The effect of hydro-oceanographic factors on the community structure of plankton in natural and artificial coral reefs in Paiton waters

[1]Endang Y. Herawati, [2,3]Ruly I. Khasanah, [3]Muliyana Ambarwati, [2,4]Dini Sofarini

[1] Faculty of Fisheries and Marine Sciences, Universitas Brawijaya, Malang, Indonesia; [2] Post Graduate Program of Fisheries and Marine Sciences, Faculty of Fisheries and Marine Sciences, Universitas Brawijaya, Malang, Indonesia; [3] Program Study of Marine Science, Faculty of Science and Technology, Universitas Islam Negeri Sunan Ampel, Surabaya, Indonesia; [4] Department of Aquatic Resource Management, University of Lambung Mangkurat, Jl. Brigadir H. Hasan Basry, Banjarmasin 70123, Indonesia. Corresponding author: R. I. Khasanah, ulick.isfatul@gmail.com

Abstract. Hydrooceanographic factors influence the plankton occurrence. These are aquatic environmental parameters that take important role in plankton community structure. This study was aimed at knowing the effect of the hydro-oceanographic factors on the abundance and the diversity of plankton in the natural coral reef ecosystem and the artificial reef in the waters of Steam-Based-Electric Power Plant (SBEPP), Paiton. It employed quantitative analysis and Principle Component Analysis (PCA) method. Results showed that the phytoplankton abundance in the natural coral reef ecosystem ranged from 3,209 to 5,589 cells L^{-1} and in the artificial reef from 598 to 856 cells L^{-1}. Zooplankton abundance in the natural coral reef and the artificial reef were 48-70 ind L^{-1} and 23-36 ind L^{-1} respectively. Phytoplankton abundance in both localities was more than 500 cells L^{-1} reflected high fertility category of the waters, while plankton diversity of both localities of 2.19-3.25 indicated moderate diversity. PCA analysis showed that water brightness and pH were moderately correlated with plankton abundance and diversity. Water salinity, dissolved oxygen (DO), and phophate were very strongly positively correlated with plankton abundance and diversity, while water temperature and nitrate were very strongly negatively correlated with plankton abundance and diversity. The latter in the natural coral reef is indicated with increased plakton abundance in low nitrate and phosphate concentrations, while in the artificial reef, the plankton abundance was low in the high nitrate and phosphate concentrations.
Key Words: plankton, coral reef, abundance, diversity, Paiton.

Introduction. Indonesia seawater is rich in various living resources. One of them whose presence is very important is plankton. According to Nontji (2008), plankton is microscopic organisms floating in the water or on the surface whose movement is influenced by currents. In general, plankton is distinguised into phytoplankton and zooplankton.

Plankton occurrence highly influences life in aquatic ecosystem because it is an aquatic organism that plays important role as primary producer in marine food chain (Cheng 1997). This role can come from its ability to produce organic matters in the ocean (Rissik 2009). Thus, plankton can be considered as fertility bioindicator of the waters. Water fertility can be based on the abundance and the composition or the diversity of the plankton in the waters. Plankton abundance above 500 ind L^{-1} indicates high fertility level of the waters (Odum 1996).

Although plankton can be considered as the fertility bioindicator of the water, there are also limiting factors that affect its occurrence. These are physical and chemical factors that are important variables for the plankton density in the waters. Plankton have strong correlation with coastal and marine ecosystem, one of which is coral reef ecosystem. According to Guntur (2011), coral reef ecosystem is a very complex ecosystem with high biodiversity. One of the main roles of coral reef is as habitat for various marine biota.

In coral reef ecosystem, one of the plankton function is coloration of the coral reef ecosystem (Wibisono 2011). Some coral animals live as meroplankton, being plankton at the larval stage and coral organisms at the adult stage (Guntur 2011).

In the Steam-Based-Electric Power Plant (SBEPP) waters, Paiton, Probolinggo, there are natural coral reef and artificial reef ecosystems. The presence of artificial reef ecosystem can increase the water fertility quality around the SBEPP Paiton waters. Since plankton have strong relationship with coral reef ecosystem, it is necessary to value the water fertility around the SBEPP Paiton waters, Probolinggo. This study was intended to know the plankton abundance and diversity in the natural coral reef and the artificial reef and factors that can affect their growth.

Material and Method

Study site and period. Measurements of the physical and chemical parameters and sample collection were carried out in the SBEPP Paiton waters, Probolinggo (Figire 1) in April 2019.

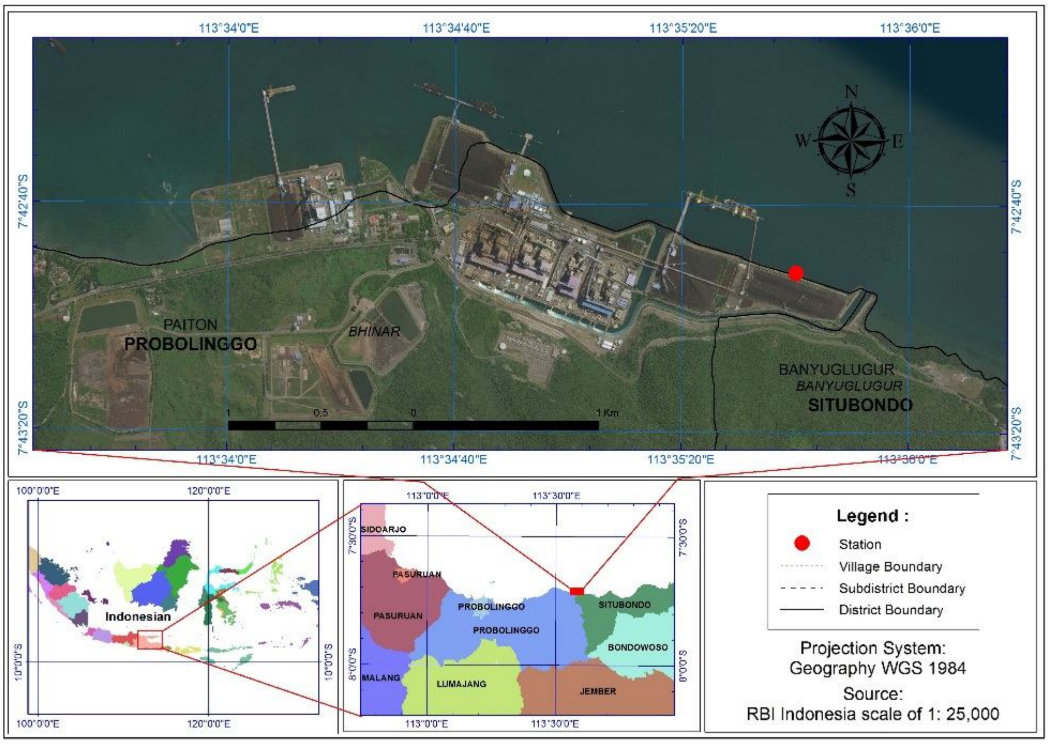

Figure 1. Study site.

Study site determination. Sampling station determination used cluster random sampling method. Based on this method, 2 areas were selected, natural coral reef and artificial reef each of which had 3 sampling points randomly selected, TS 1a, TS 2a, and TS 3a in the natural coral reef and TS 1b, TS 2b, and TS 3b in the artificial reef (Table 1).

Data collection. Physical parameters measured were water brightness and temperature, while the chemical parameters included pH, salinity, dissolved oxygen (DO), nitrate (NO_3), and phosphate (PO_4). The measurement methods are presented in Table 2.

Table 1

The geographic coordinates of the study site

Station	*Latitude*	*Longitude*
	Natural coral reefs	
Sampling point 1 (TS 1a)	07° 42' 3.00 S	113° 34' 25.00 E
Sampling point 2 (TS 2a)	07° 42' 0.29 S	113° 34' 20.57 E
Sampling point 3 (TS 3a)	07° 42' 1.36 S	113° 34' 27.70 E
	Artificial reefs	
Sampling point 1 (TS 1b)	07° 42' 51.00 S	113° 35' 41.00 E
Sampling point 2 (TS 2b)	07° 42' 51.32 S	113° 35' 41.69 E
Sampling point 3 (TS 3b)	07° 42' 50.66 S	113° 35' 40.57 E

Table 2

Tools and methods used

Parameter	*Unit*	*Tools*	*Method*
Brightness	m	Secchi disc	In situ
Temperature	°C	DO meter	In situ
pH	-	pH paper	In situ
Salinity	ppt	Refractometer	In situ
DO	mg L^{-1}	DO meter	In situ
Nitrate	mg L^{-1}	Spectrophotometer	Laboratory
Phosphate	mg L^{-1}	Spectrophotometer	Laboratory

Plankton sampling. Plankton sample collection used vertical hauling method, in which the plankton net was set down vertically from the boat at a position down to the desired depth and then pulled back on board. Before sampling, the water depth was taken into account in order to estimate the water volume filtered through the plankton net. The seawater collected in the cod-end of the plankton net was then removed into the labelled sample bottle (Rachman et al 2018).

In this study, 12 bottles of samples were obtained and then preserved. Lugol solution was added to the water sample as needed up to the seawater color turn red. For 100 mL of water sample, as much as 3 drops of 4% lugol solution were used (Rachman et al 2018). The plankton samples were observed and analyzed in the Integrated Laboratory of UIN Sunan Ampel Surabaya.

Plankton sample analysis. Plankton observations adopted Sedgewick-rafter Counting Cell (SRCC) under the microscope to know the genus and the number of cells. Identification followed Shirota (1966), Newell & Newell (1977), Yamaji (1984), and Tomas (1997). After obtaining the number of cells of plankton, the abundance and the diversity were estimated.

Plankton abundance (N). Plankton abundance value is used to know the number of plankton in each water volume (cells L^{-1}). Plankton abundance (N) analysis was calculated using the formula of APHA (1998) as follows:

$$N = \left(\frac{Oi}{Op} x \frac{Vr}{Vo} x \frac{1}{Vs} x \frac{n}{p}\right) \quad [1]$$

where: N = number of cells per liter (cells L^{-1});
Oi = area of cover glass (mm^2);
Op = area of a view space (mm^2);
Vr = volume of filtered water (mL);
Vo = volume of sample under the cover glass (mL);
Vs = volume of filtered seawater sample (L);
n = number of phytoplankton cells in entire view space (cells);
p = number of spaces observed (mm^2).

According to Odum (1996), phytoplankton abundance can reflect the fertility in the waters. The phytoplankton abundance-based water fertility category is as follows:

N > 500 cells L^{-1} = highly fertile;
N < 500 cells L^{-1} = moderately fertile.

Plankton diversity (H'). This analysis was applied to know the diversity of the biota in the water. The present study used Shanon-Wiener's diversity index (Odum 1993):

$$H' = -\sum_{i=0}^{i} Pi \ln Pi \qquad [2]$$

where: H' = diversity index;
Pi = ni/N;
ni = number of individuals i;
N = total number of individuals.

Principle Component Analysis (PCA). This correlation analysis is used to examine the relationship between the physical and chemical parameters with plankton abundance. Those cover water temperature, brightness, DO, salinity, pH, nitrate, and phosphate. The physico-chemical parameter data were analyzed using Microsoft Excel in the form of tables and graphs, then the correlation between the physico-chemical parameters and plankton abundance and diversity was estimated to gain the matrix value. The matrix value of the PCA analysis to know the correlation between the physico-chemical parameters and the plankton abundance is presented in Table 3 (Khasanah et al 2013).

Table 3

Correlation level between variables

Interval coefficient	*Correlation level*
0.00-0.199	Very low
0.20-0.399	Weak
0.40-0.599	Moderate
0.60-0.799	Strong
0.80-1.00	Very strong

Results and Discussion

Physico-chemical water parameters. The water physical and chemical parameters measured in situ are temperature, salinity, brightness, DO and pH, while phosphate and nitrate were examined in the Laboratory of Living Environmental Board of East Java Province. The parameters measured are given in Table 4.

Table 4

Mean water physico-chemical paramenters

Parameter	*Natural coral reef*	*Artificial reef*	*Quality standard*
Physical			
Temperature (^oC)	30.3*	32.4*	Natural[3(c)]
Brightness (m)	5.2*	5.7*	Natural[3]
Chemical			
Salinity (ppt)	31*	30*	Natural[3(e)]
DO (mg L^{-1})	6.4*	5.7*	>5
pH	7.5*	7.2*	7-8.5[(d)]
Nitrate (mg L^{-1})	0.055*	0.103*	0.008
Phosphate (mg L^{-1})	0.021*	0.011	0.015

Natural[3] is normal environmental condition that varies with time (day, night, and season); [c] allowed to change < 2^{o}C of the natural temperature; [d] allowed to change up to < 0.2 of the pH unit; [e] allowed to change up to < 5% of mean seasonal salinity; *in line with the quality standard established by Indonesian Minister's decree KEPMEN LH no 51 year of 2004 concerning water quality for marine biota.

Based on Table 4, all measurement values of the physical and chemical parameters in the natural coral reef ecosystem are in line with those of the quality standard. Therefore, the water quality condition in the natural coral reef ecosystem is normal and very suitable for plankton growth. In the artificial reef ecosystem, mean phosphate concentration is not in agreement with the quality standard.

Temperature. Mean water temperature in the artificial reef ecosystem is higher than that in the natural coral reef ecosystem, 32.4^{o}C and 30.3^{o}C, respectively. The same result is also recorded by Indraswari et al (2015). Higher water temperature in the artificial reef ecosystem could also result from the position of the sampling point, where the artificial reef ecosystem is near water discharge canal of the SBEPP Paiton, while the natural coral reef is far from the water discharge canal of the plant. The water temperature difference between the natural coral reef and the artificial reef ecosystems is clearly shown in Figure 2.

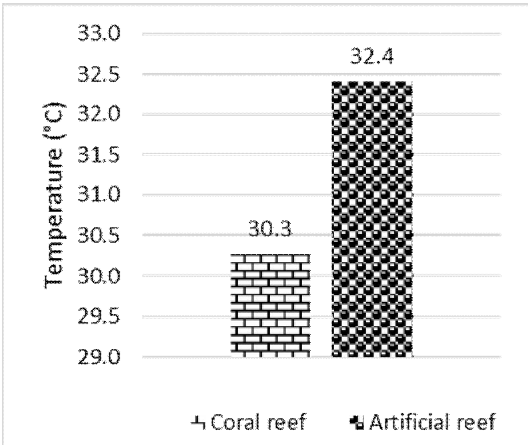

Figure 2. Mean water temperature.

Brightness. Water brightness in the natural coral reef ecosystem was lower than that in the artificial reef ecosystem (Figure 3). Nevertheless, the water brightness in both ecosystems was still in the range of the water quality standard for marine biota (KEPMEN LH no 51/2004), > 3 meters.

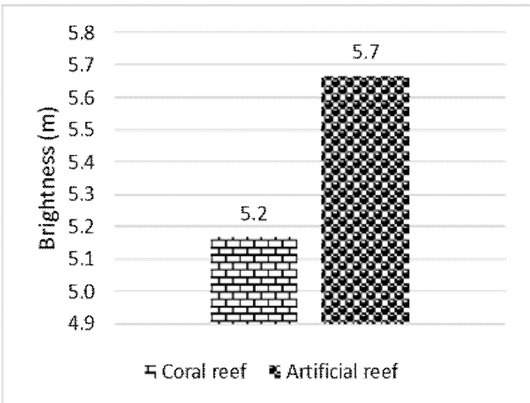

Figure 3. Mean water brightness.

Salinity. Mean water salinity in the natural coral reef ecosystem was 31 ppt. It is similar to that reported in Ali Sofani & Muzaki (2015). In the artificial reef ecosystem, mean salinity was lower than that of the natural coral reef ecosystem, 30 ppt (Table 4). Based on the Indonesian Minister's decreee, KEPMEN LH no 51/2004, both sites have normal seawater salinity. Nontji (2008) states that seawater salinity, in general, ranges from 34 to 35 ppt. The seawater salinity distribution is influenced by several factors, such as water circulation, rainfall, and river flow (Shanggao 1989). Low salinity in the artificial reef ecosystem could result from the position of the reef close to the water discharge canal of the SBEPP Paiton. In contrast, the further the sampling point position to the water discharge canal of SBEPP Paiton is, the higher the salinity will be.

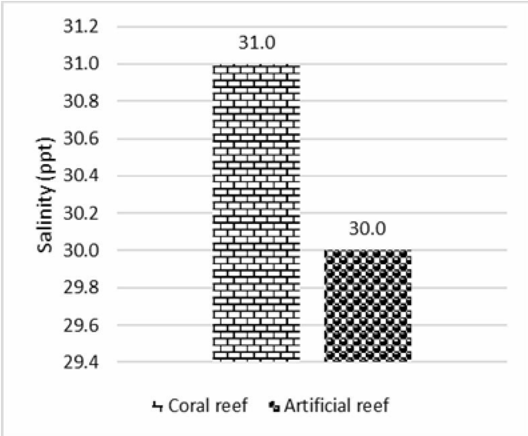

Figure 4. Mean water salinity.

Dissolved oxygen (DO). According to Dwirastina & Wibowo (2015), DO in the water comes from photosynthetic process and oxygen diffusion from the atmosphere. DO measurements in the natural coral reef ecosystem obtained mean DO of 6.4 mg L^{-1}, while it was lower in the artificial reef ecosystem, 5.7 mg L^{-1} (Figure 5). Although DO concentration in the artificial reef is low, it is in the good range of the quality standard, > 5 mg L^{-1}. Decline in seawater DO concentration could result from increased water temperature and salinity and could affect the marine life, particularly in the intertidal area.

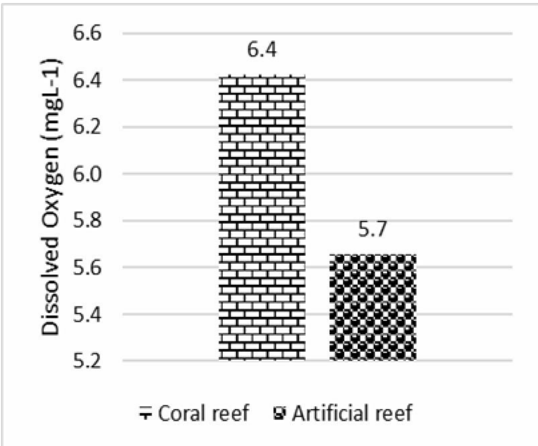

Figure 5. Mean dissolved oxygen.

pH. The present study found slightly different pH between the natural coral reef and the artificial reef ecosystems. Mean pH was 7.5 in the natural coral reef ecosystem and 7.2 in the artificial reef ecosystem (Figure 6). According to Indraswari et al (2015), water pH in the natural coral reef ecosystem is normally 7.4, only 0.1 different from that measured in this study.

Very acid or very alkaline water condition could influence the survivorship of the aquatic organisms (Barus 2004) because it could cause metabolism and respiration disturbances. Very low pH can result in the mobility of various toxic heavy metal compounds and hazard the survivorship of the aquatic organisms. On the other hand, very high pH will disturb the balance between ammonium and ammonia in the water and can be very toxic to the organisms as well (Abowei 2010).

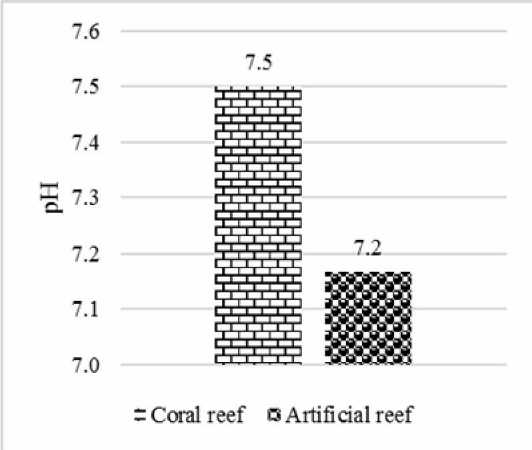

Figure 6. Mean pH.

Nitrate. Mean nitrate concentration in the natural coral reef ecosystem is lower than that in the artificial reef ecosystem, 0.0522 mg L^{-1} and 0.103 mg L^{-1}, respectively (Figure 7). As a whole, nitrate concentration in both ecosystems passes the quality standard threshold established by the Indonesian Minister's decree, KEPMEN LH no 51/2004 concerning water quality for marine biota, 0.008, so that the nutrient availability could highly support the phytoplankton life. Therefore, it is apparent that SBEPP Paiton waters is oligotrophic or sufficiently fertile. It is in agreement with Wetzel (1975) that waters with nitrate (NO_3) concentration of 0-1 mg L^{-1} belong to oligotrophic ones. Based on the measurements in the natural coral reef ecosystem and the artificial reef ecosystem, the nitrate concentration in the present study is still in the normal range to support the phytoplankton life, 0.01-1 mg L^{-1} (Agustiadi et al 2013).

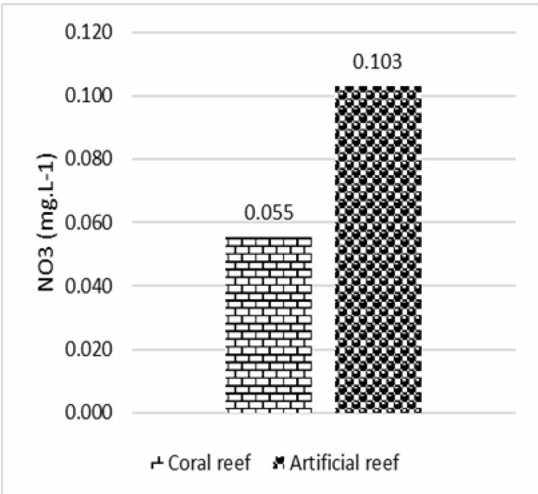

Figure 7. Mean nitrate concentration.

Phosphate. Figure 8 demonstrates that phosphate concentration is 0.021 mg L^{-1} in the natural coral reef ecosystem and 0.011 mg L^{-1} in the artificial reef ecosystem. According to the Indonesian Minister's decree, KEPMEN LH no 51/2004 concerning water quality for marine biota, seawater phosphate concentration is 0.015 mg L^{-1}. In the artificial reef ecosystem, it was below the water quality standard. It was also lower than phosphate concentration in the natural coral reef ecosystem (Figure 8). This condition could result from lack of organic matter input from the terrestrial to the artificial reef ecosystem.

Even though the artificial reef occurred near the coastalline, there was no residential activity in the surrounding land but only coal storage area. High phosphate concentration in the natural coral reef ecosystem could be caused by water currents and turbulence that make the phosphate-containing materials from the bottom be lifted to the surface (Ho et al 2008). Phytoplankton can optimally grow in the water with phosphate content of 0.27-5.51 mg L^{-1} (Agustiadi et al 2013), and in the concentration less than 0.02 mg L^{-1}, phosphate can be a limiting factor for the growth.

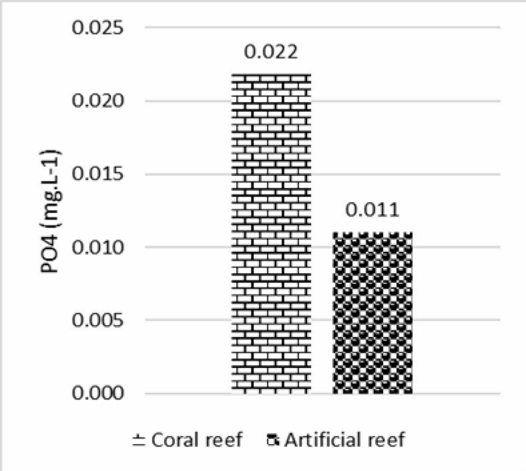

Figure 8. Mean phosphate.

Plankton abundance. Species identification following Shirota (1966), Yamaji (1984), and Thomas (1997) found 4 classes of phytoplankton, Bacillariophyceae, Dinophyceae, Cyanophyceae and Oligotriceae from 6 sampling points in the waters of SBEPP Paiton. All the phytoplankton species are presented in Table 5.

Table 5

Phytoplankton composition in the natural coral reefs and the artificial reef

Genera	*Natural coral reef*			*Artificial reef*		
	TS 1a	*TS 2a*	*TS 3a*	*TS 1b*	*TS 2b*	*TS 3b*
Bacillariophyceae						
Chaetoceros sp.	828	652	970	428	335	399
Thalassionema sp.	236	60	201	-	-	41
Thalassiosira sp.	215	150	235	61	-	50
Pseudonitzchia sp.	385	193	397	50	27	45
Lauderia sp.	87	-	163	-	-	-
Guinardia sp.	-	-	-	32	25	-
Cylindrotheca sp.	31	49	22	27	-	38
Thalassiotrix sp.	24	-	24	-	-	-
Stephanopyxis sp.	-	-	-	43	-	45
Coscinodiscus sp.	24	26	30	41	70	63
Skeletonema sp.	-	20	-	-	-	-
Leptocylindrus sp.	487	151	35	52	54	52
Biddulphia sp.	-	-	9	-	-	-
Rhizosolenia sp.	14	16	23	20	-	-
Bacteriastrum sp.	15	13	19	-	9	16
Pleurosigma sp.	33	17	21	45	43	43
Dinophyceae						
Ceratium sp.	8	10	12	9	-	5
Gymnodinium sp.	-	-	8	-	-	-
Protoperidinium sp.	3	-	21	-	-	-
Prorocentrum sp.	6	11	16	-	-	-
Oligotriceae						
Favella sp.	7	6	5	-	-	-
Cyanophyceae						
Tricodesmium sp.	65	43	77	16	15	14
No. cells	2,468	1,417	2,288	369	264	364
Total abundance (cells L^{-1})	5,589	3,209	5,182	856	598	836

Based on Table 5, the phytoplankton found during the study are very different in either number of individuals or genera. Difference in number of phytoplankton found, according to Adawiyah (2011), could result from competition for living need of the phytoplankton in the waters. The genera rarely found could be caused by succession and tolerance of each genus to the change in the environmental condition (Bresnan et al 2008).

Genera of Bacillariophyceae that could be found in all sampling points were *Chaetoceros, Pseudonitzchia, Pleurosigma, Leptocylindrus,* and *Coscinodiscus*. However, *Chaetoceros* was the highest number found with 970 cells (at the sampling point 3) in the natural coral reef ecosystem (Table 5).

According to Wulandari (2009), the water with genus *Chaetoceros* sp. dominance is related with the shape of *Chaetoceros* sp. itself. *Chaetoceros* sp. has chain-like body shape (the cells clump forming the chain) and has chaeta, so that *Chaetoceros* sp. is more capable of standing against the current and less selected for food by zooplankton (Jin 1982; Du 1996; Cheng 1997).

Phytoplankton abundance varies with sampling point. The highest abundance was recorded in sampling point 1 of the natural coral reef ecosystem, 5,589 cells L^{-1} and the lowest occurred at the sampling point 2 of the artificial reef ecosystem, 598 cells L^{-1}. The abundance in the natural coral reef ecosystem ranged from 3,209 to 5,589 cells L^{-1} while in the artificial reef it ranged from 598 to 856 cells L^{-1}. It means that the natural coral reef ecosystem has higher phytoplankton abundance than that in the artificial reef ecosystem (Figure 9).

Nevertheless, according to Odum (1996), the waters in the artificial reef belong to high fertility category, because its phytoplankton abundance has reached more than 500 cells L^{-1}.

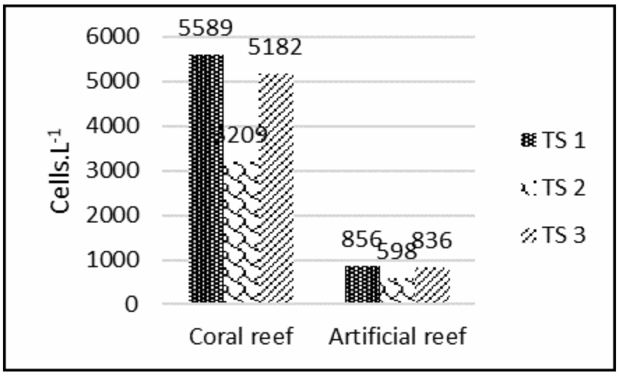

Figure 9. Phytoplankton abundance at each sampling point.

Low phytoplankton abundance in the artificial reef ecosystem could result from unoptimal nutrient utilization by the phytoplankton. Figure 7 shows that high nitrate concentration, but low phytoplankton abundance. In contrast, high phytoplankton abundance in the natural coral reef could result from nitrate utilization for the phytoplankton growth. It is indicated with lower nitrate concentration in the natural coral reef ecosystem than in the artificial reef. The importance of nitrate for phytoplankton is also reported by Khasanah et al (2013) and Xie et al (2007) that nitrate is major source of nutrients used by the phytoplankton for growth and photosynthesis.

Zooplankton abundance. Table 6 demonstrates zooplakton data at each samplingpoint. This study found 5 classes, Crustacea (6 genera), Gastropoda (2 genera), Scyphozoa (1 genus), Sagittoidea (1 genus), and Malacostraca (1 genus). Zooplankton abundance ranged from 48 to 70 ind L^{-1} in the natural coral reef ecosystem and 23 to 36 ind L^{-1} in the artificial reef ecosystem (Figure 10). The highest abundance occurred at the sampling point 2 in the natural coral reef ecosystem, 70 ind L^{-1} and the lowest at the sampling point 3 in the artificial reef ecosystem, 23 ind L^{-1}.

Table 6

Zooplankton composition in the natural coral reefs and the artificial reef

Genera	*Natural coral reef*			*Artificial reef*		
	TS 1a	*TS 2a*	*TS 3a*	*TS 1b*	*TS 2b*	*TS 3b*
Crustacea						
Nauplius sp.	8	12	4	-	-	-
Calanus sp.	3	-	2	1	-	2
Eucalanus sp.	1	2	3	-	5	-
Pseudeuphasia sp.	-	6	-	-	-	-
Ostracoda sp.	5	1	8	-	-	-
Scolecithrix sp.	-	-	-	3	-	-
Gastropoda						
Creseis sp.	-	-	-	8	6	7
Limacina sp.	-	4	-	-	-	-
Scyphozoa						
Mastigias sp.	-	-	-	4	3	1
Sagittoidea						
Sagitta sp.	-	-	7	-	1	-
Malacostraca						
Nebalia sp.	4	6	-	-	-	-
No. individuals	21	31	24	16	15	10
Total abundace (ind L^{-1})	48	70	54	36	34	23

Table 6 demonstrates that *Nauplius* sp., *Pseudeuphasia* sp., *Ostracoda* sp., *Limacina* sp., and *Nebalia* sp. only occur in the natural coral reef ecosystem, while *Scolecithrix* sp., *Creseis* sp., and *Mastigias* sp. are only found in the artificial reef. Other genera are recorded in both reef ecosystems.

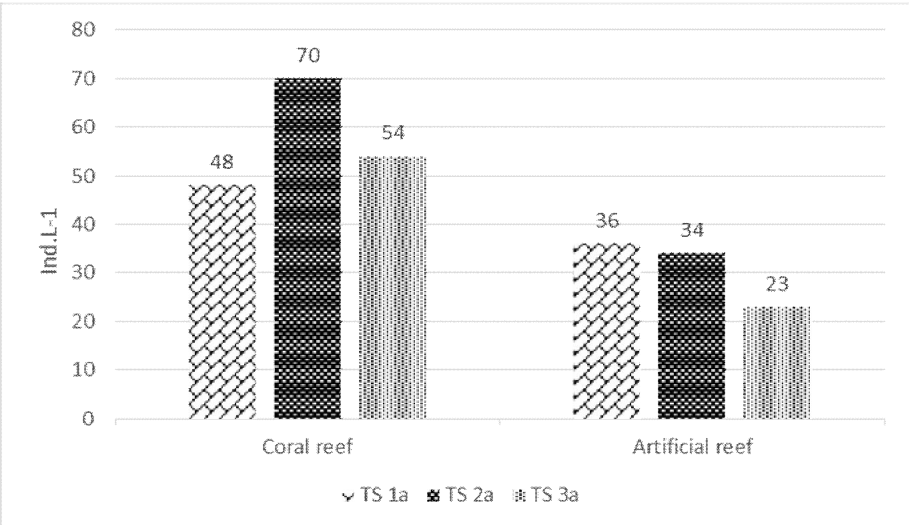

Figure 10. Zooplankton abundance at each sampling point.

The present study found that zooplankton abundance was lower than that of phytoplankton. It could result from sampling time, in which sampling was done in daytime, and at this time, phytoplankton need sunlight to photosynthetize, while zooplankton go to deeper water to avoid the sunlight (Zheng 2014). According to Arinaldi et al (1997), sunlight is a major stimulus that results in daily migration of zooplankton. Zooplankton tends to get rid from high sunlight intensity on the surface in the day, while at night, with no sunlight, it will move to the surface to feed on phytolankton.

Plankton diversity (H'). Plankton diversity estimation at each sampling point in both the natural coral reef ecosystem and the artificial reef ecosystem is presented in Figure 11. The highest diversity was recorded at the sampling point 3 of the natural coral reef ecosystem, 3.25. It is shown with number of plankton genera found in this area, 19 genera of phytoplankton and 5 genera of zooplankton. The lowest was recorded at the sampling point 3 of the artificial reef ecosystem. In this site, only 8 genera of phytoplankton and 4 genera of zooplankton were found (Tables 5 and 6).

Different plankton diversity in the natural coral reef ecosystem and the artificial reef ecosystem could result from water quality condition. Water quality can be influenced by many factors, such as position of the water body, human activities affecting the nutrient input into the waters and the natural factors of the waters itself (Vallina et al 2014).

Odum (1993) claimed that the diversity index can be in the range of 2.3 < H' < 6.9. The diversity range of 3.12-3.25 reveals that the natural coral reef ecosystem has high ecological pressures, high diversity index and community stability. In the artificial reef ecosystem at the sampling point 1 and 3, the diversity index was 2.82 and 2.34, respectively. Thus, according to the category of Odum (1993), both sampling points have moderate diversity and community stability, while the sampling point 2 with the diversity index of 2.19 belongs to low diversity and community stability category.

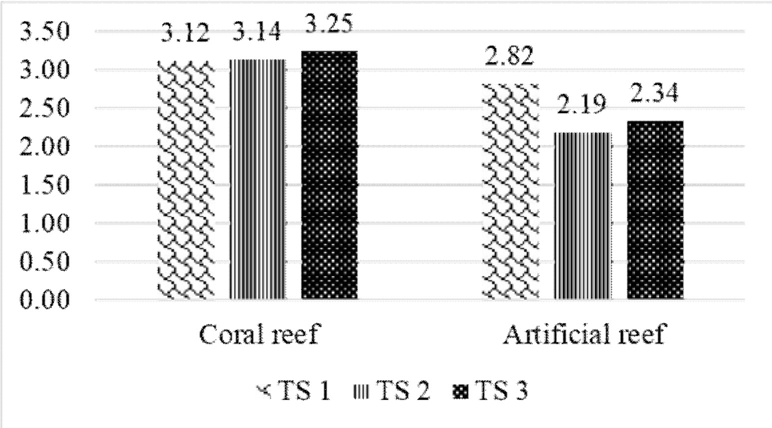

Figure 11. Plankton diversity.

Principle Component Analysis (PCA). Principle Component Analysis (PCA) between the physico-chemical parameters and plankton abundance is demonstrated in correlation matrix using XLSTAT 2019. The relationship between the water physico-chemical factors and plankton the abundance is given in the form of correlation matrix and biplot,while the values of the correlaton matrix is shown in Table 7.

Table 7

Correlation matrix of water physico-chemical parameters and plankton abundance

Physico-chemical water parameters	*Plankton diversity*
Temperature	-0.741
Brightness	-0.370
Salinity	0.878
DO	0.829
pH	0.414
Nitrate	-0.878
Phosphate	0.878

Spearman coreelation analysis showed that water salinity, DO, and phosphate (PO_4) had positive correlation matrix value approach to 1 meaning that these parameters have very strong correlation or direct correlation with plankton abundance, in which increased water salinity, DO, and phosphate will be followed with increase in plankton abundance.

Water pH has the correlation matrix value of 0.414. It means that water pH has moderate correlation with plankton abundance. Similar result was also reported by Wulandari (2009) that change in water pH does not really influence the development of the phytoplankton abundance. Besides, normal water pH condition promotes optimal photosynthesis of the phytoplankton (Pratiwi et al 2017). Normal seawater pH ranges from 7 to 8.5 (Indonesian Minister's decreee, KEPMEN LH no 51/2004).

According to Wulandari (2009), positive correlation between phytoplankton and water salinity indicates that increased salinity will affect the development of phytoplankton abundance. Also, high plankton abundance will be followed with increased DO concentration in the water. It is supported by Siregar (2010) that DO concentration is as a result of oxygen diffusion from the atmosphere and phytoplankton phosynthesis in the water.

Nitrate concentration has correlation matrix value of -0.878 indicating that nitrate content is very strongly correlated with plankton abundance. This correlation is negative meaning that low nitrate concentration is followed with high plankton abundance. Increased plankton abundance with nitrate concentration decline could result from that the phytoplankton could optimally utilize the nitrate as major source of nutrients. Similar finding was recorded in previous study as well (Wulandari 2009).

According to Khasanah et al (2013), water temperature does not significantly influence the plankton abundance. It could result from that there is no significant water temperature change in Situbondo waters, so that water temperature does not become limiting factor for plankton abundance in the area.

Figure 12 shows the correlation between water physico-chemical parameters illustrated with the contribution of each parameter on 2 main axes, F1 and F2 (variable) and F1 and F2 (observation).

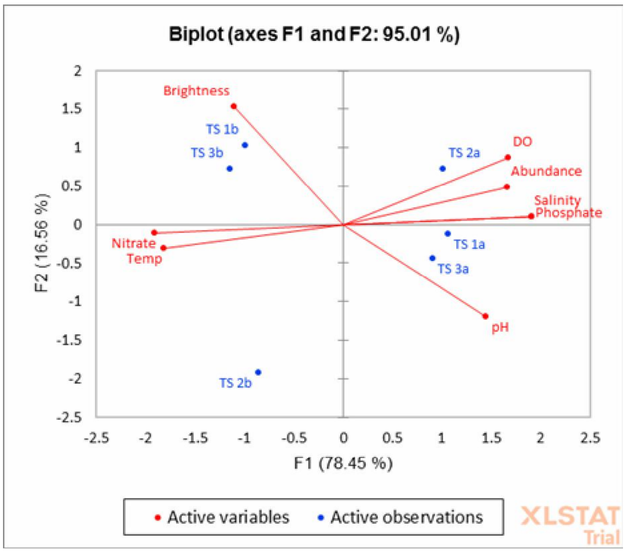

Figure 12. Sampling point distribution based on parameters influencing the phytoplankton abundance.

On both axes, it is apparent that procent of information quality as much as 78.45% of F1 and 16.56% of F2, with characteristic variance at the study sites of 95.01%. Based on the correlation graph in Figure 12, the sampling points TS 1a, TS 2a, and TS 3a are characterized by the main axis or F1 since it is near the F1 axis. Therefore, TS 1a, TS 2a, and TS 3a have the parameter characteristics affecting the plankton abundance, salinity, phosphate, DO that have positive correlation, meaning that the higher the parameters are, the higher the plankton abundance will be. Moreover, water temperature and nitrate are negatively correlated with plankton abundance, indicating that the higher the plankton abundance, the lower the water temperature and nitrate content. Figure 12 shows that the highest plankton abundance and DO concentration in the sampling point TS 1a, because in quadrant I, DO concentration line and plankton abundance line lie close to TS 1a. In quadrant II, it is shown that the highest brightness is found in TS 3b, then followed by TS 1b. Quadrant IV indicates that the highest pH is recorded in TS 2a, and the highest salinity and phosphate is in TS 3a. The water temperature and nitrate lines do not occur near one of the sampling points, because both water temperature nitrate content have the same value at the sampling points of TS 1b and TS 3b. TS 2b does not look close to any linear line since the sampling point TS 2b has the lowest parameter value and plankton abundance.

The correlation matrix between plankton diversity and salinity, DO and phosphate is > 80. It means that water salinity, DO, and phosphate have very strong correlation with plankton diversity, meaning that increased water salinity, DO and phosphate concentration will give good contribution to plankton diversity.

However, water pH, in fact, did not influence the plankton diversity. It is indicated by the correlation matrix of 0.414, and based on the coefficient interval value of Sugiyono (2005), it belongs to weak correlation. The water brightness has correlation matrix value of -0.370 meaning that it has inversely low effect on the plankton diversity.

Meanwhile, water temperature has negatively strong correlation with plankton diversity with matrix correlation value of -0.794. It reflects that the higher the water temperature is, the lower the plankton diversity will be. However, nitrate concentration has very strong negative correlation with plankton diversity. It is shown by the correlation matrix value of -0.878, meaning that increased plankton diversity occurs in low water nitrate concentration. The correlation between plankton diversity and physico-chemical parameters is demonstrated in Figure 13.

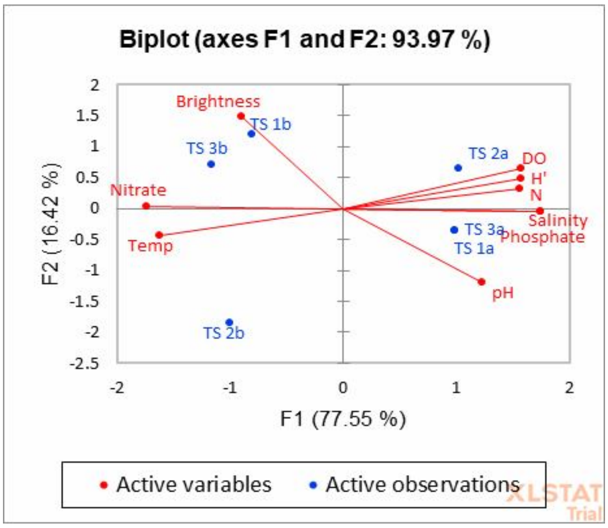

Figure 13. Sampling point distribution based on the parameters influencing the plankton diversity.

Figure 13 shows percent information quality of F1 of 77.55% and F2 of 16.42% with the characteristic variance of 93.97% at the sampling points. The sampling points of TS 1a, TS 2a, and TS 3a are characterized by the main axis or F1 axis since they are close to F1 axis. Therefore, TS 1a, TS 2a, and TS 3a have parameter characteristic affecting the plankton diversity, i.e. salinity, phosphate, DO, temperature, and nitrate. TS 3b is more characterized on F1 axis as well, so that it has characteristic similarity to TS 1a, TS 2a, and TS 3a, in which salinity, phosphate, DO, temperature, and nitrate influence the diversity, while TS 1b and TS 2b indicate the closeness to F2 axis, so that plankton diversity is rather related with water brightness parameter.

Conclusions. Phytoplankton abundance estimation in the natural coral reef ecosystem ranged from 3,209 to 5,589 cells L^{-1}, while in the artificial reef ecosystem, it ranged from 598 to 856 cells L^{-1}. Zooplankton abundance in the natural coral reefs ranged from 48 to 70 ind L^{-1} and in the artificial reef 23-36 ind L^{-1}. Based on Spearman's correlation using Principle Component Analysis (PCA), water brightness and pH in the SBEPP Paiton were moderately correlated with plankton abundance and diversity. Water salinity, DO, and phosphate had positively very strong correlation with plankton abundance and diversity. Nevertheless, water temperature, and nitrate had negative very strong correlation with plankton abundance and diversity.

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Authors:
Endang Yuli Herawati, Faculty of Fisheries and Marine Sciences, Universitas Brawijaya, Jl. Veteran, 65145 Malang, Indonesia, e-mail: eyulih@yahoo.co.id
Ruly Isfatul Khasanah, Post Graduate Program of Fisheries and Marine Sciences, Faculty of Fisheries and Marine Sciences, Universitas Brawijaya, Jl. Veteran, 65145 Malang, Indonesia, e-mail: ulick.isfatul@gmail.com
Muliyana Ambarwati, Program Study of Marine Science, Faculty of Science and Technology, Universitas Islam Negeri Sunan Ampel, Jl. Ahmad Yani No. 117, 60237 Surabaya, Indonesia, e-mail: muliyanaambar856@gmail.com
Dini Sofarini, Department of Aquatic Resource Management, University of Lambung Mangkurat, Jl. Brigadir H. Hasan Basry Banjarmasin 70123, Indonesia, e-mail: sofarini@gmail.com

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