungai Nibung*

During the study periods, 22 microalgae genera were found that belonged to 3 classes, such as Bacillariophyceae (14 genera), Dinophyceae (7 genera), and Chlorophyceae (1 genera). In the waters of Desa Sungai Nibung, Bacillariophyceae (diatoms) had the highest percent contribution and was found to be dominant (Figure 2). This condition is due to that Bacillariophyceae is cosmopolite organism (Kaczmarska et al., 2014), widely distributed in waters (Arsad et al., 2021), and is the main group in the microalgal community (Fu et al., 2022). This is well recognized that the domination of Bacillariophyceae in Indonesian waters as natural phenomenon and it has been reported by numerous studies (Mahmudi et al., 2023; Arsad et al., 2024; Rahimi et al., 2024). Everest & Aslan (2016) stated that the occurrence of the Bacillariophyceae class is very common in almost aquatic environments, which is due to its high adaptability to varied environmental conditions. This high adaptation is supported by the presence of silica ($SiO_2$) content in the Bacillariophyceae internal skeleton/cell wall (Williams & Kociolek, 2011) which provides the ability to withstand environmental challenges.

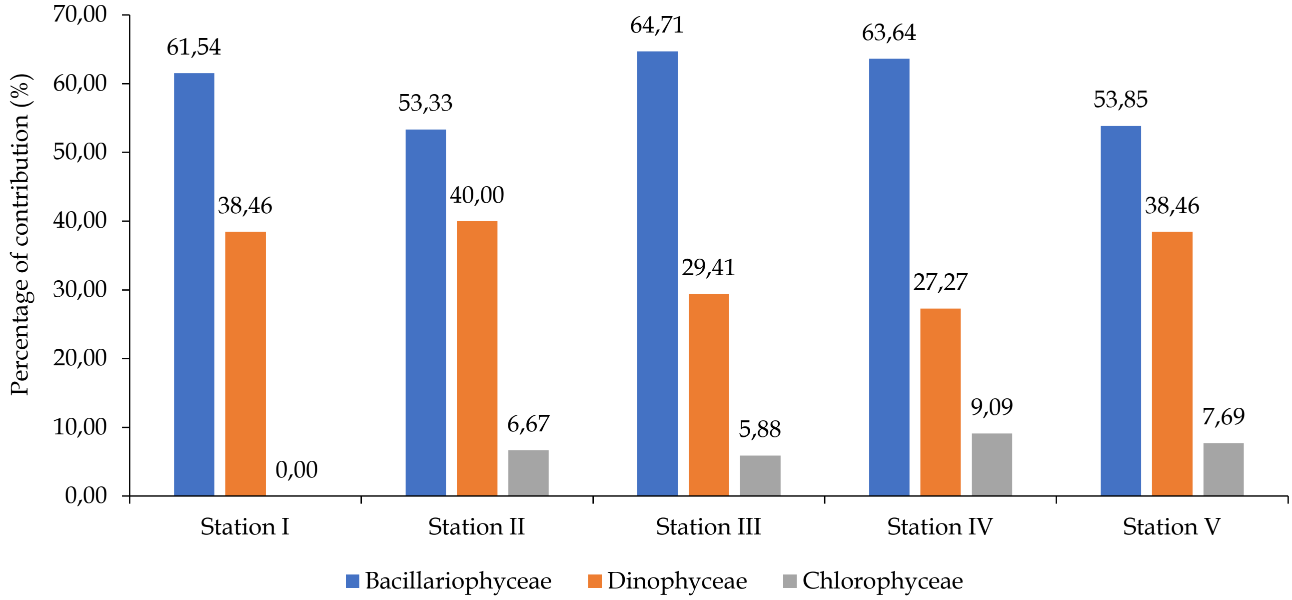


**Figure 2.** Percentage of microalgae in the waters of Desa Sungai Nibung

Bacillariophyceae is easily be found and reproduce rapidly in a variety of different habitat characteristics (Arsad et al., 2021), both in freshwater (Purwati et al., 2022; Kryvenda et al., 2023; Maulana & Prihantini, 2023), brackish (Chang et al., 2023), marine (Tambaru et al., 2021; Japa et al., 2022; Zainal et al., 2023), and terrestrial habitats (Gonçalves et al., 2021). In addition, some species are reported to have high adaptability to changing water conditions (Arsad et al., 2021) and fast growth rates (Inomura et al., 2023) supported by nutrient availability (Zakiyah et al., 2020; Giri et al., 2022). As one of the groups that has a high level of diversity, diatoms are widely used as bioindicators for assessing the ecological status of a water body (Apriansyah et al., 2021; Persada et al., 2022; Barinova et al., 2023).

The Dinophyceae class (dinoflagellates) was also found in the waters of Desa Sungai Nibung with the highest percent contribution at station II (40%). Dinophyceae can be found both in surface (planktonic) and bottom waters (benthic) by attaching to various types of substrates (Lee et al., 2020; Reñé, 2023; Durán-Riveroll et al., 2023), such as sediments, corals, seagrasses, or macroalgae. Most dinoflagellate genera play an important role in trophic levels in a community, either as primary producers or grazers (Horiguchi, 2015). In aquatic ecosystems, dinoflagellates showed a lower growth rate compared to the diatom (Litchman et al., 2007) because they do not use available nutrients in their surrounding efficiently. Although dinoflagellates are not competitors at nutrient uptake, under certain conditions they can proliferate in high abundance, even some species have been reported to produce toxins, causing Harmful Algae Blooms (HABs) (Nasution et al., 2021; Wang et al., 2021; Al-Has et al., 2022). In nature, approximately 2% of microalgae species can produce toxins, where 75% of which are dinoflagellates (Smayda & Reynolds, 2003). Some species found in Desa Sungai

Nibung waters such as *Dinophysis*, *Ceratium*, *Protoperidinium*, and *Prorocentrum* where these species were reported to produce toxins causing HABs (Véronique et al., 2021; Samudra et al., 2023). Some types of toxins synthesized by dinoflagellate species include maitotoxin (MTX), Brevetoxin (BTX), Zooxanthellatoxins (ZTs), Palytoxin (PLTX), Karlotoxin (KmTx), Spirolides (SPX), Gymnocin-A (GYMA), Azaspiracid (AZA) (Pradhan & Ki, 2022) and recent research has found new types of toxins (Gin et al., 2021) that have a negative impact on the environment, human health and biota in these waters (Su et al., 2020; Rolton et al., 2022).

The presence of Chlorophyceae (green algae) was also detected in the waters of Desa Sungai Nibung with a percent contribution between 5.88 - 9.09%. This class is reported to be cosmopolite (Novis et al., 2024), which can be found ranging from freshwater, brackish, marine waters (Arsad et al., 2021; Apriansyah et al., 2021; Zainal et al., 2023) to extreme habitats such as snow, deserts, and hot springs (Jonker et al., 2013; Patel et al., 2019). Chlorophyceae also have high adaptation to various types of environmental conditions, such as changes in temperature, salinity, pH, DO, organic matter, and nutrients (Soeprapto et al., 2023). Several previous studies have reported that green algae species can be used as bioindicators of polluted waters (Bonanno et al., 2019; Zikriah et al., 2021). In addition, the dominance of Chlorophyceae species with high abundance could be used as well an indication of eutrophication phenomenon (Suryono & Sudarso, 2019) where waters have excess nutrient content. Household effluents from human activities are responsible for the presence and high content of nutrients in waterways (Barokah et al., 2017). The sewage entering the waters may contain nitrogen, nitrate, orthophosphate, silicate, and ammonia (Balqis et al., 2021). Nitrate and phosphate play a role in growth of microalgae spesies (Gurning et al., 2020), cellular metabolic processes and biomass production (Millán-Oropeza et al., 2015; Pratama et al., 2017).

**Table 4.** Microalgae genera in the waters of Desa Sungai Nibung, West Kalimantan

| Class | Station I | Station II | Station III | Station IV | Station V | % |
|---|---|---|---|---|---|---|
| Bacillariophyceae | | | | | | 63.66 |
| *Cerataulina* | - | * | * | - | - | |
| *Chaetoceros* | * | - | * | * | * | |
| *Cocconeis* | - | - | * | - | - | |
| *Coscinodiscus* | - | * | * | * | * | |
| *Cyclotella* | * | * | * | * | * | |
| *Lauderia* | * | * | - | * | * | |
| *Navicula* | - | - | * | - | - | |
| *Nitzschia* | * | * | * | - | * | |
| *Odontella* | * | - | - | - | | |
| *Paralia* | - | * | * | * | * | |
| *Phaeodactylum* | * | - | - | - | * | |
| *Synedra* | - | - | * | * | - | |
| *Thalassionema* | * | * | * | - | - | |
| *Thalassiosira* | * | * | * | * | - | |
| Dinophyceae | | | | | | 31.81 |
| *Actiniscus* | * | * | - | - | - | |
| *Amylax* | * | * | * | - | * | |
| *Ceratium* | * | * | * | * | * | |
| *Dinophysis* | - | * | * | * | * | |
| *Ditylum* | * | * | * | * | * | |
| *Prorocentrum* | - | - | - | - | * | |
| *Protoperidinium* | * | * | * | | | |
| Chlorophyceae | | | | | | 4.53 |
| *Chlamydomonas* | - | * | * | * | * | |
| Total Genera | 13 | 15 | 17 | 11 | 13 | |

(*) : present ; (-) : don not present

Based on the the analysis, there are variations of microalgae types found at each sampling station (Table 4). The variety of species found is strongly influenced by environmental characteristics and water quality parameters (Al-Harbi, 2017). At station III, which is close to the river mouth, the highest number of microalgae species (17 genera) was found. The estuary is one of the most productive waters (Burford & Faggotter, 2021) by carrying nutrients from the land and ocean, allowing the high presence and abundance of aquatic biota, including microalgae.

Some of the most common genera are *Chlamydomonas*, *Thalassiosira*, *Amylax*, and *Ditylum* which have high adaptation and wide distribution. These genera were found in almost all sampling stations with high abundance. The waters of Desa Sungai Nibung had an abundance of microalgae between 3.94 - 7,329.25 ind/L with an average of 423.78 ind/L (Figure 3). Based on the abundance of microalgae, the waters of Desa Sungai Nibung was categorized as the oligotrophic to mesotrophic (Linus et al., 2016). *Chlamydomonas* has the highest abundance, due to its rapid growth and reproduction rate with cell division time between 8-12 hours (Calatrava et al., 2023). Saloméa & Merchanta (2019) also reported that *Chlamydomonas* is widely distributed in waters around the world. Previous research by Zikriah et al. (2021), *Chlamydomonas* can be used as a bioindicator of water pollution. Another genus that has a high abundance is *Thalassiosira* (7,423.83 ind/L). The genus has a wide distribution and has an important role ecologically because it is the main group in the microalgal community (Li et al., 2013). *Thalassiosira* is the dominant species found in coastal waters both in the water column and sediments (Naya, 2012), forming colonies and blooming, and potentially as harmful algae (Prasad et al., 2018). *Ditylum* sp. as a centric diatom has morphological characteristics like cells are elongated, prismatic to box-shaped, and the cell walls contain silica. This species is generally discovered in coastal waters (Zakiyah et al., 2020; Zainal et al., 2023; Widianingsih et al., 2024) and has fast growth rate in favorable condition.

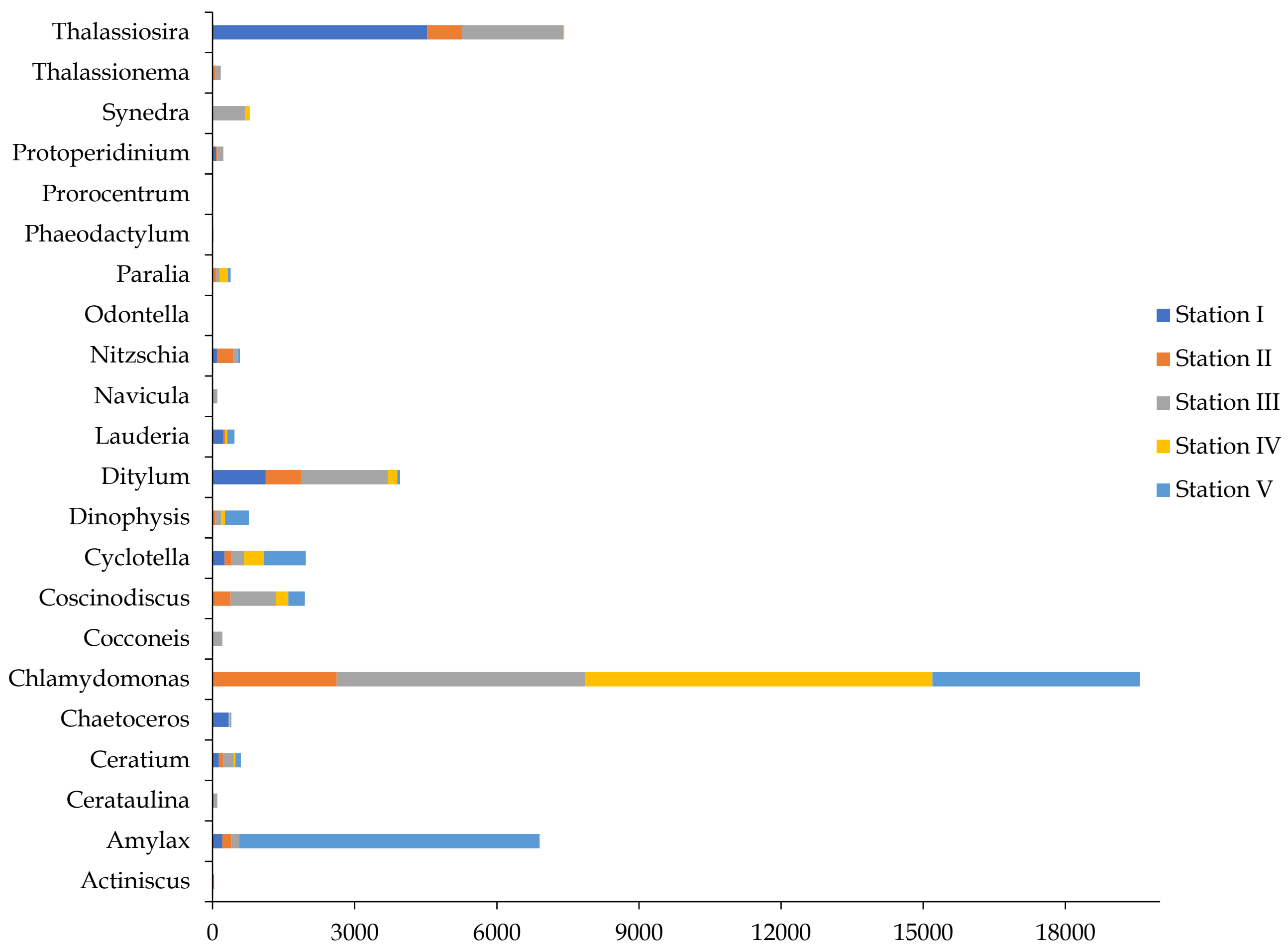


**Figure 3.** Abundance of microalgae in the waters of Desa Sungai Nibung

*Biological Index of Microalgae*

Biological indices including diversity (H'), Evenness (E), and dominance (C) can provide information on the level of stability of a microalgal community in the waters. The waters of Desa Sungai Nibung have biological index values that vary between sampling stations. The variation in value is influenced by the number of species, the number of individuals found, and the distribution pattern.

The diversity index (H') of microalgae is in the range of 0.74 - 1.78 which interprets the level of water stability in the low to medium category (Odum, 1993). The condition of the aquatic environment is thought to be the main factor affecting the level of diversity, so that only certain genus can survive with a high level of adaptation. However, these conditions are still relatively good for microalgae growth (Arsad et al., 2022). In addition, the diversity index can also be used to assess the level of water pollution (Begon et al., 1986), where the waters of Desa Sungai Nibung was categorized as moderately to heavily polluted. This is retrieved because the waters are close to residential areas with household waste and other sources of pollution which are not managed properly.

The Evenness index (E) value of microalgae in the waters of Desa Sungai Nibung ranging from of 0.31 to 0.66 where in general the waters fall into the low to medium category. This value indicated that each genus is not evenly distributed and there was a tendency for certain genera to dominate in the community. This condition correlates with the dominance index (C) value which was in the range of 0.24 - 0.71 and classified as low to high category. This indicated that not all genera have the same opportunity and ability to grow under environmental conditions. The high value of domination index could be used as an initial indicator of microalgal blooms.

## Conclusion

There were 22 genera of microalgae in the waters of Desa Sungai Nibung, where the Bacillariophyceae class dominated the waters with a percent contribution of 63.66%. In general, the most commonly found genera were *Chlamydomonas*, *Thalassiosira*, *Amylax*, and *Ditylum*. The microalgae abundance ranging from 3.94 - 7,329.25 ind/L with an average of 423.78 ind/L, indicated that Desa Sungai Nibung waters was categorized as the oligotrophic to mesotrophic level. The diversity index (H') is in the low to medium category, exhibited that the waters condition was categorized as moderately to heavily polluted. The Evenness index (E) was low to medium, and dominance was in the low to high category, indicated that there was a tendency for certain genera to dominate in the community.

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**Author Contributions**

onceptualization, I. S.; methodology, I. S. and M. S. J. S.; validation, I. S. and M. S. J. S.; formal analysis, I. S.; investigation, I. S.; resources, I. S.; data curation, I. S.; writing—original draft preparation, I. S. and M. S. J. S.; writing—review and editing, I. S. and M. S. J. S.; visualization, I. S. and M. S. J. S. All authors have read and agreed to the published version of the manuscript.

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**Conflicts of Interest**

The authors declare no conflict of interest or personal relationship that could have appeared to influence the work reported in this paper.

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