Poll Res. 40 (2) : 515-521 (2021)

ISSN 0257–8050

RELATIONSHIP OF WATER QUALITY WITH PHYTOPLANKTON ABUNDANCE IN KENJERAN COASTAL WATERS, SURABAYA, EAST JAVA, INDONESIA

ANJANI ARUM MAHENDA[1], PUTU ANGGA WIRADANA[2], RADEN JOKO KUNCORONINGRAT SUSILO[3], AGOES SOEGIANTO[3*], ARIF NUR MUHAMMAD ANSORI[4] AND NOVIA ARINDA PRADISTY[5]

[1]*Study Program of Marine Science, Faculty of Science and Technology, UIN Sunan Ampel, Surabaya 60115, East Java, Indonesia*
[2]*Study Program of Biology, Faculty of Health, Science and Technology, Universitas Dhyana Pura, Jl. Raya Padang Luwih, Tegaljaya, Dalung, North Kuta, 80361 Bali, Indonesia*
[3]*Department of Biology, Faculty of Science and Technology, Universitas Airlangga, Surabaya 60115, East Java, Indonesia*
[4]*Study Program of Veterinary Science, Faculty of Veterinary Medicine, Universitas Airlangga, Surabaya 60115, East Java, Indonesia*
[5]*Institute for Marine Research and Observation, Agency for Marine and Fisheries Research and Human Resources, Ministry for Marine Affairs and Fisheries, Bali 82251, Indonesia*

(Received 4 August, 2020; Accepted 9 October, 2020)

ABSTRACT

Phytoplankton play an important role as a bioindicator of water quality. Its abundance is also considered a primary source of feed for these aquatic organisms. This study aims to measure the water quality and phytoplankton abundance and to know their relationship in Kenjeran coastal areas, Surabaya, East Java, Indonesia. This study was conducted in 3 stations (Kedung Cowek, Sentra Bulak, and Surabaya Bridge) for sample collection. The water quality parameters of temperature, brightness, salinity, dissolved oxygen (DO), pH, phosphate (PO_4^{3-}), and nitrate (NO_3^-) values were measured. Phytoplankton was collected using plankton net and counted using Sedgwick-Rafter cell. Relationship of water quality with phytoplankton abundance were analyzed using the Pearson's correlation test on SPSS 21 software and Principal Component Annalysis (PCA), while images and tables were presented using MS. Excel program. Station 1 showed the highest abundance of phytoplankton and diversity index of 539.2 Ind/L and 2.03 H', respectively. Meanwhile, the highest phytoplankton population was found in the *Bacillariophyaceae* group. The correlation analysis results showed a significant correlation between the *Dinobryaceae* group and pH parameters. It can be concluded that Station 1 has the good water quality compared to the other two stations based on the results of monitoring conducted.

KEY WORDS: Phytoplankton, Diversity index, Environmental monitoring, Abundance

INTRODUCTION

Recently, Kenjeran coastal, which is located in the Northeast of Surabaya, Indonesia has become one of marine tourism objects and a gathering place for the general public so that it has the potential to produce industrial waste and fishing vessel activity waste. In addition, the resulting waste can trigger climate change and disrupt water resources including the Kenjeran coastal waters (El Gammal *et al*., 2017). Moreover, intensive use of coastal areas is also capable of causing pollution, overfishing, degradation of natural habitats and abrasion (Bardey, 2020). Damage control and policies in coastal area must be accompanied by regular water quality monitoring (Berge *et al*., 2010). Monitoring can be done by measuring the water physical and chemical parameters. However, biological parameters can also be used for monitoring (Sharma *et al*., 2016). Phytoplankton is a bioindicator to assess the aquatic ecosystem quality (Haroon and Hussian, 2017). It is an organism that acts as a producer in aquatic ecosystem (Saifullah *et al*., 2014). Therefore, the physical-chemical parameters of water act as a major factor in controlling the phytoplankton dynamics in aquatic ecosystem (Sharma *et al*., 2016). Alteration in these parameters have a major impact on aquatic species that live in them, causing changes in the distribution, periodicity and quantitative and qualitative composition of aquatic biota (Cantonati *et al*., 2020).

Furthermore, decreasing in phytoplankton abundance can be one indicator of water quality in aquatic environment. This is related to the increase in pollution that can disrupt the species survival. Diversity in aquatic ecosystem is expressed in the number of species found in that ecosystem. Thus, the calculation of diversity index is needed to determine the ecosystem quality (Bu•anèic *et al*., 2016). In this regard, monitoring is needed to assess water quality with the abundance and diversity index from phytoplankton. This study aims to measure the water quality and phytoplankton abundance and to know their relationship in Kenjeran coastal areas, Surabaya, East Java, Indonesia.

MATERIALS AND METHODS

Physical and chemical analysis

Water sample were collected to three stations, namely Kedung Cowek, Sentra Bulak, and Surabaya Bridge (Table 1). Sampling was carried out in the dry season, namely April to May 2019. Water quality parameters such as temperature, brightness, salinity, DO, and pH were measured *in situ* at each station using a Thermometer (RFM 742 Indonesia), DO Meter (Thermo Scientific Orion Star A329 Portable), pH meter (EUTECH). Other parameters measured were PO_4^{3-} and NO_3^- (El Gammal *et al.*, 2017).

Table 1. Coordinates of study locations in the Kenjeran coastal, Surabaya, East Java, Indonesia.

Station	Location	GPS
1	Kedung Cowek	7"13’11.9"S 112"47’26.5"E
2	Sentra Bulak	7"12’40.9"S 112"47’17.3"E
3	Surabaya Bridge	7"14’03.0"S 112"48’00.5"E

PHYTOPLANKTON

Phytoplankton was collected by filtering a water mass using a mesh size plankton net (sized 30μm). Previously, the plankton net was calibrated by spraying distilled water on all surfaces. Then, a film bottle was attached to the end of the plankton net and tied. Water samples were collcted using a water sampler and filtered using plankton net. The phytoplankton was collected in an environmental sampling bottle and then labelled. The phytoplankton samples obtained were put into a cool box and taken to the laboratory. It was counted by Sedgwick-Rafter cells. The appliance was filled with plankton samples and covered with a glass cover. Sedgwick-Rafter cells and plankton are placed under a microscope whose ocular lens is equipped with a Whipple ocular micrometer. The number of phytoplankton in each sampling station was calculated with the following equation:

$$N = Oi/Op \times Vr/Vo \times 1/Vs \times n/p$$

(N is number of individuals per liter, while Oi is extensive glass cover)

Data analysis

The data of phytoplankton abundance was analyzed using the Shannon Wienner diversity index formula. The classification degree of aquatic ecosystem pollution was refered to the Decree of the Minister of Environment of the Republic of Indonesia in 2004, while the diversity index of phytoplankton was determined according to Lee (1978) (Table 2). Principal Component Analysis (PCA) of the standardized water quality and phytoplankton parameters were performed by statistical package R version 3.4.4 (R Core Team, 2018) with “*vegan*” package. Kaiser-Guttman criterion was determined to select the principal component axes that presented the most variation, in which any principal with variance less than 1 is not worth retaining (Jolliffe, 2002). Pearson (r) correlation of phytoplankton analysis was performed using SPSS 22 Software.

RESULTS AND DISCUSSION

The phytoplankton composition species is influenced by the physicochemical character of water such as pH, DO, temperature, salinity, PO_4^{3-}, and NO_3^- (Touliabah *et al.*, 2016). In this study, the water temperature was relatively high at the three stations, each of which was 32.57 °C (St.1); 32.60 °C

(St.2); and 32.83 °C (St.3). The temperature value was higher when compared to the quality standard value issued by the Decree of the Minister of Environment of the Republic of Indonesia Number 51 of 2004 (Table 2), which was 28 - 30 °C for aquatic ecosystems, especially in supporting the growth of seagrass and coral reefs. According to Ge and Jung-yan (2011) state that there is a positive correlation between the increase in photosynthetic activity with increasing water temperatures especially in summer and autumn. El Gammal *et al*. (2017) also states that water temperature values in spring and early summer are ideal condition for phytoplankton growth. Molecularly, an increase in water temperature causes eukaryotic phytoplankton to require lower ribosomal density for protein synthesis (Toseland *et al*., 2013). The results showed that the pH value of each station was slightly acidic (Table 3), where the pH value ranged from 6.80 - 6.90. The pH value is very low and is below the water quality standard permitted based on the Decree of the State Minister for the Environment of the Republic of Indonesia Number 51 of 2004 (Table 2) which states that the pH of seawater must be in the range of 7-8.5 which has neutral to alkaline properties. The impact of household waste in the three research stations can affect the decrease in the pH of the waters so that sea water will become more acidic and disrupt the productivity of aquatic organisms in Kenjeran waters. Another study was also reported by El Gammal *et al*. (2017) that phytoplankton can reach a maximum growth value at pH 8 especially for the Bacillariophyceae, Dinophyceae, and Cyanophyceae families. Similarly, according to Haroon *et al*. (2017) which states that pH values between 8.0 - 8.6 are ideal alkaline conditions for phytoplankton growth in waters. Decreasing pH levels at sea can potentially reduce the primary production of phytoplankton. Carbon emission from anthropogenic substances that continue around the waters can produce an increase in atmospheric CO_2 concentrations to 700 ppm which affects the decrease in pH (Berge *et al*., 2010).

Dissolved oxygen (DO) is one of the important parameters in determining environmental survival and protecting aquatic life (Decker *et al*., 2004). The average DO value in this study ranged from 3.84 - 4.50 mg/l. Based on this data, DO values in Kenjeran coastal are still very low when compared to the decision of the Minister of Environment of the Republic of Indonesia Number 51 of 2004 (Table 2) which is equal to > 5 mg/l. The low DO value in this study can be caused by the high input of nutrients and organic waste into the water system (Decker *et al*., 2004). Kenjeran coastal had a salinity level of 32.23-33.30‰. The salinity value is still within the normal range to be able to support aquatic biota based on the Decree of the Minister of Environment of the Republic of Indonesia Number 51 of 2004 (Table 2). Dramatic changes in salinity can affect green algae and cyanobacteria in freshwater ecosystems (Chakraborty *et al*., 2011). Dramatic changes in salinity values that occur in the dry season are associated with high evaporation rates (El Gammal *et al*., 2017).

PO_4^{3-} and NO_3^- have an important role in regulating the aquatic microbial communities (Adyasari *et al*., 2020) including phytoplankton. PO_4^{3-} values were obtained in this study ranged from 0.03 - 0.05 mg/l (Table 3). Similarly, the NO_3^- values were also obtained with 0.05 - 0.09 mg/l. Nutrients such as PO_4^{3-} and NO_3^- also play a role in the developing process in phytoplankton populations that are highly dependent on aquatic environment nutrition. Thus, based on these results it is still necessary to measure the chlorophyll-a produced by phytoplankton in the Kenjeran coastal ecosystem so that it can determine the correlation between these two parameters. The highest phytoplankton diversity index (H') was obtained at Station 1 (Kedung Cowek) which was 2.02227, followed by Station 3 (Surabaya Bridge) and Station 2 (Sentra

Table 2. Water quality standard

Parameter	Quality Standards
Temperature (°C)[1]	Coral: 28-30Mangrove: 28-32Seagrass: 28-30
Salinity (‰)[1]	Coral: 33-34Mangrove: 33-34Seagrass: 33-34
pH	7-8.5
DO (mg/l)[1]	>5
PO_4^{3-} (mg/l)[1]	0.015
NO_3^- (mg/l)[1]	0.008
Diversity index (H')[2]	>2.0

Source: [1]Decree of the Minister of Environment of the Republic of Indonesia in 2004; [2]Lee (1978).

Table 3. Water quality parameters and phytoplankton abundance in the Kenjeran Coastal region, Surabaya, East Java, Indonesia at several stations.

Station	Temp (°C)	pH	DO (mg/L)	Salinity ‰	PO_4^{3-} (mg/L)	NO_3^- (mg/L)	Diversity Index (H′)	Density (Ind/L)
St.1	32.57	6.90	3.84	32.97	0.03	0.05	2.02227	539.2
St.2	32.60	6.80	4.36	33.30	0.05	0.09	1.53399	195.2
St.3	32.83	6.90	4.50	32.23	0.05	0.07	1.89404	174.4

Note: St.1: Kedung Cowek; St.2: Sentra Bulak; St.3: Surabaya Bridge.

Bulak) respectively 1.89404 and 1.53399 (Table 3). Based on this study, the water pollution degree with diversity index at station 1 and 3 are included in the light pollution category (H′ = 2.0-1.6). While station 2 is included in the medium pollution category (H′ = 1.5-1.0). The abundance of phytoplankton at station 1 can be caused by the proximity of this station to fish farming, and lead the phytoplankton diversity to thrive at this station. Meanwhile, station 2 is close to residential areas and has the potential for pollution or accumulation of anthropogenic materials from households. Furthermore, station 3 is adjacent to a reclamation project that allows for a potential reduction in the number of phytoplankton and other aquatic biota such as zooplankton, benthos and fish.

The total phytoplankton identified in the three stations was 15 species, which were divided into five groups. The most dominant phytoplankton groups were Bacillariophyceae, Dinobryaceae, Coscinodiscophyceae, Conjugatophyceae, and Cyanophyceae (68%, 14%, 6%, 6%, 6%) (Figure 1). However, the Cyanophyceae group was the most dominant found especially at station 1 with a count of 144 × $10^4/m^3$ (Figure 2). Meanwhile, station 3 had the lowest composition of the phytoplankton group compared to the other two stations. Based on the location of sampling, station 1 (Kedung Cowek) has environmental characteristics that are close to floating net cages or aquaculture. Therefore, the possibility of abundant phytoplankton species diversity at this location can be seen from the phytoplankton group such as Cyanophyceae, Dinophyceae, and Euglenophyceae. The abundance of phytoplankton from the aquatic environment is also influenced by the increasing chlorophyll trend, especially in summer as its productive season (El Gammal *et al*., 2017). The low Phytoplankton group found at station 3 is due to the proximity of this station to the reclamation project. Reclamation activity results in a reduction of aquatic biota quality in the area, so phytoplankton may also experience a decline. According to Ge and Jun-yan (2011), sea reclamation is an important sea utilization activity in supporting human activities to produce good and provide more living space for humans. In Indonesia, reclamation activities have been carried out in Batam which reduces the function of mangrove forest in holding excess water due to rain and tides. The total area of mangroves lost due to reclamation is from 24,000 m^2 to 2,500 m^2 and this condition affects the surrounding community when it is flooded due to rainwater and tide (Jin *et al*., 2016). Aquatic biota such as plankton, benthos, and other biological diversity are also affected by reclamation activities that occur in the Tianjin Port industrial

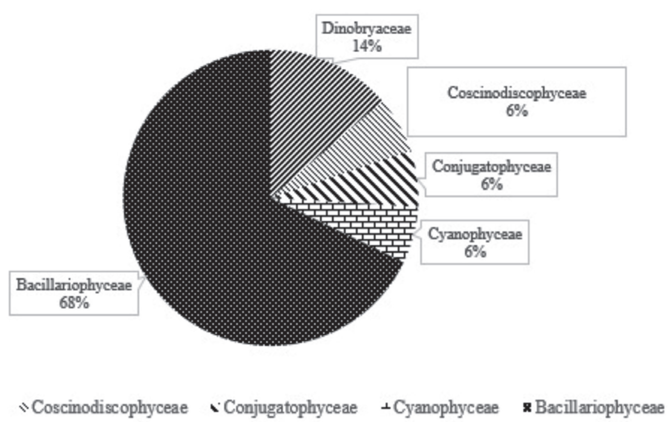

Fig. 1. Diversity of phytoplankton groups during investigation at Kenjeran Coastal area, Surabaya, East Java.

area (Chen *et al*., 2017).

A total of nine species included in the Bacillariophyceae group were identified in this study. The highest abundance of Bacillariophyceae was at station 2 (Figure 2). Some species were found in the Bacillariophyceae group include *Cyclotella striata*, *Asterionella japonica*, *Thalassiothrix spathulata*, *Chaetoceros dydymus*, *Nitzschia sigma*, *Nitzschia lanceolata*, *Navicula* sp, and *Nitzschia pacifica* (Table 4). The Dinobryaceae and Coscinodiscophyceae groups were the second most dominant species (Table 4). However, *Ditylum brightwellii* and *Chaetoceros* sp. in the Coscinodiscophyceae group had a dominant percentage of > 50% when compared to the species in the Dinobryaceae group whereas the dominant value of the Cyanophyceae group ranks third when compared to the Conjugatophyceae group (Table 4).

The eigenvalues of Principal Component Analysis (PCA) of water quality and phytoplankton variables showed that the first and the second principal component (PC1 & PC2) explained 60.5% and 39.5% of the total variation, respectively (Figure 3). The Guttman-Kaiser criterion suggested that both PC1 and PC2 axes can be retained, because these axes has the variance higher than 1: 4.84 and 3.16. As presented in the distance biplot of PCA, PC1 axis was positively correlated with phosphate, nitrate and DO and negatively correlated with phytoplankton density and phytoplankton diversity index. These variables can explain more than 50% of the total variation, and thus possibly suitable for environmental monitoring. Additionally, the PC2 axis was positively correlated with temperature and pH and negatively correlated by salinity. By correlating the PCA scores of environmental variables with sampling stations, it is predicted that Station 1 had the highest phytoplankton density due to low concentration of phosphate and DO. In Station 2, low phytoplankton diversity index is possibly related to high nitrate concentration. High water temperature differentiates Station 3 from other stations.

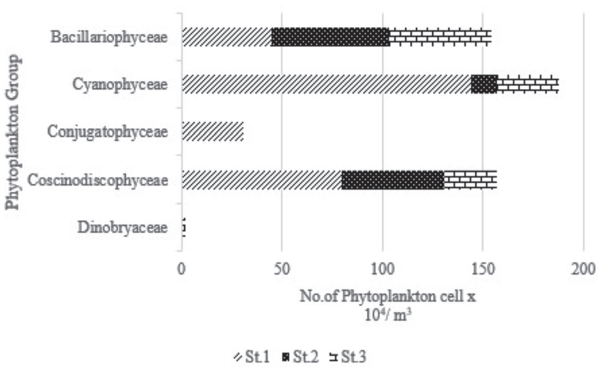

Fig. 2. The variation density of phytoplankton during investgation at Kenjeran coastal area, Surabaya, East Java.

Dinobryaceae has a significant positive relationship with pH (r = 1.000) at $P < 0.01$, while a negative relationship in this group was obtained by DO (r = -0.315), salinity (r = -0.738), PO_4^{3-} (r = -0.421), nitrate (r = -0.909), and Bacillariophyceae (r = -0.887) (Table 5). Species from the Dinobryaceae group were likely to develop with the pH values obtained in this study. Water quality with a low pH value can affect the health and viability of phytoplankton, some species are significantly affected by changes in water pH due to eutrophication from coastal (Toseland *et*

Table 4. Dominant of phytoplankton species at each station in Kenjeran Coastal area, Surabaya, East Java

Species	Station 1	Station 2	Station 3
Ceratium sp.	+	-	-
Dinobryon sp.	-	-	+
Ditylum brightwellii	+++	-	-
Chaetoceros sp.	++	+++	++
Mougeotia sp.	++	-	-
Nostoc sphaericum	+++	+	++
Cyclotella striata	++	-	-
Asterionella japonica	++	++	+
Thalassiothrix spathulata	-	+	+
Chaetoceros dydymus	-	-	+
Nitzschia sigma	-	-	++
Nitzschia lanceolata	-	-	+
Biddulphia longicruris	+	+	-
Navicula sp.	+	-	-
Nitzschia pacifica	+	+	-

al., 2013). Meanwhile, oxygen utilization did not occur optimally by the Dinobryaceae group so that this could be one of the least abundance of species in the Kenjeran coastal (Table 4).

A positive relationship was also obtained by the Bacillariophyceae group with NO_3^-, while a negative relationship was reported between Bacillariariophyceae and pH (Table 5). NO_3^- and ammonium (NH_4^+) are the most important sources of nitrogen for phytoplankton growth (Domingues *et al*., 2011). Phytoplankton is very sensitive with environmental changes and this condition can provide insight into the water quality as a result of the eutrophication process (Bu•anèiæ *et al*., 2016). Eutrophication is a water enrichment process with nutrients such as nitrogen and phosphorus and lead to stimulate primary production. However, an increase in excessive eutrophication due to anthropogenic material can reduce DO levels, causing serious death of many fish and other hydrophytes in water including coastal water (Wang *et al*., 2013).

CONCLUSION

This study fòund that the highest amount of phytoplankton abundance and diversity index was found at station 1 which was 539.2 Ind/l and 2.03 H′, respectively. Meanwhile, the most found phytoplankton group was the Bacillariophyceae group. In addition, samples from station 1 showed the number of phytoplankton found mainly in the Cyanophyceae group compared to other groups. Hence, the species found were dominated by *Ditylum brightwellii*, *Chaetoceros* sp, and *Nostoc sphaericum*. Pearson correlation test results showed a positive correlation between physical parameters with the amount of phytoplankton available, especially between pH and the Dinobryaceae group. These results indicate that station 1 is an area with good water quality compared to other groups. However, further tests using other indicators need to be done to further ensure conditions in the water quality from Kenjeran region. Based on this study, it can be seen that environmental management efforts still need to be done, especially in Kenjeran waters, Surabaya, East Java. Public awareness about environmental cleanliness is very important to be able to support the sustainability of the aquatic environment, livelihoods, ecotourism, and the health of the community around Kenjeran waters.

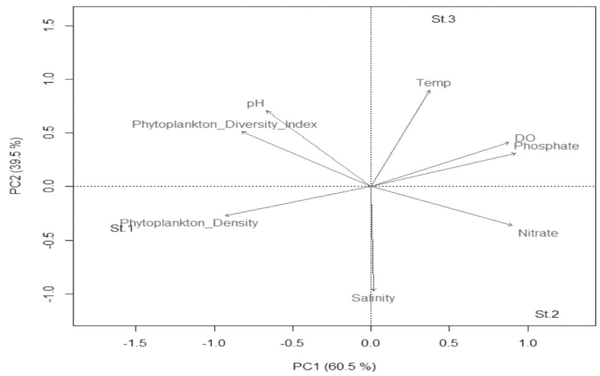

Fig. 3. Distance biplot of Principal Component Analysis (PCA) showing variation in water quality parameters and phytoplankton density index and density, based on three sampling station

Further Research

Further research still needs to be done, especially regarding heavy metal contamination, pathogenic microbial contamination, and its resistance to antibiotics in aquatic biota which are used as a food source, so that it can complement information on water environmental health management in Surabaya, East Java.

Table 5. Correlation between phytoplankton groups with water physics-chemical parameters in the Kenjeran Coastal area, Surabaya, East Java

Parameter	Temperature	pH	DO	Salinity	PO_4^{3-}	NO_3^-	Dinobrya-ceae	Coscinodis-cophyceae	Conjuga-tophyceae	Cyanophy-ceae
pH	0.406									
DO	0.739	-0.315								
Salinity	-0.917	-0.738	-0.408							
PO_4^{3-}	0.658	-0.421	0.994	-0.302						
NO_3^-	0.013	-0.909	0.683	0.388	0.761					
Dinobryaceae	0.406	1.000**	-0.315	-0.738	-0.421	-0.909				
Coscinodisco-phyceae	-0.896	0.043	-0.962	0.643	-0.924	-0.456	0.043			
Conjugato-phyceae	-0.589	0.5	-0.98	0.216	-0.996	-0.816	0.5	0.887		
Cyanophy-ceae	-0.481	0.606	-0.946	0.091	-0.977	-0.883	0.606	0.821	0.992	
Bacillariophy-ceae	0.061	-0.887	0.717	0.343	0.792	0.999*	-0.887	-0.499	-0.843	-0.904

REFERENCES

Adyasari, D., Hassenrück, C., Montiel, D. and Dimova, N. 2020. Microbial community composition across a coastal hydrological system affected by submarine groundwater discharge (SGD). *PloS One.* 15 (6) : e0235235.https://doi.org/10.1371/journal.pone.0235235

Bardey, D.J. 2020. Overfishing: pressure on our oceans. *Research in Agriculture Livestock and Fisheries*. 6 (3) : 397-404. https://doi.org/10.3329/ralf.v6i3.44805

Berge, T., Daugbjerg, N., Balling Andersen, B. and Hansen, P. 2010. Effect of lowered pH on marine phytoplankton growth rates. *Marine Ecology Progress Series*. 416 : 79-91. https://doi.org/10.3354/meps08780

Buzancic, M., Gladan, •.N., Marasoviæ, I., Kušpilic, G. and Grbec, B. 2016. Eutrophication influence on phytoplankton community composition in three bays on the eastern Adriatic coast. *Oceanologia*. 58 (4) : 302-316. https://doi.org/10.1016/j.oceano.2016.05.003

Cantonati, M., Poikane, S., Pringle, C.M., Stevens, L.E., Turak, E., Heino, J., Richardson, J.S., Bolpagni, R., Borrini, A., Cid, N., Ètvrtlíková, M., Galassi, D.M.P., Hájek, M., Hawes, I., Levkov, Z., Naselli-Flores, L., Saber, A.A., Cicco, M.D., Fiasca, B., Hamilton, P.B., Kubeèka, J., Segadelli, S. and Znachor, P. 2020. Characteristics, main impacts, and stewardship of natural and artificial freshwater environments: consequences for biodiversity conservation. *Water*. 12(1) : 260. https://doi.org/10.3390/w12010260

Chakraborty, P., Acharyya, T., Raghunadh Babu, P.V. and Bandyopadhyay, D. 2011. Impact of salinity and pH on phytoplankton communities in a tropical freshwater system: An investigation with pigment analysis by HPLC. *Journal of Environmental Monitoring.* 13 (3) : 614. https://doi.org/10.1039/c0em00333f

Chen, W., Wang, D., Huang, Y., Chen, L., Zhang, L., Wei, X., Sang, M., Wang, F., Liu, J. and Hu, B. 2017. Monitoring and analysis of coastal reclamation from 1995-2015 in Tianjin Binhai New Area, China. *Scientific Reports.* 7 (1) : 3850. https://doi.org/10.1038/s41598-017-04155-0

Decker, M., Breitburg, D. and Purcell, J. 2004. Effects of low dissolved oxygen on zooplankton predation by the ctenophore *Mnemiopsis leidyi*. *Marine Ecology Progress Series.* 280 : 163-172. https://doi.org/10.3354/meps280163

Domingues, R.B., Barbosa, A.B., Sommer, U. and Galvão, H.M. 2011. Ammonium, nitrate and phytoplankton interactions in a freshwater tidal estuarine zone: potential effects of cultural eutrophication. *Aquatic Sciences.* 73 (3) : 331-343. https://doi.org/10.1007/s00027-011-0180-0

El Gammal, M.A.M., Nageeb, M. and Al-Sabeb, S. 2017. Phytoplankton abundance in relation to the quality of the coastal water - Arabian Gulf, Saudi Arabia. *Egyptian Journal of Aquatic Research.* 43 (4) : 275-282. https://doi.org/10.1016/j.ejar.2017.10.004

Ge, Y. and Jun-yan, Z. 2011. Analysis of the impact on ecosystem and environment of marine reclamation–A case study in Jiaozhou Bay. *Energy Procedia*. 5 : 105-111. https://doi.org/10.1016/j.egypro.2011.03.020

Haroon, A.M. and Hussian, A.E.M. 2017. Ecological assessment of the macrophytes and phytoplankton in El-Rayah Al-Behery, River Nile, Egypt. *Egyptian Journal of Aquatic Research.* 43 (3) : 195-203. https://doi.org/10.1016/j.ejar.2017.08.002

Jin, Y., Yang, W., Sun, T., Yang, Z. and Li, M. 2016. Effects of seashore reclamation activities on the health of wetland ecosystems: A case study in the Yellow River Delta, China. *Ocean and Coastal Management*. 123 : 44-52. https://doi.org/10.1016/j.ocecoaman.2016.01.013.

Jolliffe, I. 2002. *Principal Component Analysis.* https://doi.org/10.1007/b98835

R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Retrieved from https://www.r-project.org/

Saifullah, A.S.M., Abu Hena, M.K., Idris, M.H., Halimah, A.R. and Johan, I. 2014. Composition and diversity of phytoplankton from mangrove estuaries in Sarawak, Malaysia. *Journal of Biological Sciences*. 14 (5) : 361-369. https://doi.org/10.3923/jbs.2014.361.369

Sharma, R.C., Singh, N. and Chauhan, A. 2016. The influence of physico-chemical parameters on phytoplankton distribution in a head water stream of Garhwal Himalayas: A case study. *The Egyptian Journal of Aquatic Research.* 42 (1) : 11-21. https://doi.org/10.1016/j.ejar.2015.11.004

Toseland, A., Daines, S.J., Clark, J.R., Kirkham, A., Strauss, J., Uhlig, C., Lenton, T.M., Valentin, K., Pearson, G.A., Moulton, V. and Mock, T. 2013. The impact of temperature on marine phytoplankton resource allocation and metabolism. *Nature Climate Change*. 3 (11) : 979-984. https://doi.org/10.1038/nclimate1989

Touliabah, H. and Elbassat, R. 2016. Plankton and some environmental variables as a water quality indicator for saline pools at the Western Red Sea (Saudi Arabia). *Journal of Coastal Zone Management.* 19 (01) : 1-7. https://doi.org/10.4172/2473-3350.1000417

Wang, X., Wang, Y., Liu, L., Shu, J., Zhu, Y. and Zhou, J. 2013. Phytoplankton and eutrophication degree assessment of Baiyangdian Lake Wetland, China. *The Scientific World Journal.* 2013 : 1-8. https://doi.org/10.1155/2013/436965.