Abundance and diversity of macrobenthos at Tanjung Api-Api waters, South Sumatra, Indonesia

[1]Siska Almaniar, [2]Rozirwan, [3]Herpandi

[1] Environmental Management Program, Sriwijaya University, Palembang, South Sumatra, Indonesia; [2] Department of Marine Science, Faculty of Mathematics and Natural Sciences, Universitas Sriwijaya, Indralaya, South Sumatra, Indonesia; [3] Department of Fisheries Product Technology, Faculty of Agriculture, Sriwijaya University, Indralaya, South Sumatra, Indonesia. Corresponding author: Rozirwan, rozirwan@unsri.ac.id

Abstract. Anthropogenic activities around the waters of Tanjung Api-Api, such as plantations, settlements and port activities, will result in changes to the marine environment. Excessive use of an area can result in loss of resources. This study aimed to analyze the abundance of macrobenthos around Tanjung Api-Api waters using the Principal Component Analysis (PCA) approach. The results show that the water quality parameters around Tanjung Api-Api waters are generally classified as moderate to heavily polluted, but they are still considered to be suitable for the macrobenthos growth. This is indicated by the temperature range of 26.0-33.06°C, the dissolved oxygen values between 6.45 and 9.81 ppm, the pH values from 6.59 to 7.29 and the salinity ranging between 12-18 ppt. Moreover, the sediment texture was found to be dominated by a clay substrate, while the macrobenthos abundance ranged between 1 and 8 ind m^{-2}, the diversity index ranged from 0.20 to 1.33, the equitability index ranged from 0.41 to 1 and the dominance index ranged from 0.28 to 0.85. Furthermore, the first group formed on the negative F1 axis showed that stations 2 and 9 were characterized by the variables of dominance and abundance, where the dominant class was Bivalvia, with 42%. Based on the PCA, the water quality parameters analyzed in Tanjung Api-Api waters were characterized by higher levels of salinity, pH and dissolved oxygen.

Key Words: diversity, estuary, macrobenthos, water quality.

Introduction. Tanjung Api-Api is a marine environment located in Banyuasin Regency, which is categorized as a special economic zone. The existence of several economic activities, such as plantations, settlements and ports, in this area has both immediate and periodic negative effects on the physical, chemical and biological environment, causing damages to the marine ecosystem (Dandan & Diocton 2019). The increased rate of marine voyages has also been reported to be leading to a continuous change in the waters around the port (Meisaroh et al 2019).

Overuse of a particular area causes the loss of natural resources and this is also applicable to the coast areas (Tabatabaie & Amiri 2011; Hasidu et al 2020). Therefore, a biomonitoring process through the use of macrobenthos should be implemented in order to assess the quality status of the water's environment (Xu et al 2013; Paller et al 2020). It is possible to use macrobenthos as a bioindicator of the ecology disturbance in one ecosystem due to the slow movements of these underwater organisms, which can help in rating the quality of the water environment (Gao et al 2011; Manoharan et al 2011; Shi et al 2014; Amri et al 2014; Widowati et al 2016; Matin et al 2018; Sahidin et al 2018; Zhang et al 2019; Bo et al 2020).

Studies have been conducted on the macrobenthos community structure (Hakiki et al 2017), on the environmental observation based on the spread of macrobenthos (Indarmawan & Manan 2011) and on the use of benthos as a water quality bioindicator in Nimbai River, West Papua (Leatemia et al 2017), as a bioindicator (Sahidin et al 2018) and as a water condition indicator in Sindhu beach, Sanur, Bali (Wijana et al 2019).

Meanwhile, there are currently no publications on macrobenthos, environment quality and their correlation in the Tanjung Api-Api waters. Therefore, the focus of this research was to analyze the abundance of macrobenthos and the quality of the marine environment surrounding Tanjung Api-Api, Banyuasin Regency, South Sumatra, as well as the correlation of the two factors.

Material and Method

Study area. This research was conducted around the waters of Tanjung Api-Api, Banyuasin Regency, South Sumatra Province, as indicated in Figure 1. The samples were selected during the month of February 2020 (rainy season) using the purposive sampling method (Afif et al 2014). Moreover, the environmental parameters and macrobenthos samples were measured at 9 observation stations, using the transect method. Station 1 is currently being reclaimed to be used as the Tanjung Carat Deep Sea Port, station 2 is directly adjacent to the Bangka Strait with a general dominance of seawater, station 3 has a dense mangrove vegetation, station 4 is an illegal residential area, station 5 is a relatively rare mangrove plants area, station 6 is a relatively protected mangrove plants space, station 7 is an area with oil palm plantation activities, station 8 is where the loading and unloading activities of cargo ships are conducted, and station 9 is the passenger port area.

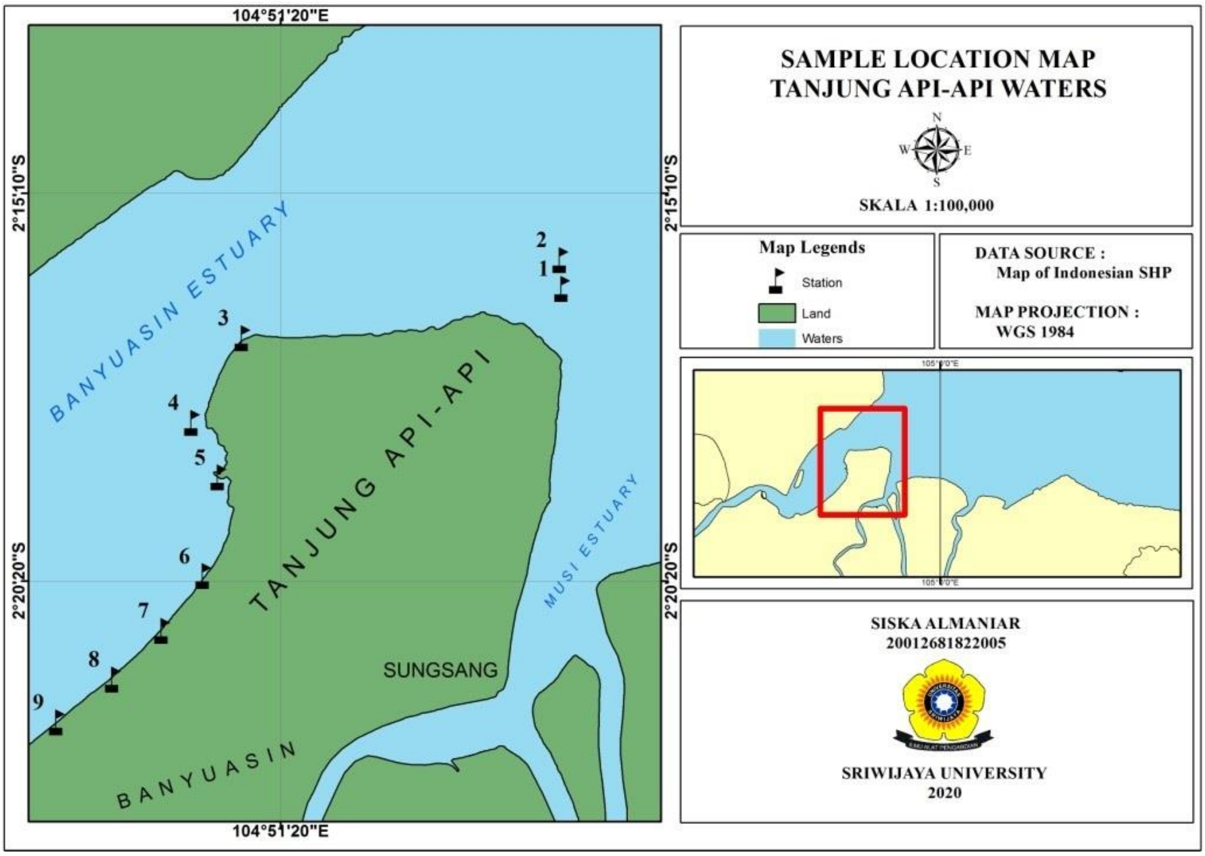

Figure 1. The sampling area of Tanjung Api-Api waters, South Sumatra, Indonesia.

Data and sample processing. The environment quality parameters directly measured in the field include: temperature, dissolved oxygen (DO), pH, salinity and sediment texture, and they were obtained and analyzed based on Standard Methods (APHA 2012).The water temperature was measured using a digital thermometer, DO through a DO meter, water pH using a pH meter and the water salinity was determined through a hand refractometer. Meanwhile, the sediments were sampled using a core made of 2-inch diameter pipe with a length of 20 cm. The process involved sinking the core into the sediment and lifting the instrument back up after which the sediment collected was placed in a sample bag and stored in a cool box.

The macrobenthos sampling on the substrate was conducted at low tide, using a random grab pipe in a 1 m^2 transect. The procedure involved pressing the instrument into the substrate to a depth of 20-30 cm three times after which the samples were filtered to separate the organisms from the substrate using a 1 mm sieve. The sample obtained was later placed in a sample bottle, labeled, given a 4% formalin solution and stored in a cool box.

The sediment grain size was determined through dry sieving methods and this involved weighing and classifying the servings of the sediment retained on each sieve according to the grain size, while the sediment sample was analyzed in reference to Wentworth (1922). Meanwhile, the macrobenthos samples were identified using the nomenclature provided by the World Register of Marine Species (Worms 2020).

Data analysis. The abundance of macrobenthos was also calculated using the following formula with reference to Brower & Zar (1984):

$$D = \frac{ni}{A}$$

Where:
D - density of macrobhentos (ind m^{-2});
ni - number of individuals for each species;
A - area (m^2).

Diversity index. The diversityof the species at each observation station was calculated using the Shannon-Wiener Diversity Index, with the formula (Shannon & Wiener 1949):

$$H' = -\sum\left(\frac{ni}{N}\right)\ln\left(\frac{ni}{N}\right)$$

Where:
H' - diversity of the macrobenthos;
ni - the number of individuals species i;
N - the total of individuals per station.

Equitability index. The equitability (evennes) index (E) of the observed species (Odum & Barrett 2004) was calculated with the formula:

$$E = \frac{H'}{H\,max}$$

Where:
E - equitability index;
H' - diversity index;
Hmax - ln S;
S - number of species found.

Dominance index. The dominance index was calculated with the Simpson's index (Odum & Barret 2004), with the formula:

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

Where:
C - dominance index;
ni - the number of individuals species i;
N - the total of individuals per station.

Principal components analysis (PCA). Multivariate analysis was used to correlate environmental parameters such as temperature, dissolved oxygen, pH, and salinity with the abundance and diversity of macrobenthos at all the observation stations. This correlation will show the relationship in the form of groups that are formed in the biplot. The analysis was performed using the XLstat 2021 software.

Results. The retrieval of data on the water environmental quality parameters has a very important role for the macrobenthos and was based on the measurements obtained directly from the field on water temperature, dissolved oxygen, pH, salinity and sediment texture (Figure 2).

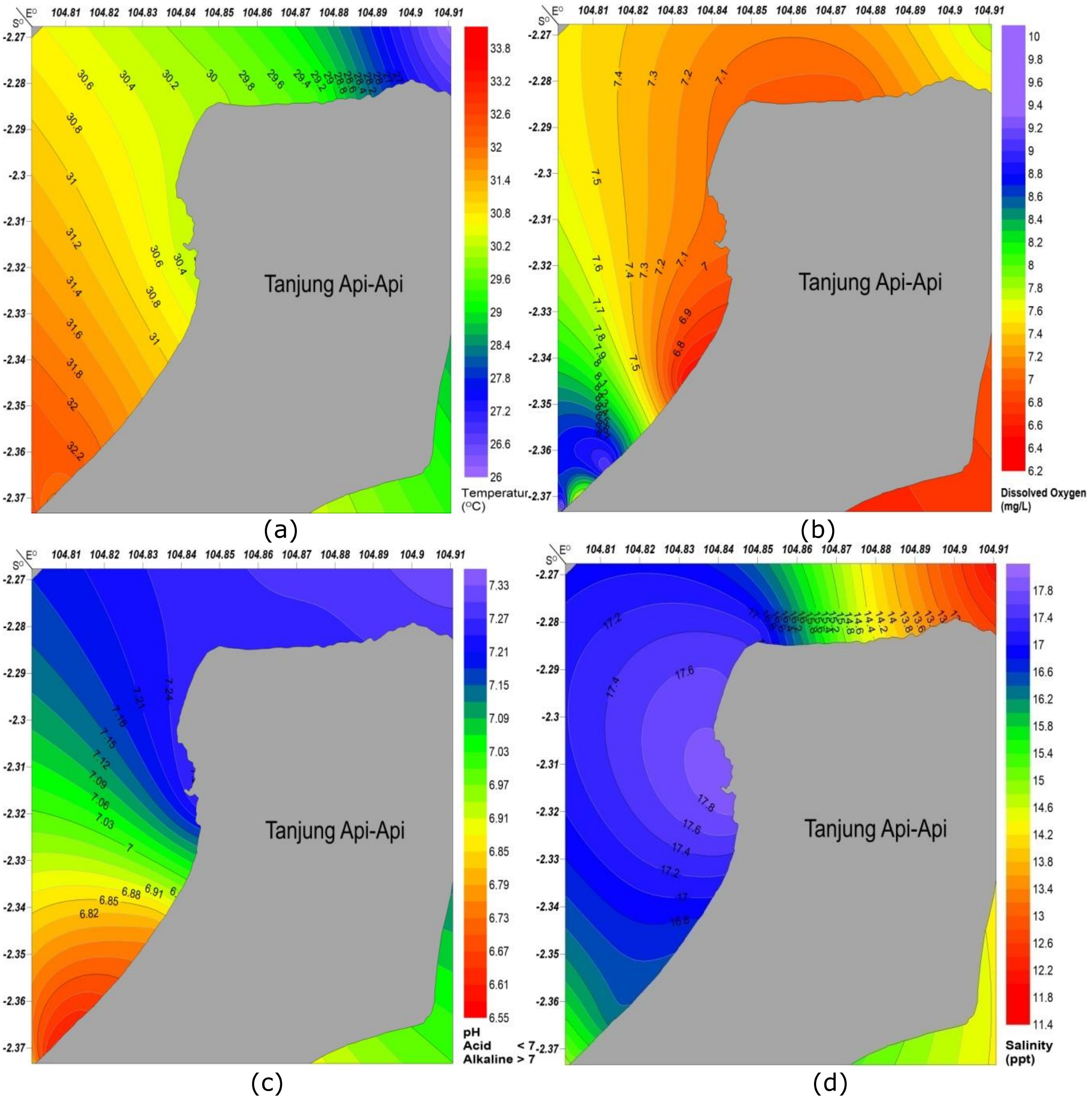

Figure 2. Water quality parameters around Tanjung Api-Api waters, (a) Temperature, (b) Dissolved oxygen, (c) pH of water, and (d) Salinity.

The values for the water temperature measured on the field ranged from 26.10 to 33.06°C and were different between stations, due to the variations in the period of measurement. The sampling started at station 9 during the day and ended at station 1 in the afternoon and the intensity of sunlight at noon was observed to be higher, causing the differences recorded in the values. Meanwhile, the dissolved oxygen levels, which are very important to the aquatic biota, showed values ranging from 6.45 to 9.81 ppm at all observation points, with the lowest recorded in station 5 and the highest in station 8. The pH concentration of the waters was also variable at all station points, with the lowest value, 6.59, found at station 6 and the highest value, 7.29, observed at station 4, while values >7 were measured at the stations 1, 2, 3 and 4, and those with values <7 were measured at the stations 5, 6, 7, 8 and 9. Moreover, the salinity levels were observed to be fairly high at all the stations ranging from 12-18 ppt, with the lowest recorded at the station 1 and the highest at the station 4. Meanwhile, the salinity levels measured at each station were classified as brackish, due to the fact that the research location is in the estuary area. The data of the sediment texture measurement in the Tanjung Api-Api marine environment suggest that clays are dominant (Table 1).

Table 1

Sediment texture of Tanjung Api-Api waters

Station	*Sediment texture*
1	Clay sand
2	Sandy loam
3	Clay
4	Clay
5	Clay
6	Sandy loam
7	Clay
8	Clay
9	Clay

Composition of makrobentos in Tanjung Api-Api waters. The composition of macrobenthos species around the water stations was grouped into five classes with a total of 19 species (Figure 3). The first class, Bivalvia, had 42%, the second, Malacostraca, had 35%, the third, Gastropods, had 15%, the fourth, Polychaeta, had 6%, and the fifth class, Actinopterygii, had 2% of the total composition. This means the area is very dominated by the Bivalvia class due to the suitability of the water parameters for its growth.

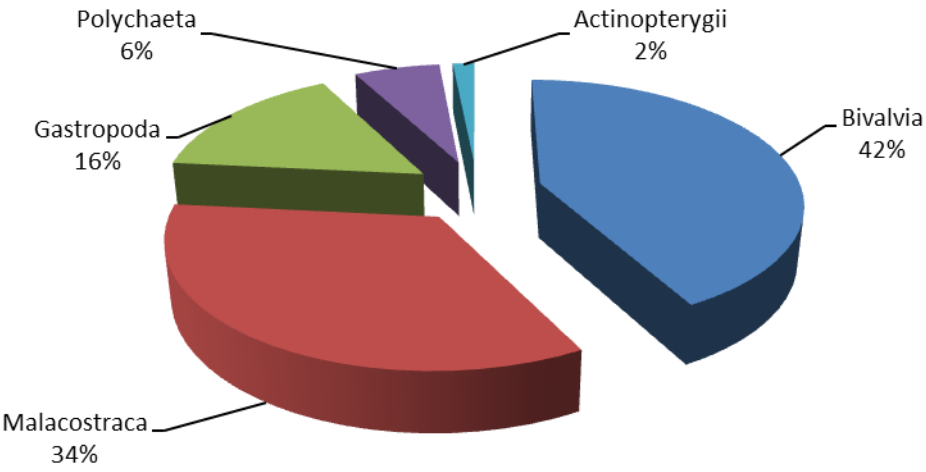

Figure 3. Macrobenthos composition structure of Tanjung Api-Api waters.

The calculation of the macrobenthos showed almost the same values of abundance at several stations, as shown in Figure 4, with the highest recorded at the station 9, 8 ind m^{-2}, while the lowest was found at the stations 1, 3 and 5, with 1 ind m^{-2}. Other stations reached only 2 ind m^{-2}. This means that the station 9 has a very high abundance when compared to the other stations and this is mainly due to the physical-chemical parameters of the waters. This factor is, however, one of the general indicators to measure the level of pollution.

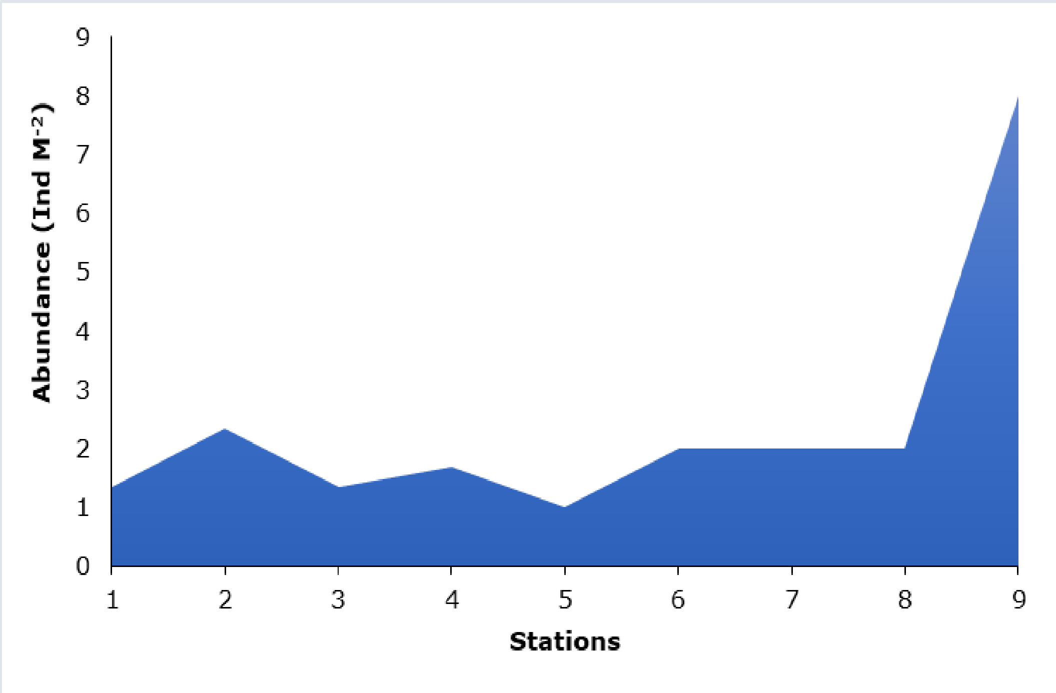

Figure 4. Macrobenthos abundance of Tanjung Api-Api waters.

The macrobenthos biodiversity was observed to be very high at each station and this led to the use of diversity, equitability and dominance indexes, as shown in Figure 5. The results of the diversity index (H') showed that the macrobenthos was in a moderate category (H'<1), except at the stations 1, 2, and 9, with low categories. This was supported by the dominance index (C), which indicated a low category at all the observation stations, with values of 0<C<0.3 except for the stations 1 and 9, which were in a dominant category, with C>0.6, and the station 2, which was in a moderate category, with 0.3<C<0.6. It is, however, important to note that the highest value was 0.85 at the station 9, while the lowest value was 0.28 at the stations 6 and 8. Moreover, the highest diversity index value of 1.33 was recorded at stations 4, 6 and 8, while the lowest, 0.28, was recorded at the station 9. The highest equitability index was also found at the station, with a value of 1, while the lowest value, 0.41, was recorded at the station 9.

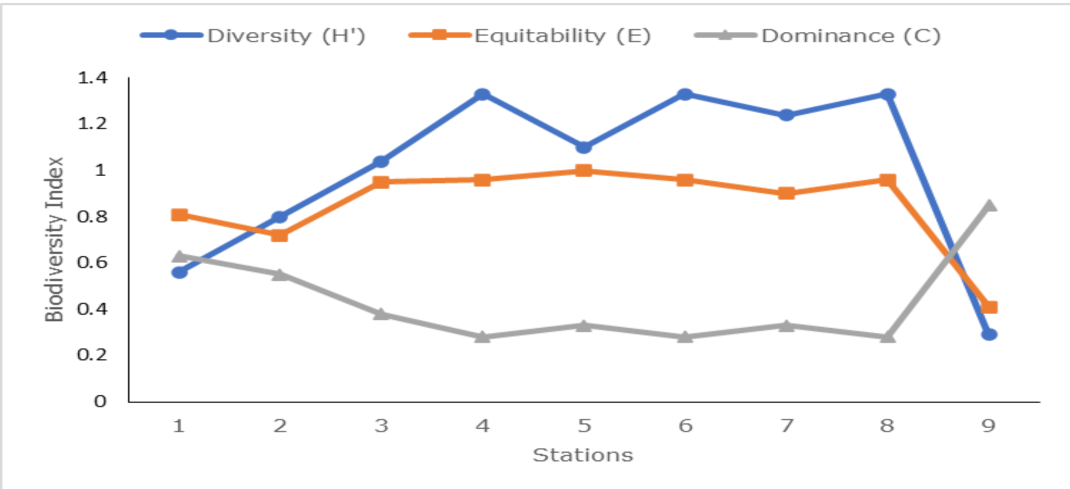

Figure 5. Macrobenthos biodiversity index of Tanjung Api-Api waters.

Relationship of abundance, macrobenthic biodiversity and aquatic chemical physics. Based on of principal component analysis (PCA), the cumulative eigenvalues were 91.45% and there were identified four groups of data for each identifier. Three groups were in the axes F1 and F2, one group was in the axis F3 (Figure 6).

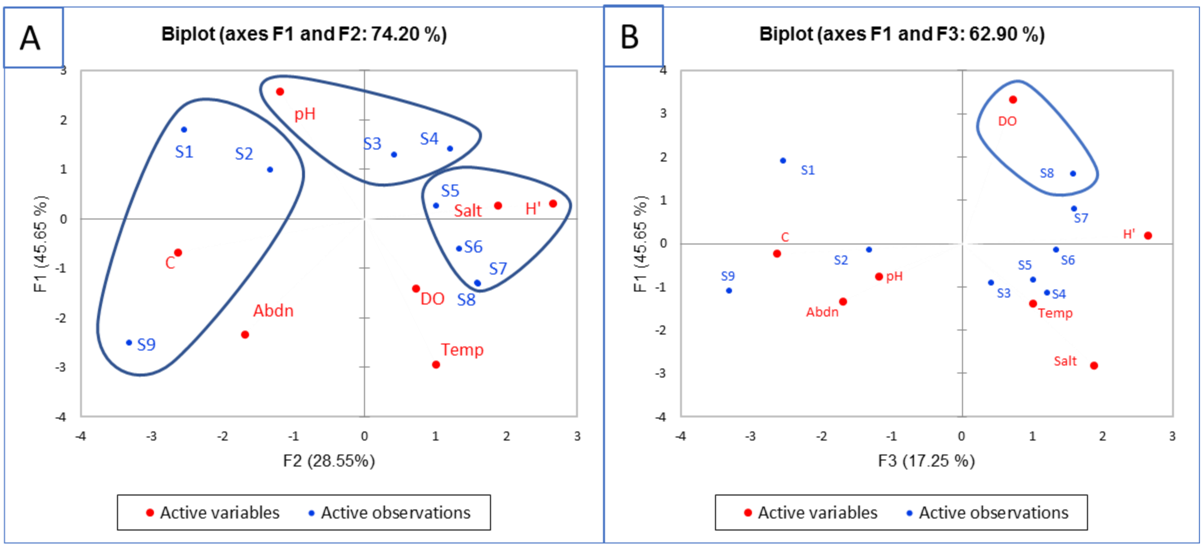

Figure 6. Correlation between water quality parameters with macrobenthos abundance and diversity, A) axes of F1 with F2; B) axes of F3.

This analysis showed the existence of four groups, where the first group was located on the positive F1 axis with the stations 5, 6 and 7, and the identifiers salinity (15.33 to 16.66 ppt) and diversity of species (H'=1.09 to 1.33). The second group was located on the negative F1 axis, involving the stations 1, 2 and 9, with the identifiers of the species dominance (C=0.55 to 0.84). The third group is mapped on the positive F2 axis, with the stations 3 and 4 and the identifier pH (7.26 to 7.29). The fourth group is formed on the positive F3 axis, with the identifier dissolved oxygen (9.81 ppm) and the station 8.

Discussion. There was a variation in the values of the water temperature measured at different times for each station and the highest average value of 33.06°C was recorded at the station 9, while the lowest, 26.10°C, was measured at the station 1. Sidik et al (2016) stated that the time delay in collecting the water quality data has the ability to cause variations in the values to be obtained. This was further reinforced by Leatemia et al (2017), who showed that the measurement time delay and the shade conditions of riparian vegetation determined variations in the water temperature values. The intensity of sunlight during the day is higher than in the afternoon and these accounts for the differences in the values of water temperature at each station: a higher intensity of sunlight usually leads to higher water temperature and vice versa, as observed in the surface waters (Sponseller et al 2001; Pratama et al 2019; Saputra el al 2021; Rozirwan el al 2021a). Meanwhile, the water temperature values recorded at all stations ranged between 26.10 and 33.06°C, being optimal for the growth of aquatic animals such as macrobenthos, according to Sidik et al (2016), Basyuni et al (2018) and Wang et al (2020), who reported that the appropriate values required for macrozoobenthic growth range between 25 and 35°C.

The dissolved oxygen levels were also observed to range from 6.45 to 9.81 ppm at stations 7 and 8, higher when compared to the other stations, while the lowest value was found at station 5. This range is classified as good for the survival of aquatic biota according to Sharani et al (2018), who reported a range between 4.32 and 7.93 ppm to be within the limits of tolerance for macrobenthic life. This was further reinforced by Rozirwan et al (2021b), who reported 3.2 to 12.5 ppm as optimal conditions for the macrobenthos growth. Moreover, Lestari et al (2021) discovered that the number and types of macrobenthos in waters are influenced by the dissolved oxygen (DO) content in a directly proportional relationship. The physical-chemical parameters of the water were affected by the tides, showing increasing values towards the sea and slightly decreasing values in the rivers (Rozirwan et al 2021b).

The survey of pH is very important due to the dissolution of heavy metals in water, leading to the reduction of the pH (Tabatabaie & Amiri 2011). The pH values observed at the 9 stations ranged between 6.62 and 7.32, being neutral and slightly alkaline. The highest value was found at the station 1, while the lowest was observed at the station 7. Emeka et al (2020) showed that the pH value tends to be mildly acidic to alkaline (6.42 to 7.6). This was further reinforced by Rozirwan et al (2021b): the water pH values between 7.6 and 8.1 are optimal for the growth of macrobenthos. The benthos has been reported to have the ability to grow effectively at pH values between 6.8 and 8.5 (Gundo 2010). It has been discovered that a very acidic pH causes an increase in toxic substances in the waters and a decrease in the dissolved oxygen levels (Pratami et al 2018), while Effendi (2003) showed that values ranging between 7 and 8.5 are favorable to the aquatic biota, especially macrobenthos (Fadli et al 2012). Moreover, the salinity values at stations 3 to 9 were observed to be generally directly proportional to the position of the stations related to the sea. However, a salinity reduction was recorded at stations 1 and 2, presumably due to the fact that the values were measured when it was raining. The water salinity at each station was observed to range from 12 to 18 ppm, being influenced by the input of seawater and rainwater, as reported by Chen et al (2018), who showed that the fluctuations of salinity are due to the changes in the quantity of water inflow, such as the rainwater. Meanwhile, the values obtained at each station are within the tolerance range for macrobenthic life. According to Hakiki et al (2017), estuary aquatic organism communities are a mixture of endemic or permanent organisms and those who migrate to the estuary waters, with a higher salinity tolerance.

Baseline sediments are the last sink for several pollutants caused by anthropogenic activities and also have the ability to accumulate a good amount of organic matter affecting the oxygen content in the water bed (Balachandar et al 2016). Sediment characteristics are also one of the main factors determining the differences in species (Coblentz et al 2015; Zakirah et al 2019; Norouzi & Tavani 2016). According to Rahmawati et al (2015), the diversity of the coastal flora and fauna is determined by the sediment. The textures retrieved from the 9 stations include loamy sand, sandy loam and loam. The station 1 was found to have loamy sand with a ratio of 53% sand and 47% clay, being predominantly sand textured. The stations 2 and 6 have a sandy clay and the ratio between sand and clay at the station 2 was recorded to be 34 to 65%, while at the station 6 it reached 22 to 71%. This means that station 2 also has a sand texture, due to its close proximity to the station 1 while the sand content found at the station 6 is thought to be due to the reclamation activities.

The macrobenthos found around the waters of the study area consisted of 19 species which were divided into 5 classes with different compositions. The highest abundance, 8 ind m^{-2}, was found at the station 9, while the lowest, 1 ind m^{-2}, was found at the stations 1, 3 and 5. The highest species abundance was found in the Bivalvia class, with 42%, a class of macrobenthos with a very wide distribution in the world, due to its ability to live in different types of substrates, such as sand, rock and mud (Fadli et al 2012; Khalil 2016). The abundance of certain species is one of the general indicators measuring the pollution levels (Sany et al 2015).

The macrozoobenthic diversity index of all the stations also varies between 0.29 to 1.33, with the highest values recorded at stations 4, 6 and 8. The values higher than one and lower than three have been classified in the medium category, due to a moderate environmental pressure (Brower & Zar 1984). The aquatic environmental condition at the aforementioned stations is good and supportive for the life of macrobenthos as shown by their diversity index high values (Sidik et al 2016). Meanwhile, the lowest value of 0.29 was recorded at the station 9. Any value lower than 1 was classified in the low diversity category (Brower & Zar 1984), with strong environmental pressures, due to anthropogenic activities (Yolanda et al 2015). According to Shi et al (2014), competition and predation between the species affects the community structure.

The macrozoobenthic equitability index was also observed to have different values for each station and ranged from 0.41 to 1. This factor generally ranged between moderate to high around the Tanjung Api-Api waters, with the lowest value, of 0.41, recorded at the station 9, while the highest value, of 1, was found at station 5, due to the balanced number of the species in the area, classified in the high equitability category.

Moreover, it has been previously reported that the distribution and diversity of benthic communities are strongly influenced by all the environmental parameters (Kumar & Khan 2013; Amri et al 2014; Rozirwan et al 2014; Iskandar el al 2019; Rozirwan et al 2020). Therefore, the dominance index value ranged from 0.28 to 0.85 at all the stations, with the highest values, of 0.63 and 0.85, recorded at stations 1 and 9, respectively, while at station 2 the dominance was classified as moderate, with 0.55, and at the others it was categorized as low. According to Fadli et al (2012), a lower dominance index indicates that each species has a balanced control on the community demographics and resources, and that its sustainability can be maintained.

Correlation of the water quality parameters with the macrobenthos abundance and with the diversity in Tanjung Api-Api waters. The PCA results showed the main identifier at the stations 5, 6 and 7 is the salinity (15.33 to 16.66 ppt) and the diversity of species, meaning that the salinity is the most influent factor on the distribution of the macrobenthos community at the these stations. This is in line with the findings of Ramses et al (2020): the Polychaeta in the Batam waters was influenced by the salinity. Meanwhile, the identifiers at stations 1, 2, and 9 were based the dominance of species. Stations 3 and 4 were the most influenced by the pH water and the station 8 was the most influenced by the dissolved oxygen. The DO was affected by tides of the waters (Rozirwan et al 2021a; Saputra et al 2021). Consequently, the distribution of the macrobenthos species at all observation stations is determined by the physical and chemical conditions of the waters. Moreover, they are also responsible for determining the growth and development as well as the species combination within the macrobenthos communities. This study, therefore, strengthens the results of the research of Zakirah et al (2019), who stated that the changes in the environmental characteristics have a great influence on the composition, abundance and species diversity of a habitat.

Conclusions. Although the water quality parameters around Tanjung Api-Api waters are classified as moderate to heavily polluted, they are are considered suitable for the growth of macrobenthos. The abundance of the macrobenthos was found in low conditions, around 1-8 ind m^{-2}, with the diversity classified as low and uneven. The water quality parameters influence on the macrobentos is mainly due to the pH, temperature and salinity.

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Conflict of interest. The authors declare no conflict of interest.

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Authors:
Siska Almaniar, Sriwijaya University, Environmental Management Programe, 30128 Palembang, South Sumatra, Indonesia, e-mail: siskaalmaniar@student.pps.unsri.ac.id
Rozirwan, Sriwijaya University, Department of Marine Science, Faculty of Mathematics and Natural Sciences, 30662 Indralaya, South Sumatra, Indonesia, e-mail: rozirwan@unsri.ac.id
Herpandi, Sriwijaya University, Department of Fisheries Product Technology, Faculty of Agriculture, 30662 Indralaya, South Sumatra, Indonesia, e-mail: herpandi@fp.unsri.ac.id

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