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MICROALGAE COMMUNITY AS AQUATIC QUALITY BIOINDICATOR IN PENITI ESTUARY WEST KALIMANTAN

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ABSTRACT

Estuaries are biogeochemical hot spots; they receive large inputs of nutrients from land and oceans to support high primary productivity rates. Estuaries also as a place for waste disposal allowing the accumulation that endangers the environment and organisms. Water quality assessment can be done by analyzing physical, chemical, and biological characteristics using microalgae. This study aimed to analyze the microalgae community as aquatic environment bioindicator. Survey method was used and sampling location was in four different sites of Peniti Estuary by purposive sampling. Identification of microalgae, density, biological indexes, and water quality measurements was taken in this research. The result showed microalgae community consists of 68 genera and Euglenophyceae was a component of microalgae with the highest percentage of abundance (60.93%). The most commonly found genera were Trachelomonas, Phacus, Lepocinclis, and Sphaerellopsis. The abundance of microalga was ranging from 0.5-2141.5 ind/L. Biological indexes indicate that Peniti estuary environment was belonging to moderately polluted and water eutrophication. The abundance of microalgae was influenced by physico-chemical factors such as temperature, current, nitrate and phosphate content.

Keywords: Microalgae; bioindicator; estuaries

INTRODUCTION

Coastal ecosystems have a high diversity and provide potential services for the production and use of biological resources. Estuaries are one of the most productive waters with nutrient input from both land and ocean. They are also places for discharge and run-off from the mainland, allowing for the accumulation of waste (Rangkuti *et al.*, 2017) which can endanger the environment and existing organisms.

The estimation of water quality is considered very important for hazard and impact assessment (Warhate *et al.*, 2006). This assessment can be done by analyzing physical, chemical, and biological characteristics (Kazi *et al.*, 2009), including using microalgae. Microalgae have an essential role in aquatic ecosystems as primary producers and as well as contributors of dissolved oxygen. Their existence is commonly used as an aquatic quality indicator (Nontji, 2005), due to their life cycle is short and have a swift response to environmental change (Nugroho, 2006). Besides, parameters of water quality can also be viewed by the content of dissolved oxygen, temperature, pH, and nutrients such as nitrates and phosphates (Nybakken, 1988).

Peniti estuary is located in Mempawah Regency, West Kalimantan. This area has been developed for various purposes and uses, such as residential activities, forestry, tourism, and fisheries. The water conditions are greatly influenced by the intensity of human activities. Community actions are a factor affecting the disposal of waste, garbage, and the presence of nutrients that have an impact on water quality. Gholizadeh *et al.* (2016) stated that anthropogenic activities are prone to result in a change in ecosystems and can endanger the habitat of fish and other aquatic organisms.

Another dominant problem in the coastal area is pollution that causes a decrease in resources quality and quantity. Decreasing water quality will reduce the productivity and carrying capacity of these aquatic resources (Hamuna *et al.*, 2018). Pollutants come from various sources, such as waste, agriculture, and other activities (Tabor *et al.*, 2011). In addition, water that come from various sources can also contain dissolved inorganic and organic substances causing health problem for the community (Duressa *et al.*, 2019).

The observation of water quality can be carried out by detecting changes in environmental parameters. Therefore, it is necessary to conduct research focusing on the analysis of physical, chemical and biological characteristics. This study aims to analyze the structure of microalgae community as aquatic bioindicator and the conditions of physico-chemical parameters in Peniti estuary, West Kalimantan.

RESEARCH METHODS

This research was conducted in Peniti estuary, Mempawah Regency, West Kalimantan (Figure. 1). The location of microalgae sampling and measurement of physico-chemical parameters were carried out in-situ at four stations, where each location consisted of three sampling points. The station I is located close to settlements and aquaculture activities. Station II is near to settlement area, station III represents area far from human activities and directly adjacent to the sea, and station IV is the sea, respectively. Measurement of each parameter was carried out in three replicates.

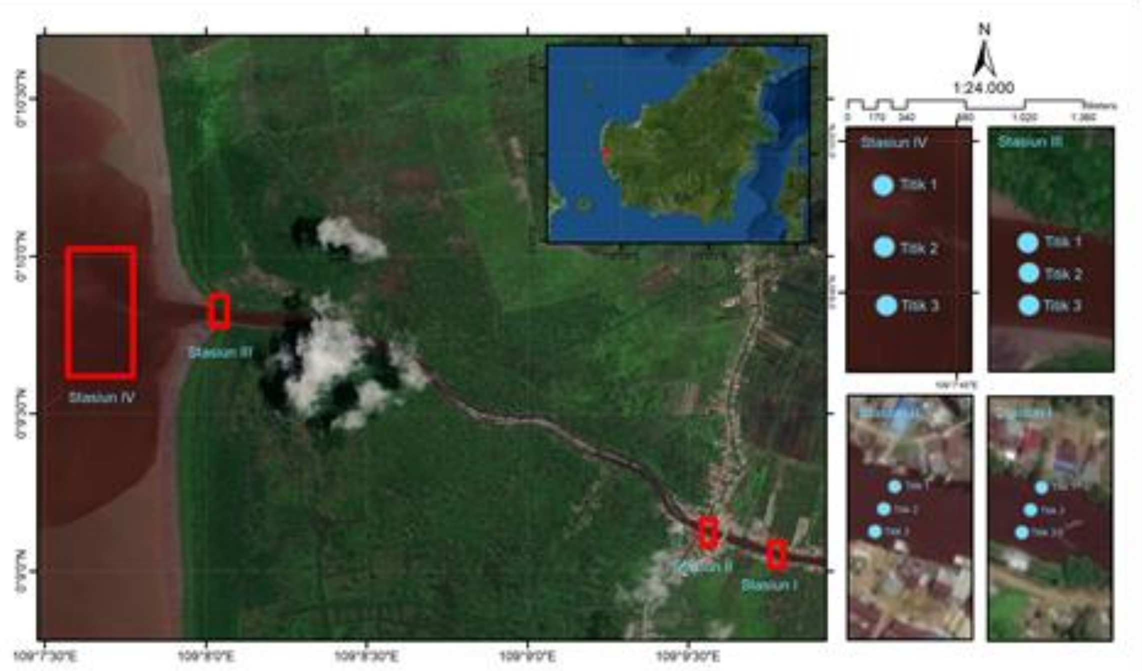

Figure 1. Sampling locations in Peniti Estuary

Sampling of Microalgae

Microalgae samples were collected by filtering 100 L of water using a plankton net, with diameter of net mouth of 30 cm, mesh size 30 µm, and net length 100 cm long (Aquino *et al*., 2010; Mulyani *et al*., 2012). The filtered samples were put into a clean specimen falcon bottles and added with filtered seawater to a final volume of 20 mL. Samples were then fixed and preserved by adding three drops of formalin (4%) solution (Edler and Elbrachter, 2010) on the sites. The sampling was conducted in three replicates each stations. All samples were strored in a coolbox and protected from direct light (Aryawati *et al*., 2017) to avoid the damage of samples.

Measurement of Water Quality Parameters

Water samples were taken together with the collection of microalgae in all sampling locations that had been determined. Water quality parameters such as temperature, dissolved oxygen (DO), salinity, pH were measured using the AZ 8603 of WQC instrument. All parameters were measured in three replications. Water depth was measured using an echosounder, and current velocity was using a current meter at three different depths. The concentration of nitrate and phosphate were tested in the Laboratory of Industrial Research and Standardization Center Pontianak according to (SNI 6989.79:2011) and (SNI 06.6989.31-2005)

Microalgae Sample Analysis

Microalgae identification was conducted up to genus level using identification book guide by Yamaji (1984), Tomas *et al*. (1996), Tomas *et al*. (1997), Omura *et al*. (2012), and Witkowski *et al*. (2000). Quantitative analysis was done by putting one drop of fixed sample (0.02 mL) on the glass slide (Ganai and Parveen, 2014) and the numerical microalgae was carried out using binocular light microscope. The abundance was calculated according to the following formula (APHA, 2009) :

$$K = \frac{Vr}{Vo} \text{ x } \frac{1}{V} \text{ x ni} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where, K is the abundance of microalgae (ind/L); Vr is the volume of concentrate in the sample bottle (20 mL); Vo is the volume of the unit drop of water sample (1 mL); V is the volume of filtered seawater (100 L); ni is the individual amount of microalgae (ind).

The relative abundance was calculated using the formula :

$$KR = \frac{\text{K suatu jenis}}{\text{K total}} \text{ x } 100\% \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where, KR is the relative abundance (%) and K is the abundance of microalgae (ind/L).

Microalgae species diversity index (H') was determined following Shannon-Wienner (1969) formula

$$H' = -\sum_{i=1}^{s} \text{pi ln pi} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where, H' is diversity index, pi is a proportional abundance of each species, is given pi = ni/N; ni is number of individuals species i; and N is total abundance of individuals species in a community.

Microalgae diversity was classified into three criteria (Odum, 1993), namely H'<1 indicates a low level, 1<H'<3 indicates a moderate level, and H'>3 indicates a high level of diversity, respectively. In addition, the value of diversity index can also be used to evaluate the water quality. The value of H'<1 expressed the water is in polluted condition, 1<H'>3 expressed the water is in moderately polluted, and H'>3 expressed the water is not polluted or in clean condition, respectively (Begon *et al*., 1986).

The Evenness index (E) was used to determine the distribution of microalgae in a community. This index was calculated following the formula (Odum, 1993)

$$E = \frac{H'}{H max} \qquad \text{.............................} \ (4)$$

where, E is Evenness index, H' is species diversity index, and H_{max} is maximum possible value of species diversity, is expressed H_{max} = ln S; and S is total number of species in a community.

The value of Evenness index ranges from 0-1, where the value near to 0 determines the uniformity of population is getting smaller, the distribution of individuals for each genus is not the same, and there is a tendency for a genus to dominate the population. Otherwise, if the value is close to 1, showing the uniformity and indicating that the individuals number of each genus is not much different and there is no tendency for a genus to dominate in the population (Krebs, 1985).

The dominance index Simpson was used to determining the existence of a specific type of microalgae species dominance in the column waters, and was calculated following the formula (Odum, 1993)

$$C = \sum (ni/N)^2 \qquad \text{.............................} \ (5)$$

where, C is dominance index, ni is number of indivial species i; and N is the total number of individual species in the community.

The value of dominance index was classified into three criteria (Odum, 1993), $C<0.50$ shows low dominance, $0.50<C>0.75$ indicates moderat dominance, and $C>0.75$ indicates high dominance, respectively.

RESULTS AND DISCUSSIONS

Composition and Abundance of Microalgae

During the study period, a total of 63 microalgae genera were recorded, belonging to seven classes, Bacillariophyceae (29 genera), Chlorophyceae (9 genera), Cyanophyceae (4 genera), Dinophyceae (3 genera), Euglenophyceae (6 genera), Zygnematophyceae (11 genera), and Ulvophyceae (1 genus).

In Peniti estuary, among the identified microalgae, Euglenophyceae have the highest per cent contribution and were found to be dominant (Figure. 2). This class were often discovered in the aquatic environment. Community structure and composition of different microalgae in each sampling location occur due to the influence of environmental factors, such as currents (Kersen *et al*., 2011; Al-Harbi, 2017), temperature, salinity, pH, Dissolved Oxygen content, nutrient availability, light and the quality of water (Simanjuntak, 2012; El-Din et al., 20150, as well as a predator (Borowitzka et al., 2006) can affect the colonization and growth of microalgae.

The Euglenophyceae was a component of microalgae that can be found in fresh, brackish, and marine waters (Yubuki *et al*., 2009; Breglia *et al*., 2010), however most commonly in the freshwater ecosystem (Nixdorf et al., 2003; Wołowski and Hindák, 2005; Poniewozik, 2007; Kim et al., 2010; Adl et al., 2012; Salmaso and Cerasino, 2012; Naselli-Flores et al., 2016) which were high in organic matter. This class was susceptible to changing environmental conditions and became dominant (blooming) (Wołowski and Hindák, 2004; Wołowski and Walne, 2007; Poniewozik, 2009; Duangjan and Wołowski, 2013; Duangjan et al., 2014; Pęczuła et al., 2014) with high species diversity (Train and Rodrigues, 2004).

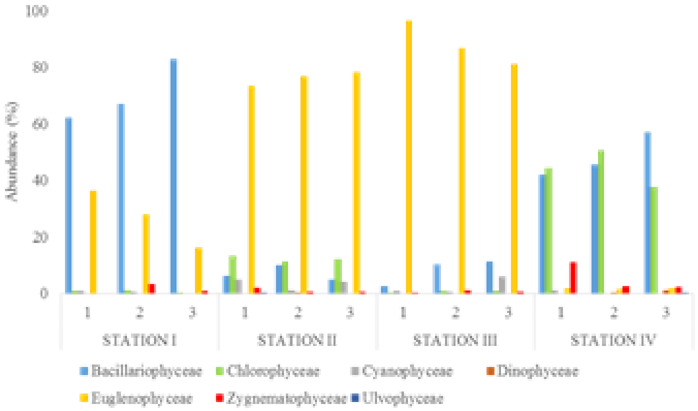

Figure 2. Microalga composition in Peniti estuary

Bacillariophyceae (diatom) are a major group of microalgae, and usually the most common type of microalgae in open ocean waters, freshwater, and river flows communities (Larasati *et al*., 2015; Purnawan *et al*., 2016), and was commonly used as a biological indicator of aquatic quality (Putra *et al*., 2012; Arifin *et al*., 2015). In addition, Bacillariophyceae has high adaptability in various extreme environmental conditions (Nurfadillah *et al*., 2012; Andriansyah *et al*., 2014; Arifin *et al*., 2015), has fast growth caused by the high availability of nutrients in waters as a result of human activities (household waste) (Barokah *et al*., 2016). Anthropogenic activities contribute waste to waters containing lots of inorganic nitrogen (N), phosphate (P), nitrate (NO_3), silicate (SiO_2), and ammonia (NH_3) (Larasati *et al*., 2015; Haninuna *et al*., 2015).

Several studies have observed that diatom remains dominant and occur in the highest percentage than other groups (Al. Hassany *et al*., 2012; Badsi *et al*., 2012; Ganai and Parveen, 2014; Aryawati *et al*., 2017). It is well known that the domination of diatom also as a phenomenon in Indonesian waters and it was recorded by several studies (Haumahu, 2004; Soedibjo, 2006; Fathi and Al-Kahtani, 2009; Setiabudi *et al*., 2016; Herlina *et al*., 2018).

Class of Chlorophyceae was also found in Peniti estuary waters with the highest abundance percentage (50.48%) at station IV point 2. This class was to be cosmopolite (Ferial and Salam, 2016), has high adaptability to widely changing of environmental condition such as changes in temperature, current speed, light penetration, pH, DO, salinity, and the availability of nutrients as well (Sagala, 2013). The abundance and domination of Chlorophyceae species indicate an eutrophication phenomenon (Suryono and Sudarso, 2019).

The most common genera were *Trachelomonas*, *Phacus*, *Lepocinclis*, dan *Sphaerellopsis* which have high adaptability and wide distribution. It can be seen that these species were found in each sampling sites (Figure 3.) with high abundance. The abundance of microalgae in Peniti estuary waters ranges from 0,5-2141,5 ind/L with an average of 154,62 ind/L. The highest abundance was *Trachelomonas* (2141,5 ind/L), *Phacus* (1713,5 ind/L), *Lepocinclis* (1540,5 ind/L), and *Sphaerellopsis* (1346,5 ind/L), respectively. Meanwhile, the respective percentage contributions were 21,98%, 17,59%, 15,81%, dan 13,82%, of the total microalgae found at the observation location.

According to previous research, from the group of Euglenophyceae, *Trachelomonas* was the dominant genus discovered in waters (Ariyadej *et al*., 2004; Poniewozik and Juráň, 2018). In addition, the genera *Lepocinclis*, *Phacus*, dan *Sphaerellopsis* were also frequently found (Duangjan *et al*., 2014; Jati *et al*., 2018) with various abundances. *Phacus* was a genus found mainly in river, ponds, and swamps Long with other Euglenophyceae species (Wołowski, 2011). The abundance of *Phacus* can be affected by high-temperature conditions and water pollution by organic matter (Duangjan *et al*., 2014).

The abundance and growth of microalgae was influenced by physico-chemical factors in the aquatic environment, such as light, salinity, and availability of nutrients (Ariyadej *et al*., 2004), currents, temperature, and seasons ((Kersen *et al*., 2011; El-Din *et al*., 2015; Al-Harbi, 2017). Microalgae play a crucial role as primary producers, are the basis of the food chain (Danilov and Ekelund, 2000), as can also be used as important biological indicators of waters (Agrawal, 2018). However, some species can be harmful to human and another aquatic biota by releasing toxins.

Water Quality Status According to Biological Index

The stability of microalgae community in waters can be observed from the value of diversity index (H'), Evenness index (E), and dominance index (C) (Table 1.). The diversity index was determined by the number of species, number of individuals, and the distribution pattern (Krebs, 1985). A community was considered to have high species diversity if there were many species found with the number of individuals of each species relatively equal. However, if a community consists of a few species with the number of individuals of each species not relatively equal, then the community has low diversity (Barus, 2004).

The diversity index (H') of microalgae in Peniti estuary ranged from 1,289 to 2,178. The highest H' value was at station I point three, and the lowest was at station III point 1. According to the diversity level criteria (Odum, 1993), the waters of Peniti estuary have a moderate level of microalgae diversity. This was presumably due to the influence of physico-chemical factors resulting in only certain types of microalgae were able to adapt to these conditions. Furthermore, the diversity value based on the Shannon-Wiener index associated with the pollution (Begon *et al*., 1986), Peniti estuary was in moderately polluted condition. This condition was due to the waters were close to settlement areas, and lots of garbage (household waste and other sources of pollutants) enters these waters.

The Evenness index (E) of microalgae in Peniti estuary ranged from 0,438 to 0,740. The highest E value was at station I point three and the lowest was at station III point 1. This condition indicates that in general, the waters have high microalgae uniformity. This index showed that the distribution of individuals for each genus was equally distributed and there was no tendency for a genus to dominate the population.

The dominance index (C) of microalgae in Peniti estuary ranged from 0,152 to 0,320. The highest value was at station III point 1 and the lowest was at station I point 3. According to the range of these value, the waters have low dominance category. This indicates that there were no certain types of microalgae that dominate the population, and a high E value followed this condition.

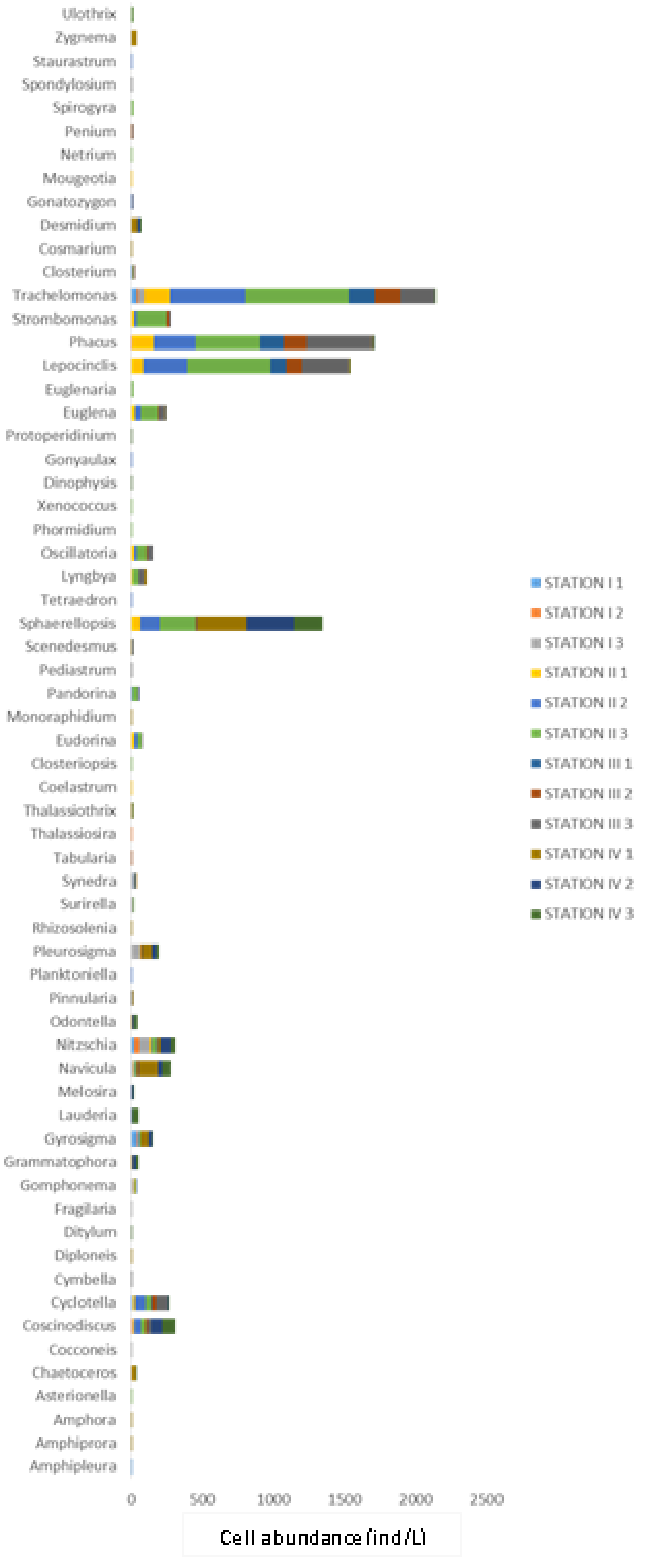

Figure 3. Microalgae Abundance in Peniti Estuary

Table 1. Diversity, Evenness, and Dominance Index of Microalgae in Peniti Estuary

Index	Station I			Station II			Station III			Station IV		
	1	2	3	1	2	3	1	2	3	1	2	3
H’	1.737	1.810	2.178	2.134	1.947	2.141	1.289	1.763	1.902	1.864	1.758	1.996
E	0.626	0.668	0.740	0.647	0.578	0.630	0.438	0.579	0.577	0.565	0.577	0.666
C	0.243	0.276	0.152	0.177	0.204	0.166	0.320	0.237	0.219	0.232	0.281	0.198

Water Quality Parameters

The waters condition of Peniti estuary can be observed based on physico-chemical parameters (**Table** 2). Depth was an environmental parameter related to the intensity of light entering to the water coloum (Effendi, 2003), and this affects the level of penetration. Aquatic organisms show different responses to changes in light intensity. The group of Dinophyceae and Cyanophyceae will regulate the volume of gas vacuoles to perform Daily Vertical Migration (DVM) in water column (Effendi, 2003). Increasing the depth will reduce the penetration rate of sunlight into the water column. Depth plays an important role in the photosynthesis process (Effendi, 2003; Rosada, 2017). The photosynthetic activity of microalgae will decrease when the light penetration decreases. At a depth of 3 meters, the abundance of microalgae was lower than that at 1 meter (Siregar *et al*., 2014). According to a previous study, the optimal depth for microalgae growth ranges from 1 to 5 meters (Legina *et al*., 2014)

Table 2. Physico-chemical Parameters of Peniti Estuary

Index	Station I			Station II			Station III			Station IV		
	1	2	3	1	2	3	1	2	3	1	2	3
Depth (m)	2.0	2.8	2.2	2.3	3.2	3.1	1.4	1.9	1.4	1.1	1.1	1.1
Temperature (°C)	29	29	29	29	29	29	32	32	32	31	31	31
Current (m/s)	0.06	0.06	0.05	0.07	0.11	0.12	0.19	0.14	0.14	0.21	0.07	0.09
DO (ppm)	7.4	7.3	9.3	9.6	9.8	9.1	9.7	9.2	9.5	9.2	8.2	8.6
pH	5.66	5.03	5.13	5.80	5.63	5.59	7.03	7.02	7.19	7.45	7.44	7.58
Salinity (‰)	0.19	0.12	0.12	0.52	0.56	0.73	17.80	17.30	14.30	13.30	11.30	11.36
Nitrate (mg/L)	2.05	2.31	2.41	1.96	1.74	1.70	0.53	0.76	0.38	0.22	0.41	0.41
Phosphate (mg/L)	0.09	0.08	0.06	0.07	0.15	0.11	0.11	0.04	0.05	0.09	0.09	0.11

In the present investigation, water temperature ranged from 29 to 32 °C. Previous research conducted at the same location, the surface temperature ranged 26,5-33 °C (Minsas, 2013). This value was still following the optimum temperature range for microalgae growth (20-31 °C) (Schaduw *et al*., 2013; Effendi, 2016). Water temperature is an important physical factor that plays a crucial role and influences the growth and the distribution of species. Rising in temperature can lead to stratification affecting water agitation, and this is important in order to disperse oxygen. Changes in surface temperature influence the physical, chemical, and biological processes in wateres (Kusumaningtyas *et al*., 2014). The temperature has an effect as well in determinis the presence and distribution of aquatic organisms and influencing the life of the existing biota (Odum, 1993; Effendi, 2003; Nontji, 2005; Brahmana, 2014). The increase in temperature causes an increase in metabolism rate and respiration as well as an increase in the decomposition of organic matter by microbes. This condition thus results rising in oxygen consumption in waters (Brahmana, 2014; Rangkuti *et al*., 2017).

The measurement of current velocity ranged from 0,05 to 0,21 m/s, and this was classified as a slow category. Current plays an important role in lotic water. This was related to the spread of aquatic organisms, dissolved gases, and Minerals or nutrients in the waters (Barus, 2004; Kordi and Tancung, 2010). In addition, the current velocity was also linked to the level of microalgae diversity. Waters with current speed ranging from 0,2-1 m/s will be dominated by *Nitzschia*, *Navicula*, *Synedra*, *Tabellaria*, *Oscillatoria*, *Eunotia* (Round, 1983).

Dissolved oxygen ranged from 7,3 to 9,8 mg/L and was still in the optimal range for the growth of organisms, including microalgae. According to the Decree of the State Minister for the Environment No. 51 (2004), the DO value supporting the life of aquatic biota is >5 mg/L. Meanwhile,the DO content <2 mg/L causes death for organisms (Effendi, 2003). DO levels in waters were influenced by diffusion from air, photosynthesis, respiration, oxidation of organic matter, temperature, and salinity (Effendi, 2003; Salmin, 2005; Sanusi, 2006; Brahmana, 2014). Waters with high human activities lead to the oxygen deficiency (anoxic) and increase the supply of nutrients and organic matter. Decomposition and oxidation of organic matter can reduce oxygen levels in waters to zero (anaerobic condition). In addition, the presence of waste can also reduce oxygen content and this was related to the excessive use of oxygen, especially in the process of decomposing organic matter by bacteria (Rangkuti *et al*., 2017).

pH is one of the important chemical parameters in monitoring the stability of the waters (Simanjuntak, 2009). The pH value in Peniti estuary showed acidic to slightly alkaline conditions, in the range from 5,03 to 7,58. The magnitude of the pH value in brackish waters was more stable, ranging from 7 to 8,5 (Rangkuti *et al*., 2017) and the variation greatly affect the community structure of aquatic organisms (plants, animals, and microorganisms). Effendi (2003) stated that most aquatic biotas was sensitive to pH changes and preferred a pH range of around 7 to 8,5. Furthermore, phytoplankton will exhibites the negative response in acidic condition (pH <6). In addition, the high value also greatly determines the dominance of microalgae which affect the level of water primary productivity (Megawati *et al*., 2014). The pH range between 6,5-8,0 was considered to be suitable for the life and growth of biota (Odum, 1993).

In the present study, Peniti estuary has water salinity ranging from 0,12 to 17,80 ‰. The variation of salinity were influenced by mixing between freshwater and seawater. Several types of microalgae have a wide tolerance to changes in salinity. However, the high level of salinity will affect the rate of cell division, distribution, and productivity of microalgae. Conversely, the low salinity value will influence the photosynthesis process and growth (Wisudyawati, 2014).

Nitrate (NO_3-N) is the main form of nitrogen in natural waters, as an important nutrient source for autotrophic organisms, including microalgae and as a growth-limiting factor (Rangkuti *et al*., 2017). The high concentration of nitrate in the waters can stimulate the growth and development of aquatic organisms (Effendi, 2003). The result showed that the nitrate concentration ranged from 0,22 to 2,41 mg/L. Station I and II showed high nitrate concentrations. The highest nitrate content was found at the station I and II, close to settlements area and aquaculture activities. Household activities contribute waste to waters containing lots of inorganic nitrogen (N), ammonia (NH_3), and nitrate (NO_3) (Casali *et al*., 2010; Larasati *et al*., 2015; Haninuna *et al*., 2015). Also, areas near to fish farming contribute a lot of nutrients due to aquaculture feed waste and feces that contain lots of ammonia (Kordi and Tancung, 2010; Barokah *et al*., 2016). Zhou *et al*. (2011) also revealed that intensive fish farming activities lead to nitrogen accumulation. According to the Decree of the State Minister for the Environment No. 51 (2004), the quality standard for the nitrate concentration in waters for marine biota is 0,008 mg/L. The concentration >0.2 mg/L can lead to eutrophication (enrichment) of waters and further stimulate rapid growth of microalgae and water plants (blooming), while nitrate levels >0.5 mg/L illustrate the occurrence of pollution originating from human activities and animal waste (Effendi, 2003).

The phosphate concentration at the observation sites ranged from 0.04 to 0.15 mg/L. The highest content was observed at station II which was close to residential areas. The source of phosphorus was less than the nitrogen source in the water. Phosphorus content can be affected by anthropogenic activities such as domestic and industrial waste, as well as run-off containing fertilizers from agricultural activities (Larasati *et al*., 2015; Haninuna *et al*., 2015; Rangkuti *et al*., 2017). Orthophosphate was a form of phosphorus that can be used directly by aquatic plants. Phosphate was a nutrient needed for the growth and metabolism of microalgae and other marine organisms in determining water fertility. Phosphorus was a very important limiting factor in productive and unproductive waters, and plays an important role in the determination of the number of microalgae (Thomas, 1955 in Kadim *et al*., 2017). In general, the phosphate concentration needed by diatoms was <0.015 mg/L. High levels of phosphate can trigger an increase in the population of microalgae, especially diatoms (Pello *et al*., 2014).

CONCLUSION

The study found 63 genera of microalgae species, consisted of Bacillariophyceae (29 genera), Chlorophyceae (9 genera), Cyanophyceae (4 genera), Dinophyceae (3 genera), Euglenophyceae (6 genera), Zygnematophyceae (11 genera), and Ulvophyceae (1 genus). Among the identified microalgae, Euglenophyceae have the highest per cent contribution (60,93%). The most common genera observed were *Trachelomonas*, *Phacus*, *Lepocinclis*, and *Sphaerellopsis* with the average abundance were 2141,5 ind/L, 1713,5 ind/L, 1540,5 ind/L, and 1346,5 ind/L, respectively. Peniti estuary waters have a moderate level of diversity, high microalgae uniformity, and dominance index in the low category. The abundance of microalgae was influenced by physico-chemical factors such as temperature, current velocity, depth, nitrate and phosphate contents. According to the Shannon-Wiener index, the water conditions in Peniti Estuary were moderately polluted and there tends to be water eutrophication.

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