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Cover Page Footnote

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The Influence of Nutrient (N and P) Enrichment and Ratios on Phytoplankton Abundance in Keunekai Waters, Weh Island, Indonesia

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Abstract

The Keunekai waters around Weh Island, Indonesia, have become a prone coastal area because of degradation from climate anomalies and anthropogenic pressure. The high level of coral mortality caused by mass bleaching and fish bombing several years ago may have led to the deterioration of the water conditions and the disruption of the biogeochemical cycle, resulting in potential nutrient enrichment and algae blooms (eutrophication). This study aimed to determine the influence of nutrient ratios on phytoplankton abundance and monitor the existing water conditions around Keunekai. Spectrophotometry analysis was used to determine the concentrations of the nutrients, and the Sedgewick-Rafter counting method was used to identify the species and abundance of the phytoplankton. A large variation in N content (ranging from 1.1 to 1.6 mg N/L) and, particularly, P content (ranging from 0.02 to 0.18 mg P/L) most likely reflected differences in the supply ratios of N and P, rather than differences in absolute N and P availability. Three taxa of phytoplankton and their relative abundance were identified in the study area: Bacillariophyceae (diatom) (72%), Cyanophyceae (3%), and Dinoflagellate (25%). It was found that P-limitation mostly controls potential algae blooms, which support the density of Dinoflagellates that may endanger the water.

Abstrak

Pengaruh Pengkayaan Nutrien (N dan P) dan Rasionya terhadap Kelimpahan Fitoplankton di Perairan Keunekai, Pulau Weh, Indonesia. Perairan Keunekai di Pulau Weh, Indonesia, menjadi sebuah wilayah pesisir yang rentan karena degradasi dari anomali iklim dan tekanan antropogenik. Tingkat kematian karang yang tinggi disebabkan oleh pemutihan masal dan pengeboman ikan beberapa tahun yang lalu mungkin telah menyebabkan penurunan kondisi perairan dan gangguan terhadap siklus biogeokimia yang menghasilkan gejala blooming dan pengkayaan nutrient (eutrofikasi). Tujuan dari penelitian ini adalah untuk mengetahui pengaruh dari rasio nutrien pada kelimpahan fitoplankton dan memantau kondisi perairan terkini di Keunekai. Analisis spektrofotometri digunakan untuk mengetahui konsentrasi nutrien, dan metode perhitungan Sedgewick-Rafter digunakan untuk mengidentifikasi kelimpahan fitoplankton dan spesiesnya juga. Variasi yang besar dalam konten N (berkisar dari 1,1 hingga 1,6 mg N / L) dan khususnya konten P (berkisar 0,02-0,18 mg P / L) kemungkinan besar mencerminkan perbedaan dalam rasio asupan N dan P daripada perbedaan absolut ketersediaan N dan P. Tiga taksa dari fitoplankton dan kelimpahan relatifnya teridentifikasi di wilayah penelitian: Bacillariophyceae (diatom) (72%), Cyanophyceae (3%), dan Dinoflagellate (25%). Diketahui bahwa batasan-P mengendalikan potensi blooming alga yang mendukung kepadatan Dinoflagellate yang mungkin membahayakan perairan.

Keywords: Nutrients enrichment, N:P ratio, phytoplankton abundance, Keunekai waters

Introduction

Weh Island, one of the outermost islands of Indonesia, has become a significant area for aquaculture and marine tourism [1]. These current anthropogenic activities may be causing water degradation and playing a role in declining water quality due to the presence of associated marine litter and enhanced pollution.

Keunekai water is located in the southern Weh Island directly bordered by the Indian Ocean. As a result, this area is predisposed by the atmosphere-ocean interactions of the Indian Ocean such as Indian Ocean Dipole (IOD), Monsoons, and Madden Julian Oscillation (MJO), influencing water condition of Keunekai which has become the poorest ecosystem in Weh Island. Many biotas are demised due to anthropogenic factors, resulting in imbalanced ecosystem. If ongoing, it will disrupt the biogeochemical cycle. Moreover, the fish-bomb utilization in Keunekai Water which reaches the very alarming level also supports the degradation of the water [2].

The Keunekai water body is located off the southern coast of Weh Island, directly bordered by the Indian Ocean. As a result, this area is predisposed to the atmosphere-ocean interactions of the Indian Ocean, such as the Indian Ocean Dipole (IOD), monsoons, and the Madden-Julian oscillation (MJO), that influence the conditions of the Keunekai waters, which has become the most impoverished Weh Island ecosystem. The anthropogenic factors have also contributed to the demise of many biotas, resulting in an imbalanced ecosystem, which if it continues, will disrupt the biogeochemical cycle. Moreover, “fish bombing” in Keunekai waters, which has reached a very alarming level, also results in the degradation of the water [2].

The best way to identify water degradation is to monitor nutrients and phytoplankton because one of the impacts of an imbalanced ecosystem is nutrient enrichment, which triggers potential algal blooms due to biogeochemical cycle disruption [3]. When nutrients enter a water body from the land, algae blooms tend to occur (eutrophication) [4]. When populations of phytoplankton rapidly increase, especially toxic species of dinoflagellates and diatoms, the water potentially becomes toxic due to the existence of harmful algae, supported by high nutrient availability [5].

N- and P-based nutrients play a significant role in the recycling the of organic compounds due to their combination with carbon elements through the process of photosynthesis. Nutrients (nitrate, nitrite, ammonia, and phosphate) also play a role in the processes and development of living organisms, such as phytoplankton populations, which depend on the availability of nutrients in the water environment [6]. Inorganic compounds are naturally derived from the water through decomposition processes. The remains of dead organisms and wastes are decomposed by bacteria to become nutrient substances [7]. These substances are then involved in the remineralization process, resulting in organic materials such as nitrate and phosphate.

The abundance of phytoplankton is controlled by the nutrient conditions of the water; unusual autotroph organisms will bloom if the nutrient concentration is enhanced [8], resulting in the decline of water quality. This will cause the mass mortality of organisms, such as fish and other heterotrophic biota in the food chain [9,10].

A related study by [11] of Pria Laot Bay waters, off the northern coast of Weh Island, defined their chlorophyll-a status (ranging from 0.02 to 1.7 µg/L) and nutrient availability as above the minimum standard and extremely supportive of phytoplankton growth. This northern bay is a significant area due to its utilization as a marine tourism center (diving sites), its function as the center of port activities, and its location near the city center of Sabang. In contrast, because the Keunekai water area is harder to access, being located quite far from Sabang (± 13 km), it has been researched less.

Coral and ecosystems damaged by fish bombing several years ago may trigger an environmental imbalance (Figure 1). These conditions, resulting from imbalanced and damaged conditions, can severely disrupt biogeochemical cycles. If the biogeochemical cycle is hampered, nutrient enrichment can potentially occur because the accumulated nutrients are not able to be well-absorbed by autotroph biota. Moreover, several hydrothermal vents (fumaroles) contribute to the nutrient source in Keunekai waters. Because of all these inputs and effects, a study analyzing the nutrient enrichment and abundance of phytoplankton in the Keunekai waters is essential. This study aimed to determine the influence of the nutrient ratio on phytoplankton abundance in the Keunekai waters by monitoring water conditions.

Figure 1. Dead Coral Observed in Keunekai Waters, Probably Caused by Fish Bombing

Materials and Methods

Research location and observation stations. Keunekai water sampling was conducted between March 14 and 16, 2017 (Figure 2). The sampling points included 12 observation stations. These stations covered an area of dead coral, which became the focus of this study. The sampling was undertaken three times during the displacement times of high to low tidal conditions (07.00-12.00 AM) (Figure 3). This condition was chosen because nutrients sourced from land predominate during the low tidal condition (land-sourced nutrients). The water sampling was accomplished using a rosette sampler equipped with Niskin bottles. Shallow water samples, taken only from the water surface, were collected due to the relatively shallow water in the research location; however, they sufficiently represented the study area.

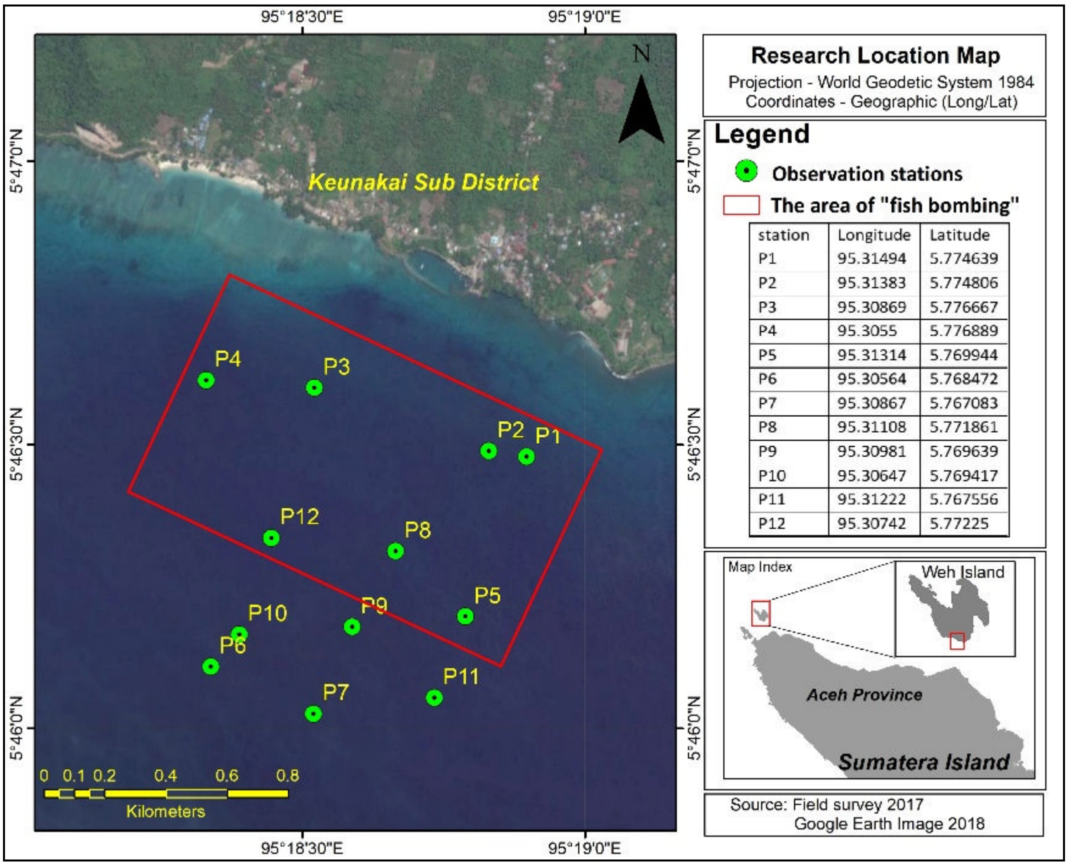

Figure 2. Research location Map Showing the Phytoplankton and Water Sampling Observation Stations

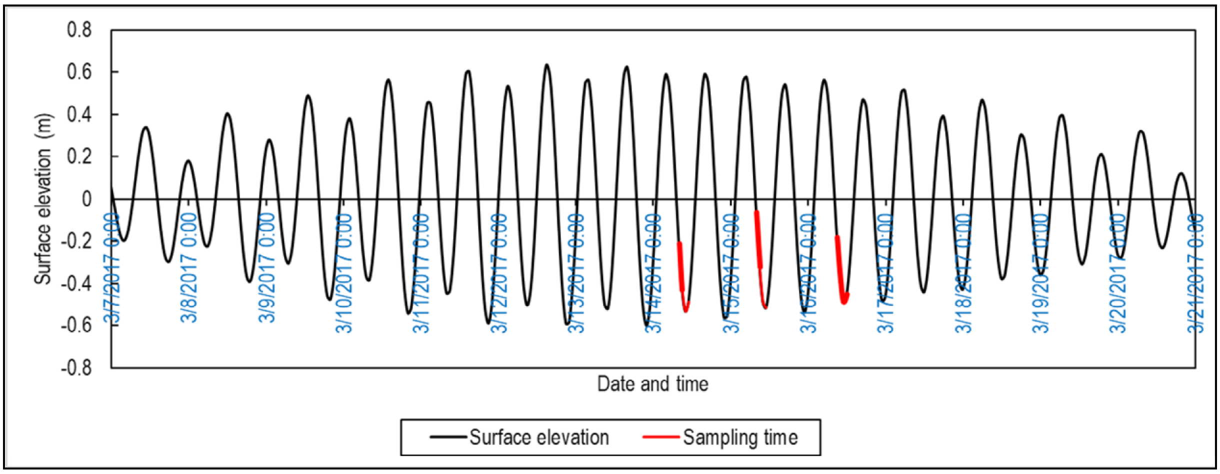

Figure 3. Tide Forecasting During Sampling Period [12]

Nutrients sampling and analysis. The collected water samples were placed in labeled sample bottles, and the N and P compounds were prepared for analyses by adding four drops of concentrated H_2SO_4, specifically for P analyses was done without pickling [13]. The prepared sample bottles were then wrapped in aluminum foil and placed in a cool box.

The samples were later filtered using a nitrocellulose membrane filter, with a pore size 0.45 µm and a diameter of 47 mm and kept cool in a refrigerator. The concentrations of dissolved nitrate, analyzed using a spectrophotometric device, ranged from 0.1 to 2 mg/L and brucine was identified (wavelength of 410 nm). The determination of ammonia concentrations, found as phenates, was performed using a spectrophotometer, using a 640 nm wavelength, and ranged from 0.1 to 0.6 mg/L NH3-N. The determination of the nitrites was performed in the range 0.01–1 mg/L under acidic conditions (pH 2–2.5) by reacting the nitrite to form azo compounds. The resulting scarlet color was measured at a wavelength of 543 nm [6].

Phosphate determination was done by employing spectrophotometer (model genesis 10s UV-VIS) method as ascorbic acid levels in the range of 0.0 – 1 mg/L. The principle of this analysis is based on the formation of complex compounds blue phosphomolybdic. The compounds are reduced by ascorbic acid to form molybdenum blue color complex. The intensity of the color formed is appropriate with the concentration of phosphorus, the wave length used is 700-880 nm [14,15].

Phytoplankton analysis. Phytoplankton filtration was done vertically and withdrawn from 5 meters depth to the surface using 0.35 µm plankton net. Filters were then preserved using 4 % formaldehyde. The preserved sample analyzed employing Sedgewick Rafter method by which it performed utilizing light microscope with 100 magnifications. To identify the types of phytoplankton, we used identification books by [16,17,18]. Total of phytoplankton abundance calculated based on [19] equation as follow:

$$N = Z \; x \; \frac{X}{Y} \; x \; \frac{1}{V} \qquad (1)$$

where, N = phytoplankton abundance (cell/m^3), V = total filtered water volume (m^3), X = sampled water volume (mL), Y = one drop of pipette volume (mL), and Z = total individuals found (cell).

To evaluate the influence of nutrients (N and P) on phytoplankton abundance, linear regression and correlation are employed in this study. However, there is a significant correlation between nutrient and phytoplankton abundance, therefore it is possible that the linear regression of any variable between nutrients and phytoplankton abundance would be contaminated to some degree by this correlation.

Results and Discussion

Nutrient concentration and its potential effect on water quality. The phosphate concentration ranged from 0.04 to 0.18 mg P/L. The highest phosphate concentrations were observed at stations P6, P10, and P11, reaching 0.14, 0.18, and 0.14 mg P/L, respectively (Figure 4). Because these were the most seaward stations, these results indicated that sea-sourced phosphate predominates during the displacement of the flood to the ebb tide. Compared to water quality standards established by the Ministry of Environment (2004), the phosphate concentrations in the Keunekai waters were within the standard but tended to be higher than the standard at several stations (Table 1). As a limited nutrient in water, phosphate is a key parameter and a chemical indicator that controls the growth of autotroph biota. A higher phosphate value (ranging from 0.035 to 0.1 mg P/L), particularly, plays a large role in creating algae blooms (eutrophication) [20].

The lowest phosphate concentrations were found at stations P1, P2, and P5, reaching 0.04, 0.04, and 0.02 mg P/L, respectively (Figure 4). These lowest concentrations of phosphate were located in eastern Keunekai waters, where no estuaries are located.

Low phosphate concentration can be the natural condition of waters due to a lack of P input from adjacent land or water masses (i.e. a lack of upwelling) [21]. Phosphate also undergoes dissolution and precipitation, becoming insoluble inorganic phosphate, such as $Ca_5(OH)(PO_4)_3$ and iron phosphate [22]; soluble inorganic phosphates, such as HPO_4^{2-}, H_2PO^{4-}; and polyphosphate [23]. These P cycles result in the deposition of biological, organic, and inorganic phosphates in sediments due to its instability as a gas, which results in limited dissolved P in water (endogenic process predomination) [24].

The concentration of ammonia ranged from 0.004 to 0.0016 mg N/L, varying across all the stations. The highest concentration of ammonia was observed at station P4, reaching 0.0016 mg N/L, while the lowest concentration of ammonia (0.004 mg N/L) was observed at station P12. These concentrations were less than the Ministry of Environment (2004) quality standard for ammonia to support biotic life of around 0.3 mg N/L (Table 1). This indicates that there are a lack of N fixation and ammonification processes in the Keunekai waters. Nevertheless, the concentration of ammonia at each station tended to follow the same pattern as the nitrate and nitrite levels (Figure 4).

In aquatic ecosystems, the existence of a cyanobacteria population (prokaryote algae) can bind free N (N_2) from the atmosphere, which then enters the water body. This process, called N fixation, results in an ammonia compound, the first formed organic N which this bound N can then be used by autotroph biota and algae to support growth [25]. While ammonia also results from the ammonification process with the help of decomposers (fungi and bacteria), it produces organic N in the form of proteins (amino acids) [26].

The concentration of nitrite ranged from 0.03 to 0.17 mg N/L (Figure 4). Its highest concentration was identified at station P10, reaching 0.17 mg N/L; this was the only station where the concentration of nitrite was greater than the water quality standard established by the Ministry of Environment (2004) (Table 1). This high concentration of nitrite was supported by a phosphate concentration, which could have potentially supported an algae bloom at station P10. According to [6], a high level of nitrite is induced by a low concentration of dissolved oxygen (Table 4) because nitrobacteria cannot work optimally, due to a lack of oxygen, to convert NO_2 compounds to NO_3^- compounds. These conditions would inhibit the N cycle in Keunekai waters.

The concentration of dissolved N in the Keunekai waters varied, ranging from 1.1 to 1.6 mg N/L. The highest nitrate concentrations were found at stations P1 and P4, reaching 1.6 and 1.5 mg N/L, respectively. The nitrate concentration tended to be constant at all the stations, which were all more than 1 mg N/L (Figure 4). These concentrations of nitrate are categorized as "enriched nutrients" and represent an extremely pernicious threat to biota because of a tendency to trigger algae blooms [27].

According to the Ministry of Environment (2004) (Table 1), the water quality standard for allowed nitrate concentration is no more than 0.008 mg N/L. The nitrate concentration in the Keunekai waters was extremely high, ranging from 1.1 to 1.6 mg N/L. Unutilized nitrate and the gradual discharge of nitrates from estuaries triggers the nitrate enrichment in Keunekai waters. These conditions are very alarming because the existence of abundant nutrient compounds in the waters may cause eutrophication, which changes the functions of the nutrients (N and P) to become toxic [28].

Another standard quality recommended by [29] is a limit of NH_3 in both freshwater and marine environments to around 0.02 mg N/L, while a nitrite concentration considered ideal for marine fish ranges between 0.01 to 0.04 mg N/L. Nitrite-N level exceeding 0.55 mg N/L can potentially cause a disease called "brown-blood" or methemoglobinemia [30]. The ideal range for nitrates is considered to be between 0.1 and 0.2 mg N/L. However, the results of the current study showed that the concentration of dissolved inorganic N (DIN) and dissolved inorganic P (DIP) in the Keunekai waters were within the range of the water quality standards established by the Ministry of Environment (2004) (Table 1).

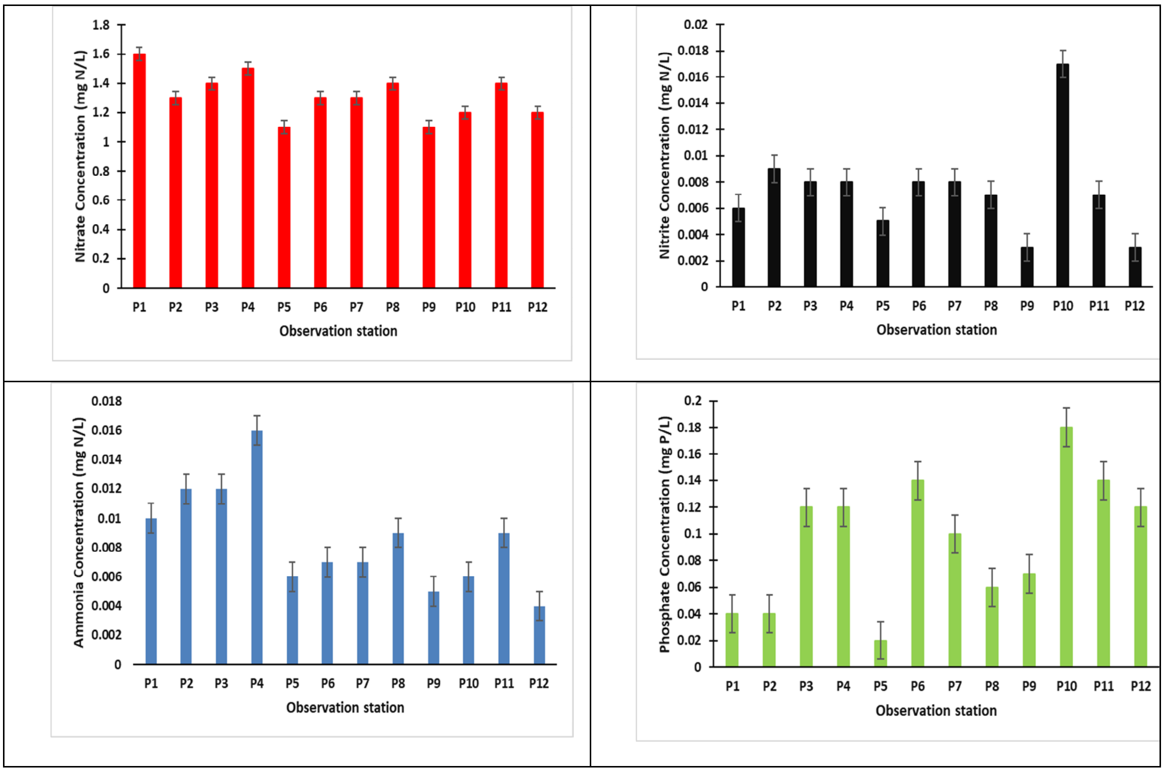

Figure 4. Comparison between nitrate (red), nitrite (black), ammonia (blue), and phosphate (green) concentrations in Keunekai Waters

Table 1. Summary of the Nutrient Concentration Monitoring Results from Keunekai Waters Compared with Ministry of Environment (2004) Water Quality Standards

N	Dissolved nutrients	Standard quality for marine biota (mg/L)	Keunekai waters (mg/L)
1	Nitrate	0.008	1.1-1.6
2	Nitrite	0.015	0.003-0.17
3	Ammonia	0.3	0.004-0.016
4	Phosphate	0.015	0.02-0.18

Table 2. Descriptive Statistics of the Keunekai Water quality Parameters

Parameters	Min	Max	Mean	ST dev
pH	8.3	8.43	8.34	0.02
Salinity ($^{o}/_{oo}$)	30.1	31.52	31.1	0.33
Dissolved oxygen (mg/L)	3.83	5.49	4.4	0.39
Temperature (^{o}C)	29	30.3	29.75	0.22
Total suspended solid (mg/L)	12	24	17.2	3.59

Levels of dissolved oxygen (DO) ranging between 3.83 and 5.49 mg/L (Table 2) are categorized as "medium polluted" waters [31]. An extremely low DO level indicates that the activity of microorganisms utilizing oxygen to break down organic matter into inorganic substances is maximal [6]. According to [32], organic matter accumulated in a bottom layer requires oxygen to break down the organic materials. Low DO values caused by the decomposition of organic materials hinders the biogeochemical cycle and reduces fertility levels [20].

Low salinity and relatively high temperature influence the concentrations of nutrients in water bodies. According to [33], the nutrient concentration will increase if the salinity value is low. Temperature conditions control efficient C and N utilization that may play a key role in photoinhibition, which is known to affect the rate of algal growth [34]. In the current study, total suspended solids (TSS) ranged from 12 to 24 mg/L. TSS disrupt the penetration of light into water bodies, resulting in reduced utilization of nutrients by autotroph biota for photosynthesis. As a result, the nutrients are enriched in the water [6].

N:P ratios in the Keunekai waters. Figure 5 illustrates the relatively high ratios of DIN and DIP and reflects the high rate of nutrient input from the mainland [35]. Anthropogenic activities cause imbalances in N:P ratios. The higher the N:P ratio, the greater the nitrogen intake from land sources, which results in an imbalanced concentration of P, N, and their derivatives.

The N:P ratios were high at stations P1 and P2, and extremely high at station P5. In addition, the concentration of phosphate at these stations was lower than at the other stations, resulting in a greater predominance of nitrate. This indicated a high N concentration and an extremely low P concentration at those stations. However, the lower N:P ratios indicated that there were large supplies of P-nutrients in the Keunekai waters, which resulted in the lower comparison values of N:P. These ratios indicate a risk of nutrient-enhanced algal bloom [36], mainly supported by the high availability of nitrate and phosphate. The relatively high P loading was possibly sourced from husbandry wastes and the high utilization of detergent.

Individual phytoplankton domination in the Keunekai waters. Three taxa of phytoplankton were identified in the study area: Bacillariophyceae (diatom) (72%), Cyanophyceae (3%), and Dinoflagellate (25%). The percentages were calculated from the number of total individuals identified (Table 3). Diatom was the most abundant class, with *Leptocylindrus sp*., *Rhizosolenia sp*., and *Triceratium sp*. the dominant genera growing in that habitat. The peak abundances of diatoms coincide with high DIN values, while the variation in nutrient requirement and utilization by phytoplankton manages the tendency for algae blooms in the waters [37].

Dinoflagellate was identified at stations P3, P4, P6, P10, P11, and P12, and was the most abundant class observed at station P10 (1830 cell/m^3). The genera mostly identified were *Prorocentrum sp.* (1900 cell/m^3). *Prorocentrum* is an epiphytic dinoflagellate, which has a high adaptation level and a vast distribution, usually being found in rubble, macroalgae, and sediment [38]. The abundance of dinoflagellate observed in the study area is probably the result of the mass of dead coral rubble in the Keunekai waters. The existence of epiphytic dinoflagellate endangers marine biota, and in the food chain, it can produce toxins that accumulate in the bodies of fish, inducing ciguatera fish poisoning [39].

The genera of the phytoplankton found in this study were possibly limited by the N:P ratios, even though physical factors such as temperature and salinity play a role in controlling their abundance in water bodies. The total abundance of phytoplankton in this study ranged from 1780 to 3580 cell/m3. The highest abundance was identified at station P10, where the N:P ratio was the lowest (N:P < 10). This proves that P availability signi ficantly influences the limiting of phytoplankton growth,

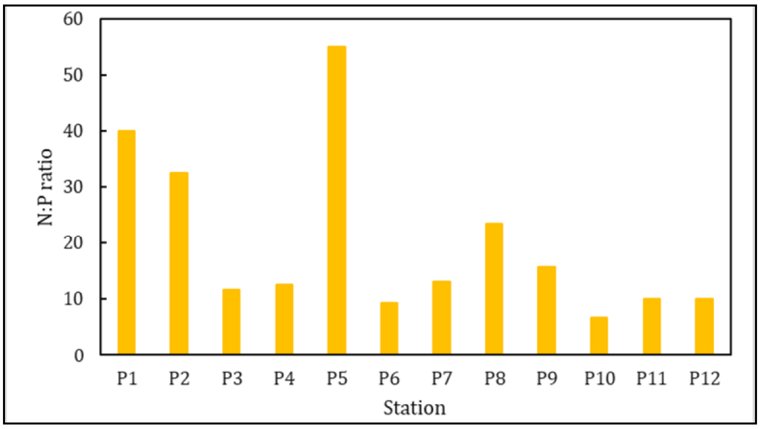

Figure 5. Comparison Between Total Dissolved Nitrogen (N) and Dissolved Inorganic Phosphate (P) Ratios in Keunekai Waters

Table 3. Phytoplankton Individual Domination in the Keunekai Waters

Phytoplankton	Phytoplankton abundance (cells/m^3)											
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Bacillariophyceae												
Actinocyclus sp.								230				
Cerataulina sp.						160		130				
Chaetoceros sp.					180							
Cocconeis sp.									150			
Coscinodiscus sp.			340	170	410	370	1070	600	170	150	150	310
Fragilaria sp.	140	100							130			
Leptocylindrus sp.	550	590	430	410	450	450	330	420	420	470	480	560
Navicula sp.		190								310		
Nitzschia sp.	420	560	330		460	190			250		190	
Rhizosolenia sp.	440	840	540	620	480	280	260	180	660	320	370	540
Thalassiora sp.	480		120	140				240		370	160	
Triceratium sp.	150	100	330	220	170	300	520	320	460		130	420
Cyanophyceae												
Pelagothrix sp.	130		150	200	100	140				130	180	180
Dinoflagellate												
Amphidium sp.			350			200				400	450	200
Ostreopsis sp.				390		350				410		
Prorocentrum sp.			300			460				570	380	250
Sinophys sp.				250		150				450	240	
Thecadinium sp.			150	170							230	310
Total cell/m^3	2310	2380	3040	3030	2050	2990	2180	2120	2240	3580	3060	2780
Total genera	7	6	10	9	7	11	4	7	7	10	11	8

while the lowest abundance was identified in station P5, where the N:P ratio was < 40. According to [40], if the critical N:P supply ratio simulating phytoplankton growth is unstable, it will decrease with increasing growth rate, reflecting systematic changes in cellular composition between nutrient depleted and replete cells.

At station P10, where the N:P ratio was low, the concentration of N and P was generally high, resulting in maximized phytoplankton growth and populations, where epiphytic dinoflagellates were predominant. In water bodies, nutrients are required by autotroph biota (phytoplankton) to conduct photosynthesis to change inorganic nutrients into organic substances, to be used by both itself and the other heterotroph biota. Phytoplankton production essentially reflects the supply of resources into an ecosystem, and the dinoflagellates identified in this study are indicative of moderate to high nutrient levels [41].

Limitation of N and P and its influence on the abundance of phytoplankton. Figure 6 shows that the N:P ratio clearly discriminated between the N- and P-limited sites. For an N:P ratio > 16, the phytoplankton community is P-limited, while for an N:P ratio < 16, N limits the abundance of phytoplankton. For N:P ratios equal to16, either N or P may limit phytoplankton productivity or both elements are equally limiting (co-limitation) [42].

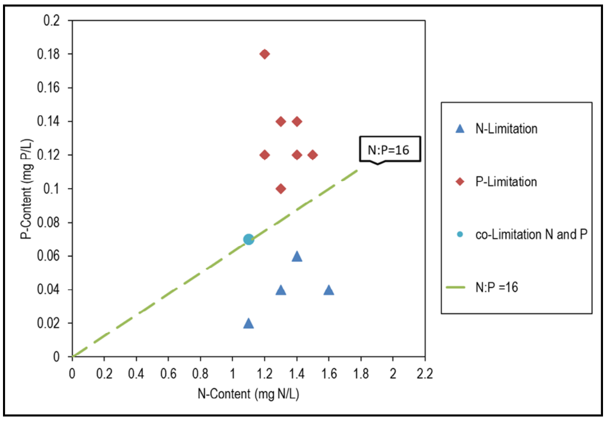

Figure 6. Relationship between N and P Content and the Nature of Nutrient Limitation in Keunekai Waters

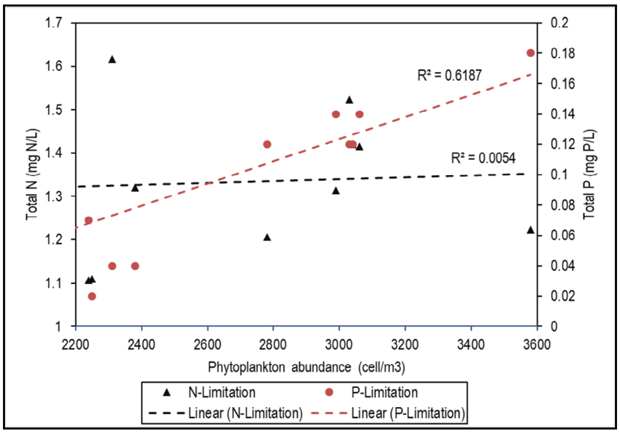

Figure 7. Relationship between the Abundance of Surface Phytoplankton and the Nutrient Content of Keunekai Water

One station, P9, had an N:P ratio equal to 16 which is the N- and P-limited site. According to [43], N will control the growth of autotroph biota if the N:P ratio is 20. The large variation in N content (ranging from 1.1 to 1.6 mg N/L) and, particularly, P content (ranging from 0.02 to 0.18 mg P/L) most likely reflected differences in the supply ratios of N and P, rather than differences in absolute N and P availability. In Keunekai waters, the P-limitation is mostly the dependent parameter controlling the N:P ratio.

Figure 7 shows that the N and P contents of the Keunekai waters were mainly determined by the supply ratios of N:P. A high N content reflects situations in which more N is available relative to P; in such situations, the total N is not necessarily high. The total N and P availability probably mainly affects phytoplankton production. This indicates whether N or P has a special limitation on phytoplankton growth. N and P, together with other nutrients (carbon and silicate) in water bodies, may play a role in controlling the abundance of phytoplankton [44].

As shown in Figure 7, the linear regression calculated from the data with higher phytoplankton density along with increasing P, P-limitation predominantly influenced the abundance of phytoplankton. In this case, phytoplankton abundance was the dependent variable, while the N and P concentrations were independent variables. The R-square value reached 0.62 for P and 0.005 for N. These values demonstrate that the ability of the independent variable (N and P concentrations) to explain the dependent variable (phytoplankton abundance) was 62% for P and 0.5% for N. A 37.5% variance of the dependent variable was explained by other factors. Previous [45] studies have proved that the high productivity of P leads to a high bacterial population and high respiration rates, which led to hypoxia and anoxia. The release of P reinforces eutrophication: the excessive value of P is the most common cause of eutrophication in the water [46]. It was clear that P became the limiting factor in Keunekai waters, but N also has a special role in triggering eutrophication; therefore, both N and P control should be considered in the eutrophication management of water bodies [47].

Conclusion

The N:P ratios fluctuated at all the observation stations. Nutrient supply plays a role in managing N:P ratios in water bodies, resulting in the risk of nutrient-enhanced algal blooms. The large variation in N content (ranging from 1.1 to 1.6 mg N/L) and, particularly, P content (ranging from 0.02 to 0.18 mg P/L) most likely reflected differences in the supply ratio of N and P, rather than differences in absolute N and P availability. In the Keunekai waters, the P-limitation mostly controlled the potential for algae blooms by supporting the density of dinoflagellates, which can reduce the water quality. The lower the N:P value, the greater the abundance of phytoplankton, and vice versa. There is a significant correlation between nutrient and phytoplankton abundance, therefore it is possible that the linear regression of any variable between nutrients and phytoplankton abundance would be contaminated to some degree by this correlation.

In this study, either the N or P especially limited phytoplankton growth. The peak abundances of diatoms coincided with the high DIN values, while variations in the nutrient requirements and nutrient utilization of phytoplankton manage the tendency of algae blooms in these waters. A relatively high abundance of epiphytic dinoflagellates (> 0.01 cells/m3) indicated that the Keunekai waters are potentially moving toward a toxic condition at several stations. It is essential that the conditions of the Keunekai water are monitored to support potential marine tourism and aquaculture.

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References

[1] Nawawiy, M., Faisal. P.I., Chairani, R. 2018. Proceedings of the 2nd International Conference on Social and Political Development (ICOSOP 2017), Atlantis Press, https://doi.org/10.2991/icosop-17.2018.88.

[2] Hastuty, R., Adrianto, L. 2014. Coral cover and composition of reef fishes inside and Outside of marine protected areas, eastern coast of weh Island, Sabang. DEPIK Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan, 3(2): 99-107, https://doi.org/10.13170/depik.3.2.1468.

[3] Xu, H., Paerl, H.W., Qin, B., Zhu, G., Gaoa, G. 2010. Nitrogen and phosphorus inputs control phytoplankton growth in eutrophic Lake Taihu, China. Limnol. Oceanogr. 55(1): 420-432, https://doi.org/10.4319/lo.2010.55.1.0420.

[4] Keeney, D., Olson, R.A. 1986. Sources of nitrate to ground water. Crit. Rev. Environ. Sci. Technol. 16(3): 257-304, https://doi.org/10.1080/10643388609381748.

[5] Ge, S., Peng, Y., Qiu, S., Zhu, A., Ren, N. 2014. Complete nitrogen removal from municipal wastewater via partial nitrification by appropriately alternating anoxic/aerobic conditions in a continuous plug-flow step feed process. water res. 55: 95-105, https://doi.org/10.1016/j.watres.2014.01.058.

[6] Wisha, U.J., Maslukah, L. 2017. Nutrient condition of kampar big river estuary: Distribution of N and P concentrations drifted by Tidal Bore" Bono". Indonesian J. Mari. Sci. 22(3): 37-45, https://doi.org/10.14710/ik.ijms.22.3.137-146.

[7] Li, Y., Cao, W., Su, C. Hong, H. 2011. Nutrient sources and composition of recent algal blooms and eutrophication in the northern jiulong river, Southeast China. Mar. Pollut. Bull. 63(5): 249-254, https://doi.org/10.1016/j.marpolbul.2011.02.021.

[8] Dzialowski, A.R., Dzialowski, W., Shih-Hsien, L., Niang-Choo, J.H. Huggins, D.G. 2008. Effects of sediment resuspension on nutrient concentrations and algal biomass in reservoir of the Central Plains. Lake Reserv. Manag. 24: 313-320, https://doi.org/10.1080/07438140809354841.

[9] De Jonge, V.N., Elliott, M., Orive, E. 2002. Causes, historical development, effects and future challenges of a common environmental problem: eutrophication. Hydrobiologia. 475: 1–19, https://doi.org/10.1007/978-94-017-2464-7_1.

[10] Khaliq, A., Abbasi, M.K., Hussain, T. 2006. Effects of integrated use of organic and inorganic nutrient sources with effective microorganisms (EM) on seed cotton yield in Pakistan. Bioresour. Technol. 97(8): 967-972, https://doi.org/10.1016/j.biortech.2005.05.002.

[11] Agustina, S., Musman, M., Ishaq, M. 2017. Status of the Chlorophyll-a in the Pria Laot Bay Sabang, Aceh Province. DEPIK Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan. 6(3): 182-187, https://doi.org/10.13170/depik.6.3.8364.

[12] Matsumoto, K., Takanezawa, T., Ooe, M. 2000. Ocean tide models developed by assimilating TOPEX/POSEIDON altimeter data into hydrodynamical model: A global model and a regional model around Japan. J. Oceanogr. 56(5): 567-581, https://doi.org/10.1023/A:1011157212596.

[13] Henson, S.A., Sanders, R., Holeton, C., Allen, J.T. 2006. Timing of nutrient depletion, diatom dominance and a lower-boundary estimate of export production for Irminger Basin, North Atlantic. Mar. Ecol.-Prog. Ser. 313: 73-84, https://doi.org/10.3354/ meps313073.

[14] Butler, E.I. (1984). A manual of chemical and biological methods for sea water analysis. Deep Sea Research Part A. Oceanogr. Res. Pap. 31(12): 1523, https://doi.org/10.1016/0198-0149(84)90086-4.

[15] Utami, T.M.R., Maslukah, L., Yusuf, M. 2016. Nitrate (NO_3) and phosphate (PO_4) Distribution in Karangsong waters, Indramayu Regency. Buletin Oseanografi Mar. 5(1): 31, https://doi.org/10.14710/buloma.v5i1.11293.

[16] Sachlan, M. 1982. Planktonology Faculty of Husbandry and Fisheries, Diponegoro University, Semarang, Indonesia, p. 141

[17] Yamaji, I. E. 1996. Illustration of the Marine Plankton of Japan. Hoikusha Publishing Co., Ltd. Osaka. Japan. p. 987

[18] Castellani, C., Edwards, M. 2017. Marine Plankton. Oxford Scholarship Online, Oxford Universty, https://doi.org/10.1093/oso/9780199233267.001.0001.

[19] American Public Health Association. 1989. Standard Methods for the Examination of Water and Waste Water Including Bottom Sediment and Sludges. 17th ed. Amer. Publ. Health Association Inc., New York. pp. 1527, https://doi.org/10.2105/ajph.56.3.387.

[20] Feaster, T.D., Conrads, P., Guimaraes, W.B., Sanders Jr, C.L., Bales, J.D. 2003. Simulation of Temperature, Nutrients, Biochemical Oxygen Demand, and Dissolved Oxygen in the Catawba River, South Carolina, 1996-97 (No. 2003-4092), https://doi.org/10.3133/wri034092.

[21] Saito, T., Brdjanovic, D., Van Loosdrecht, M.C.M. 2004. Effect of nitrite on phosphate uptake by phosphate accumulating organisms. Water Res.

38(17): 3760-3768, https://doi.org/10.1016/j.watres.2004.05.023.

[22] Sharma, S.B., Sayyed, R.Z., Trivedi, M.H., Gobi, T.A. 2013. Phosphate solubilizing microbes: sustainable approach for managing phosphorus deficiency in agricultural soils. SpringerPlus. 2(1): 587, https://doi.org/10.1186/2193-1801-2-587.

[23] Voegelin, A., Senn, A.C., Kaegi, R., Hug, S.J., Mangold, S. 2013. Dynamic Fe-precipitate formation induced by Fe (II) oxidation in aerated phosphate-containing water. Geochim. Cosmochim. Acta. 117: 216-231, https://doi.org/10.1016/j.gca.2013.04.022.

[24] Albertsen, A.N., Duffy, C.D., Sutherland, J.D., Monnard, P.A. 2014. Self-assembly of phosphate amphiphiles in mixtures of prebiotically plausible surfactants. Astrobiology. 14(6): 462-472, https://doi.org/10.1089/ast.2013.1111.

[25] Hoffman, B.M., Lukoyanov, D., Yang, Z.Y., Dean, D.R., Seefeldt, L.C. 2014. Mechanism of nitrogen fixation by nitrogenase: the next stage. Chem. Rev. 114(8): 4041-4062, https://doi.org/10.1021/cr400641x.

[26] Li, Q., Wang, X.C., Zhang, H.H., Shi, H.L., Hu, T., Ngo, H.H. 2013. Characteristics of nitrogen transformation and microbial community in an aerobic composting reactor under two typical temperatures. Bioresour. Technol. 137: 270-277, https://doi.org/10.1016/j.biortech.2013.03.092.

[27] Glibert, P.M., Wilkerson, F.P., Dugdale, R.C., Raven, J.A., Dupont, C.L., Leavitt, P.R., Kana, T.M. 2016. Pluses and minuses of ammonium and nitrate uptake and assimilation by phytoplankton and implications for productivity and community composition, with emphasis on nitrogen-enriched conditions. Limnol. Oceanogr. 61(1): 165-197, https://doi.org/10.1002/lno.10203.

[28] Gorman, D., Turra, A., Connolly, R.M., Olds, A. D., Schlacher, T.A. 2017. Monitoring nitrogen pollution in seasonally-pulsed coastal waters requires judicious choice of indicator species. Mar. Pollut. Bull. 122(1-2): 149-155, https://doi.org/10.1016/j.marpolbul.2017.06.042.

[29] Judson, R., Houck, K., Martin, M., Knudsen, T., Thomas, R.S., Sipes, N., Shah, I., Wambaugh, J., Crofton, K. 2014. In vitro and modelling approaches to risk assessment from the US Environmental Protection Agency ToxCast programme. Basic clin. Pharmacol. Toxicol. 115(1): 69-76, https://doi.org/10.1111/bcpt.12239.

[30] Njoku, O.E., Agwa, O.K., Ibiene, A.A. 2015. An investigation of the microbiological and physicochemical profile of some fish pond water within the Niger Delta region of Nigeria. Afr. J. food Sci. 9(3): 155-162, https://doi.org/10.5897/AJFS2014.1208.

[31] Ke, X., Bao, Q., Qi, Y., Huang, X., Zhang, H. 2018. Toxicity assessment of sediments from the Liaohe River Protected Area (China) under the influence of ammonia nitrogen, heavy metals and organic contaminants. Environ. Toxicol. Pharm. 59: 34-42, https://doi.org/10.1016/j.etap.2018.02.008.

[32] Young, R.G., Matthaei, C.D. Townsend, C.R. 2008. Organic matter breakdown and ecosystem metabolism: functional indicators for assessing river ecosystem health. J. N. Am. Benthol. Soc. 27(3): 605-625, https://doi.org/10.1899/07-121.1.

[33] Scuderi, D., Restuccia, C., Chisari, M., Barbagallo, R.N., Caggia, C., Giuffrida, F. 2001. Salinity of nutrient solution influences the shelf-life of fresh-cut lettuce grown in floating system. Postharvest Biol. Technol. 59(2): 132-137, https://doi.org/10.1016/j.postharvbio.2010.08.016.

[34] Juneja, A., Ceballos, R.M., Murthy, G.S. 2013. Effects of environmental factors and nutrient availability on the biochemical composition of algae for biofuels production: a review. Energies. 6(9): 4607-4638, http://dx.doi.org/10.3390/en6094607.

[35] Mukhopadhyay, S.K., Biswas, H., De, T.K. Jana, T.K. 2006. Fluxes of nutrients from the tropical River Hooghly at the land-ocean boundary of Sundarbans, NE coast of Bay of Bengal, India. J. Mar. Syst. 62: 9-21, https://doi.org/10.1016/j.jmarsys. 2006.03.004.

[36] Chen, N., Peng, B., Hong, H., Turyaheebwa, N., Cui, S., Mo, X. 2013. Nutrient enrichment and N: P ratio decline in a coastal bay–river system in southeast China: the need for a dual nutrient (N and P) management strategy. Ocean Coastal Manage. 81: 7-13, https://doi.org/10.1016/j.ocecoaman.2012.07.013.

[37] Wang, Z., Qi, Y., Chen, J., Xu, N., Yang, Y. 2006. Phytoplankton abundance, community structure and nutrients in cultural areas of Daya Bay, South China Sea. J. Mar. Syst. 62(1-2): 85-94, https://doi.org/10.1016/j.jmarsys.2006.04.008.

[38] Camacho, F.G., Rodríguez, J.G., Mirón, A.S., García, M.C., Belarbi, E.H., Chisti, Y., Grima, E.M. 2007. Biotechnological significance of toxic marine dinoflagellates. Biotechnol. Adv. 25(2): 176-194, https://doi.org/10.1016/j.biotechadv.2006.11.008.

[39] Widiarti, R., Pudjiarto, R.K., Fathonah, I., Adi, A.P.W. 2016. Proceeding national seminar on Masyarakat Biodiversitas Indonesia, pp: 97-102, https://doi.org/10.13057/psnmbi/m020119.

[40] Ptacnik, R., Andersen, T., Tamminen, T. 2010. Performance of the Redfield ratio and a family of nutrient limitation indicators as thresholds for phytoplankton N vs. P limitation. Ecosystems. 13(8): 1201-1214, https://doi.org/10.1007/s10021-010-9380-z.

[41] Effendi, H., Kawaroe, M., Lestari, D.F., Permadi, T. 2016. Distribution of phytoplankton diversity and abundance in Mahakam Delta, East Kalimantan. Procedia Environ. Sci 33: 496-504, https://doi.org/10.1016/j.proenv.2016.03.102.

[42] Tessier, J.T., Raynal, D.J. 2003. Use of nitrogen to phosphorus ratios in plant tissue as an indicator of nutrient limitation and nitrogen saturation. J. Appl. Ecol. 40(3): 523-534, https://doi.org/10.1046/j.1365-2664.2003.00820.x.

[43] Koerselman, W., Meuleman, A.F. 1996. The vegetation N: P ratio: a new tool to detect the nature of nutrient limitation. J. Appl. Ecol. 33(6): 1441-1450, https://doi.org/10.2307/2404783.

[44] Mutshinda, C.M., Finkel, Z.V., Irwin, A.J. 2013. Which environmental factors control phytoplankton populations? A Bayesian variable selection approach. Ecol. Model. 269: 1-8, https://doi.org/10.1016/j.ecolmodel.2013.07.025.

[45] Correll, D.L. 1998. The role of phosphorus in the eutrophication of receiving waters: a review. J. Environ. Qual. 27(2): 261-266, https://doi.org/10.2134/jeq1998.00472425002700020004x.

[46] Zhang, W., Jin, X., Liu, D., Lang, C., Shan, B. 2017. Temporal and spatial variation of nitrogen and phosphorus and eutrophication assessment for a typical arid river—Fuyang River in northern China. J. Environ. Sci. 55: 41-48, https://doi.org/10.1016/j.jes.2016.07.004.

[47] Dodds, W.K., Smith, V.H. 2016. Nitrogen, phosphorus, and eutrophication in streams. Inland Waters. 6(2): 155-164, https://doi.org/10.5268/iw-6.2.909.