Journal of Natural Resources and Environmental Management
http://dx.doi.org/10.29244/jpsl.14.4.855

RESEARCH ARTICLE

OPEN ACCESS

Check for updates

Pollution and the Abundance of Plankton in Rangkui Watershed on Bangka Island

Thoibatun Nashriah[a], Eddy Nurtjahya[a], Lukman Lukman[b]

[a] Department of Biology, Universitas Bangka Belitung, Bangka, 33172, Indonesia
[b] Research Center for Conservation of Marine and Inland Water Resources, National Research, and Innovation Agency (BRIN), Bogor, 16911, Indonesia

Article History
Received 12 July 2023
Revised 09 May 2024
Accepted 04 July 2024

Keywords
abundance, diversity, plankton, pollution, Rangkui Watershed

ABSTRACT

Land use and activity around the Rangkui Watershed affect water quality, and plankton have been studied to help manage the river's water quality. In the 2017 dry season, six station points representing land use functions from upstream to downstream were studied. Surface water sampling was carried out during the day with three replicates. Pollution around the Rangkui Watershed affected plankton abundance. Based on saprobity and physicochemical readings, the pollution level ranged from light upstream to heavy downstream. This study found 15 species from 15 families from six phytoplankton classes, that is, Bacillariophyceae, Chlorophyceae, Euglenophyceae, Cyanophyceae, Cryptophyceae, Dinophyceae, and 2 species of zooplankton Eurotatoria, and Branchiopoda. The highest total abundance of phytoplankton and zooplankton was observed upstream of Station 1 (721 ind/L) and gradually decreased downstream, with the exception of the absence of plankton at Station 3. Nitrate had a positive correlation with phytoplankton at different correlation levels, whereas other abiotic environments responded differently to phytoplankton and zooplankton. The water quality is highest upstream, where there are pepper plantations, and gradually decreases as it flows downstream. The station near tin mining activities was the most polluted.

Introduction

Rivers, as water bodies and distributors of water from upstream areas, play an important role in the hydrological cycle [1], and are particularly vulnerable to land use change [2], and other anthropogenic activities. Rangkui river, which is in the 6,147 ha Rangkui watershed [3], has a length of more than 9.7 km, a width of about 30 m, and a depth of 2 to 4 m [4]. The watershed has springs on several hills such as *Bukit Kemiri* (99.2 m), and *Bukit Kelowang* (46.9 m), around Pangkalpinang City, Bangka Regency, and Central Bangka Regency. The Rangkui Watershed has an important meaning for the people of Pangkalpinang City as a source of raw water for household needs, water storage, and transportation facilities to the Baturusa River, which then flows into the sea. Due to human activities along the river, the situation in the Rangkui Watershed has been much different. The flood discharge from 2011 to 2020 increased by 6.6% to 341.8 m^3/s, primarily owing to an increase in settlement (8.3%) and agricultural area (100%) [3]. The river water that was originally clear turned brown, and the biota that lived in it decreased [5].

Upstream of the Rangkui Watershed are illegal mining activities and pepper plantations. The middle and downstream areas included residential areas, offices, and markets. A significant number of fecal coliforms were present downstream (stations 4, 5, and 6), which had an amount of 11,000 MPN/100 ml, and downstream in the Rangkui River, was among the limiting parameters, confirming that the area had poor water quality conditions [6]. From the other study in 2019 [6], the water along the watershed could be classified from Class I to Class IV according to Indonesia Government Regulation No. 82 year 2001 [7]. In an

Corresponding Author: Eddy Nurtjahya eddy_nurtjahya@yahoo.com Department of Biology, Universitas Bangka Belitung, Bangka, Indonesia.

earlier study in 2013 [8], the total number of plankton at stations 4 and 5 was 18 species, 16 families, four phytoplankton classes, and four species of three zooplankton classes. Changes in land use and various human activities along the river flow affect river water quality, and plankton could be a viable tool for monitoring water bodies because it is inexpensive and easy to collect [9].

Phytoplankton is a nutritional resource that increases the composition and diversity of fisheries in mangrove estuaries [10]. Plankton is a bioindicator of water quality [9,11], and environmental conditions [12], including organic pollutants in rivers [13]. The phytoplankton species *Melosira* and *Leptocylindrus* (Bacillariophyceae) and zooplankton (*Aphelenchoides*) are tolerant to sulfur pollution in water sources [14]. Efforts to restore and manage the water quality of the Rangkui Watershed can be initiated by evaluating the diversity and abundance of plankton along the watershed from upstream to downstream.

Materials and Methods

Field Experimental Sites

The Rangkui watershed basin covers the Bangka Regency and Central Bangka Regency, and flows into Pangkalpinang City. Six station points were selected to represent the influence of land use change on river water quality, from upstream to downstream. The six points and their elevation are Station 1 (74.79 m)–upstream located in Pangkalan Baru District with Regional Water Utility Company activities, pepper plantations, and vegetation (2°13.109'S, 106°06.372'E); Station 2 (41.97 m)–located in Pangkalan Baru District, pepper and pineapple plantation area (2°12.473'S, 106°06.047'E); Station 3 (17.94 m)–located in Pangkalan Baru District, tin mining area, fast current (2°10.994'S, 106°05.280'E); Station 4 (3.2 m)–located in Rangkui District, residential and office area (2°07.729'S, 106°06.711'E); Station 5 (3.49 m)–located at in Taman Sari Subdistrict, the market waste area and fishermen pier (2°07.577'S, 106°07.023'E), and Station 6 (–0.05 m)–located in Pangkalbalam Subdistrict, connecting with the Baturusa River, many plants on the riverside (2°05.978'S, 106°08.344'E) (Figure 1). This study was conducted during the 2017 dry season. Plankton identification was performed at the Plankton Laboratory of National Research and Innovation Agency Limnology Research Center. The physicochemical properties of the water were measured in situ at the Universitas Bangka Belitung, Mathematics and Science Laboratory and Provincial Environmental Agency Laboratory. Six sampling station points (Figure 1) were determined using the purposive sampling method, based on differences in activity and input load along the river. Sampling was performed in 3 replicates at each station.

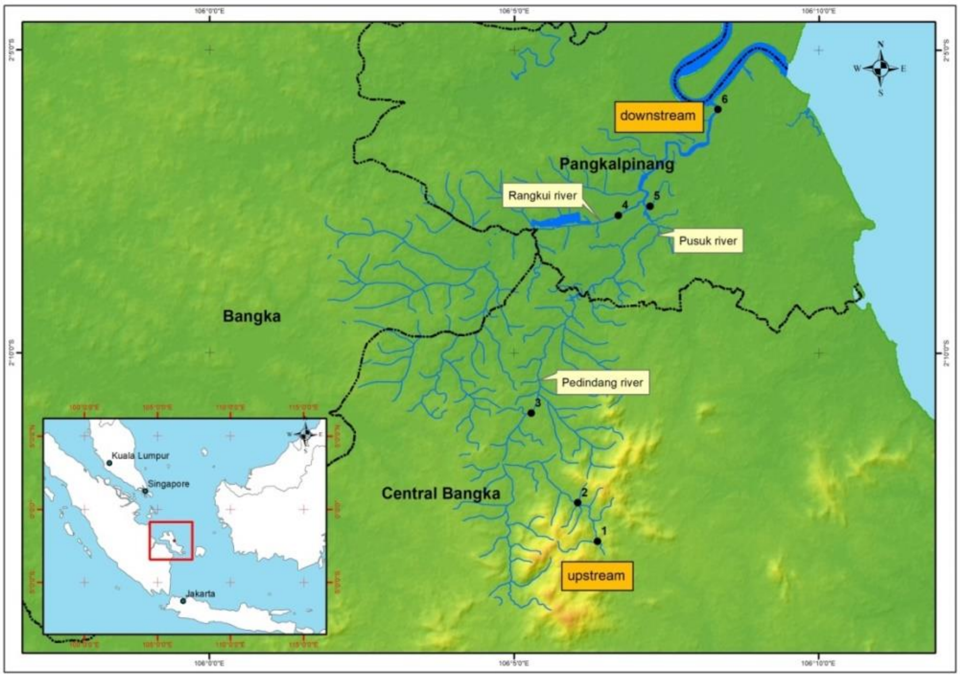

Figure 1. Research stations and elevation: 1. upstream of pepper plantations (74.79 m); 2. pepper and pineapple plantations (41.97 m); 3. tin mining area (17.94 m); 4. settlements and offices (3.2 m); 5. market garbage area and fishermen piers (3.49 m); 6. Mouth to the Baturusa River (–0.05 m).

Measurement of Microclimate and Water Physical and Chemical Properties

Measurements of air temperature, air humidity, current velocity, water temperature, dissolved oxygen, salinity, and pH were carried out simultaneously with water sampling for plankton, namely, during the day at 10.30 to 12.00 AM in situ. Turbidity, total suspended solids, biological oxygen demand, and chemical oxygen demand were measured at the Universitas Bangka Belitung Laboratory, and the concentrations of nitrate and phosphate were measured in the Provincial Environmental Agency laboratory. The surface water sampling method was based on *Standar Nasional Indonesia* (SNI) [15]. Water quality is classified into four classes based on Government Regulation Number 82 in 2001 [7]: first-class water for raw drinking water, second-class water recreation infrastructure or facilities, third-class water for freshwater fish farming, and fourth-class water for irrigating plantations.

Plankton Collection

Plankton sampling was conducted during the day at 10.30 to 12.00 AM, which is the optimum time for plankton to conduct photosynthesis [16]. Sampling was performed three times. Plankton sampling was performed by filtering up to 5 L of surface water from each station using a plankton net with a mesh size of 45. Plankton samples were preserved in Lugol's iodine solution, 4% formalin, and labeled [17].

Plankton Identification

The preserved plankton samples were homogenized and one drop was dripped onto the glass of the object and covered with a glass cover. The samples were observed under an Optilab binocular microscope. The plankton types were identified and used as bioindicators in freshwater algae [18].

Data Analysis

The data obtained were analyzed descriptively, presented in tables, and analyzed using several indices for species structure in communities. The abundance of plankton was expressed as individuals per liter. Individual abundance was determined using the Lackey drop micro-transect counting method from Bridgewater et al. [19]. The diversity index was calculated using the Shannon-Weiner equation [20]. The evenness index was used to determine the spread of individuals within a community [19]. The Dominance Index by Simpson is used to determine whether a certain type dominates the population type. The Saprobic Index is used to determine the dominant group of organisms and level of pollution [21]. The saprobic coefficient's relationship with pollution level is shown in Awaludin et al.'s table [22]. Pearson correlation analysis was used to determine the correlation between environmental factors and plankton abundance, and a dendrogram showed clustering of locations. All analyses were performed using PAST 4.03 Software.

Results and Discussion

Water Quality

The results of the average measurement of the physicochemical properties of water at each observation station are displayed (Figure 2 a–j). The best water quality that meets the class I water quality standards is Station 1, followed by Station 2. Station 3 was the worst because the turbidity value was the highest (408 NTU), DO was the smallest DO (2.91 mg/L), and pH was acidic (5.51), whereas the pH of the other five stations was above 6.45 to 6.71. Stations 5 and 6 are considered poor because of the high turbidity of 86 NTU and 88 NTU, respectively, the DOs are low which is 3.0 mg/L each, the BOD is more than 3.0 mg/L each, the salinity of Station 5 is 2.5 ppt, and Station 6 is the highest (12).

The pollution level at each station varied from light to heavy (Figure 3). The saprobic coefficient at Station 1 was 0.71, or the mild category and decreased at Station 2 (0.14), or the medium category, and Station 4 (–1), or the moderately polluted category, temporarily could not be calculated at Station 3, and stations 5 and 6 each 0. Station 1 saprobic index value of 0.71 belongs to the slightly polluted β-mesosaprobic saprobic phase. The β-mesosaprobic category has high dissolved oxygen (DO), low bacterial count, and ammonia (NH_3), which produces the final product nitrate (NO_3^-). Stations 2, 5, and 6, with saprobic index values of 0.14, 0, and 0, respectively, are moderately polluted with the saprobic β/α-mesosaprobic phase. The β/α-mesosaprobic phase shows a change in conditions in a better direction from the α-phase, which tends to be in bad condition, towards β, which tends to be in good condition. Station 4 has a saprobic index value of –1 and is classified as heavily polluted with the α-mesosaprobic saprobic phase, which is suspected to be influenced by the input of household waste.

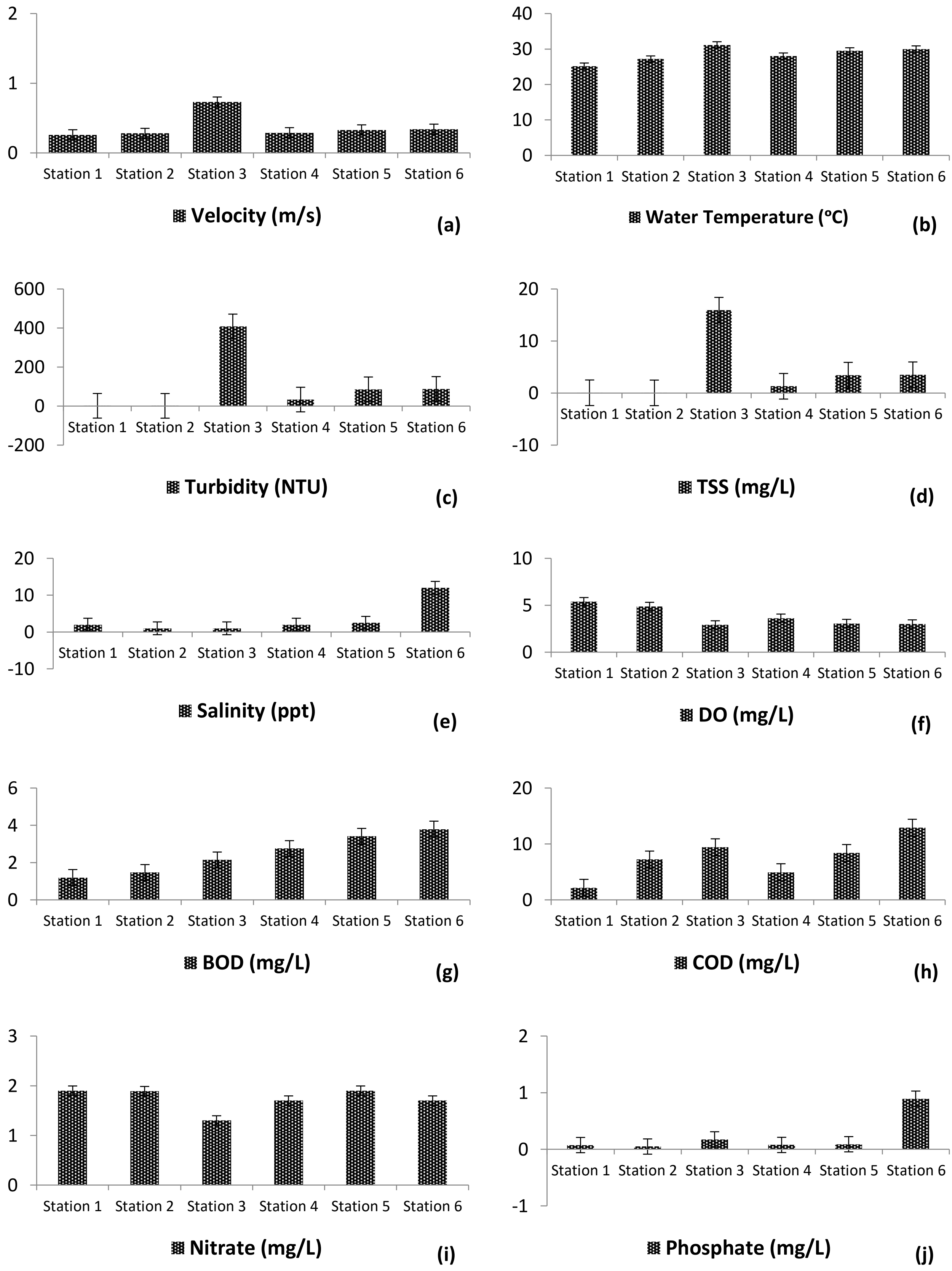

Figure 2. Physical and chemical at six stations from upstream to downstream of the Rangkui Watershed water velocity (a), water temperature (b), turbidity (c), total suspended solid (d), salinity (e), DO (f), BOD (g), COD (h), nitrate (i), phosphate (j).

Discharging treated and untreated wastewater into coastal ecosystems can result in the release of contaminants, pathogens, and nutrients, leading to eutrophication [23]. A study found that the waters of Lake Rawapening were moderately polluted, with a saprobic coefficient of 1.14 [24], owing to discharges of organic and inorganic waste from settlements, restaurants, and markets. The Rangkui Watershed is affected by pollution from palm oil and pepper plantations upstream and household waste downstream, as previously reported [4]. According to previous research in the same river, the concentration of coliform bacteria believed to have originated from *Escherichia* upstream was significantly lower (530–940 MPN/100 ml) than that downstream of the Rangkui River (approximately 11,000 MPN/100 ml) [6]. This suggests that the level of contamination in the downstream region is much higher than that in the upstream region.

Plankton Composition and Abundance

Based on the results of plankton identification in the Rangkui Watershed, 15 species were found, 15 families belonging to six phytoplankton classes, namely Bacillariophyceae, Chlorophyceae, Euglenophyceae, Cyanophyceae, Cryptophyceae, and Dinophyceae, and two species from two classes, 2 families namely Eurotatoria and Branchiopoda. The 15 identified phytoplankton species were *Aulacoseira* sp., *Chaetoceros* sp., *Pleurosigma* sp., *and Skeletonema* sp. (Bacillariophyceae); *Dictyosphaerium* sp., *Eaustrum* sp. and *Scenedesmus* sp. (Chlorophyceae); *Euglena* sp., *Phacus* sp., *Synura* sp. (Euglenophyceae); *Anabaena* sp., *Merismopedia* sp., *Oscillatoria* sp. (Cyanophyceae); *Rhodomonas* sp. (Cryptophyceae); and *Ceratium* sp. (Dinophyceae); 2 zooplankton species are *Keratella* sp. (Branchionidae) and *Daphnia* sp. (Daphniidae) (Table 1).

Table 1. Diversity of plankton at six stations from upstream to downstream in the Rangkui Watershed.

Class	Family	Species	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Phytoplankton								
Bacillariophyceae	Aulacoseiraceae	*Aulacoseira* sp.	✓	-	-	-	-	-
	Chaetocerotaceae	*Chaetoceros* sp.	-	✓	-	-	-	-
	Pleurosigmataceae	*Pleurosigma* sp.	✓	✓	-	-	-	-
	Skeletonemaceae	*Skeletonema* sp.	✓	✓	-	✓	✓	✓
Chlorophyceae	Chlorellaceae	*Dictyosphaerium* sp.	-	✓	-	-	-	-
	Desmidiaceae	*Eaustrum* sp.	✓	-	-	-	-	-
	Scenedesmaceae	*Scenedesmus* sp.	✓	-	-	-	-	-
Euglenophyceae	Euglenaceae	*Euglena* sp.	✓	-	-	-	-	-
	Phacaceae	*Phacus* sp.	✓	-	-	✓	-	-
	Synuraceae	*Synura* sp.	✓	-	-	-	✓	-
Cyanophyceae	Merismopediaceae	*Merismopedia* sp.	-	✓	-	-	-	-
	Nostocaceae	*Anabaena* sp.	✓	-	-	✓	-	-
	Oscillatoriaceae	*Oscillatoria* sp.	✓	✓	-	✓	✓	✓
Cryptophyceae	Pyrenomonadaceae	*Rhodomonas* sp.	-	✓	-	-	-	-
Dinophyceae	Ceratiaceae	*Ceratium* sp.	-	✓	-	-	-	✓
Zooplankton								
Eurotatoria	Branchionidae	*Keratella* sp.	✓	✓	-	✓	-	-
Branchiopoda	Daphniidae	*Daphnia* sp.	-	-	-	-	✓	-

The number of plankton classes, families, species, and populations at the six stations from upstream to downstream of the Rangkui Watershed are presented (Figure 3). The results of calculating the total abundance of phytoplankton and zooplankton in the Rangkui Watershed was the highest at Station 1 (upstream) at 721 ind/L with 11 species, and gradually decreased until Station 6, except for the abundance of plankton at Station 3, which was 0 ind/L. The highest number of phytoplankton families was observed at Station 1 and gradually decreased until Station 6, except at Station 3, where there were no phytoplankton and zooplankton. Only one Branchionidae zooplankton family was found at stations 1, 2, and 4; one Daphniidae family was found only at station 5; and no zooplankton were found at stations 3 and 6. The number of individual phytoplankton at each station, except for station 3, was higher than that of the zooplankton. The density of phytoplankton in lotic water is higher than that of zooplankton [19]. Generally, zooplankton are found in low-velocity and low-turbidity water.

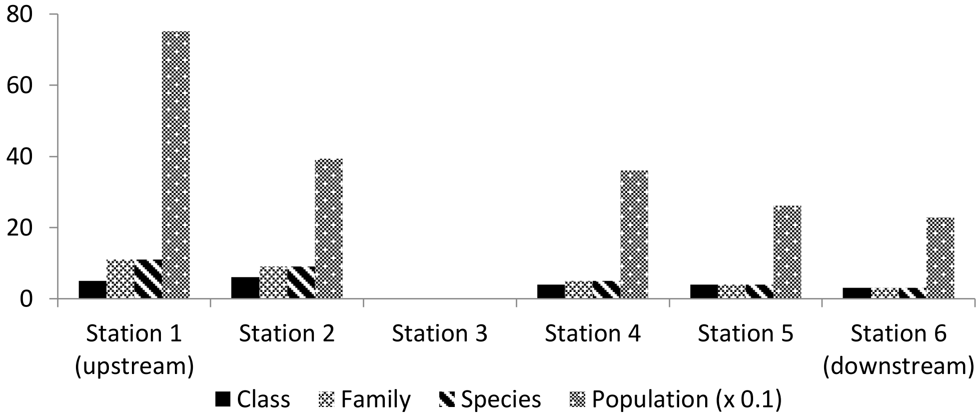

Figure 3. The number of plankton classes, families, species, and population at six stations from upstream to downstream of the Rangkui Watershed.

The high abundance of plankton at Station 1 is thought to be supported by the water temperature (25.17 °C), air temperature (31.50 °C), pH (6.54), and nitrate concentration (1.90 mg/L). No plankton found at Station 3 was suspected to be the influence of tin mining spoil around the river which caused a decrease in pH (5.51), too high turbidity level (408 NTU), current velocity (0.73 m/s) and suspected heavy metal pollution. High turbidity, a negative impact of tin mining, inhibits light penetration and interferes with photosynthesis [25]. In addition to fish, Total Soluble Solids (TSS) benchmarks also affect the function of freshwater communities [26]. A high current velocity caused the plankton to move very quickly. The rapid increase in river water velocity during the intense flow (1,475 m^3/s) caused the detachment of *Oscillatoria limosa* benthic species from the river bottom [27]. The low abundance at Station 6 (229 ind/L) was due to the poor water quality and high salinity. Certain plankton species can withstand and even thrive in environments contaminated with sulfur [13].

The highest species diversity index was observed at Station 1 (2.21), which gradually decreased to Station 6 (1.0), except at Station 3, where there was no plankton at all, and was categorized as moderate. The Uniformity Index was categorized as having the same distribution at all stations, and the highest was at Station 1 (0.96) and slightly decreased at all stations, except Station 3, where no plankton were found. No species dominated and was stable at any station, except Station 3, where no plankton were found. The lowest dominance index is at Station 1 (0.11) and gradually increases up to Station 6 (0.34).

The amounts of plankton found at stations 4 and 5 in this study were lower than those found in Meisaputra [7] at the same stations in an earlier study in 2013. The results of his research at the two stations recorded 18 species from 16 families, 4 phytoplankton classes, 4 species from 3 families, and 3 zooplankton classes. The decrease in the number of phytoplankton and zooplankton species in this study was suspected to have increased the amount of pollutants entering the Rangkui River. Plankton diversity, evenness, dominance, and saprobic indices at six stations from upstream to downstream of the Rangkui Watershed are presented in Table 2.

Table 2. Plankton indices at six stations from upstream to downstream of the Rangkui Watershed.

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
	Pepper plantation	Pepper and pineapple plantations	Tin mining activities	Housing and office	Traditional market and fishermen pier	Hydrophytes
Shannon-Wiener Index	2.21	2.09	-	1.37	1.21	1
Evenness Index	0.96	0.95	-	0.85	0.87	0.91
Dominance Index	0.11	0.14	-	0.31	0.34	0.34
Saprobic Index	0.71	0.14	-	–1	0	0

Correlation of the Abundace of Plankton and Aquatic Environment

The classes Bacillariophyceae, Chlorophyceae, Euglenophyceae, Cyanophyceae and Eurotatoria had the highest abundance at Station 1 mainly due to the availability of nutrients, and the area with tree vegetation around it. The highest nitrate content was 1.90 mg/L. Around station 1 is an area overgrown with trees, so there is a decay of leaves in the water bodies. The dominance of phytoplankton from the class Bacillariophyceae in rivers and in reservoir has been reported in several reports: Pesanggrahan River[17]; Situ Cisanti Bandung Regency [28]; Musi River [12], and Nasarawa reservoir [8]. Members of the Class Bacillariophyceae are cosmopolitan, have reproductive capacity [8,12] and high tolerance [12]. There were a few predominant diatom species and a relatively low population at high current velocities, which was due to the high rainfall and discharge from the dam, and rheophilic diatoms can grow at high velocities [29].

Phytoplankton *Skeletonema* sp. and *Oscillatoria* sp. have a high abundance of all stations except Station 3. *Skeletonema* sp. had the greatest abundance at Stations 4, 5, and 6, where the water quality decreased. *Skeletonema* sp. can adapt to various salinities to live in the sea, beaches, and estuaries and are euryhaline [30]. Benthic *Oscillatoria* sp. can adapt to low-light and hypoxic conditions and blooms, particularly under eutrophic and calm conditions [31]. *Aulacoseira* sp., *Scenedesmus* sp., and *Euglena* sp. were found at Station 1 with a current velocity (0.26 m/s) with a depth of about 15 cm. The *Aulacoseira granulata* abundance above 5% in the plankton and in the sediment in water supply reservoir during the dry season in Brazil [32]. *Scenedesmus* spp. are often found in stagnant waters and shallow rivers [33]. Phytoplankton at Station 2 with a current velocity of 0.28 m/s is *Chaetoceros* sp., *Pleurosigma* sp., *Skeletonema* sp., *Dictyosphaerium* sp., *Merismopedia* sp., *Oscillatoria* sp., *Rhodomonas* sp., *Ceratium* sp., D*ictyosphaerium* sp. and *Merismopedia* sp. are often found in low water currents [34]. *Chaetoceros* sp. can live in waters with nitrate concentrations ranging from 0.24 to 14.6 mg/L [35].

Zooplankton *Keratella* sp. was found at Station 1 (65 ind/L), and Station 2 (33 ind/L), and Station 4 (33 ind/L). The Eurotatoria class includes *Keratella* sp. are predators of other zooplankton [36], and some species are dominant in oligotrophic such as *Synchaeta stylata* and *Ascomorpha ovalis*, mesotrophic, or eutrophic waters such as *Keratella cochlearis* and *Keratella quadrata* [34]. Zooplankton *Daphnia* sp. was only found at Station 5 and it is suspected that the quality of this station is following the growth criteria, namely pH 6 to 9, water temperature 18 to 30 °C and DO ranges from 3 to 5 mg/L [37].

Nitrate is an element that has a vital role in the growth of phytoplankton. The nitrate at the study site comes from plantation residues, decomposing litter around rivers, and household waste disposal into rivers, with values ranging from 1.3 to 1.9 mg/L. The relatively high nitrate concentration was likely due to the high accumulation of industrial and household waste dumped in the water. The nitrate reading in this study is somewhat below River Niger (1.1–6.3 mg/L), Mississippi (0.7–3 mg/L) and higher than Amazon (0.001–0.036 mg/L) and some rivers in Africa (0.17 mg/L) and North America (0.23 mg/L) [38]. The optimum nitrate content for phytoplankton growth ranges from 0.9 to 3.5 mg/L [39]. The optimum pH range for phytoplankton depends on the species and conditions, generally between 7.0 and 8.0 [40].

The current velocity, water temperature, turbidity, TSS, and phosphate levels were negatively correlated with phytoplankton abundance. The high current velocity causes plankton movement and detachment of benthic species from the river floor [27]. Current speed is related to the distribution of aquatic organisms, including phytoplankton, whose lives float in water. Phytoplankton are found in small quantities in large currents. Phytoplankton can adapt to the limitations of their extant environment, and their growth is a function of external factors, including temperature [41]. The optimum range for the growth of phytoplankton in waters is 25.4 to 29.1 °C [42]. Freshwater phytoplankton size decreases with increasing temperature at the species and community levels [43]. TSS and high turbidity can inhibit light penetration; therefore, phytoplankton cannot perform photosynthesis. The high TSS content and turbidity are thought to be due to the large amount of suspended materials originating from household waste discharged into the river. Phosphate is required by phytoplankton for growth. Similarly, in their study in Banten, phosphate was positively correlated with phytoplankton abundance [44].

Anabaena sp., *Keratella* sp., and *Phacus* sp. are influenced by nitrate, salinity, phosphate, and DO levels. These three species positively and strongly correlated with nitrate availability and negatively correlated with water temperature and COD (Figure 4). *Keratella* sp. has a very strong and positive relationship with DO. *Anabaena* sp. and *Phacus* sp. have a strong and positive relation with salinity, and the two have a moderately strong and positive relation with phosphate levels. The populations of *Anabaena* sp., *Keratella* sp., and *Phacus* sp. increased as the levels of nitrate, salinity, phosphate, and DO increased and decreased as the water temperature and COD levels decreased. The COD levels significantly influenced *Anabaena* sp.

and *Phacus* sp. (Figure 4), whereas *Keratella* sp. was significantly related to the water temperature, DO, and COD. Both *Oscillatoria* sp. and *Synura* sp. showed positive correlations with phosphate, salinity, and DO levels and negative correlations with velocity, turbidity, and TSS factors. The two phytoplankton species showed a very strong and significant negative relationship with the velocity, turbidity, and TSS factors (Figure 4).

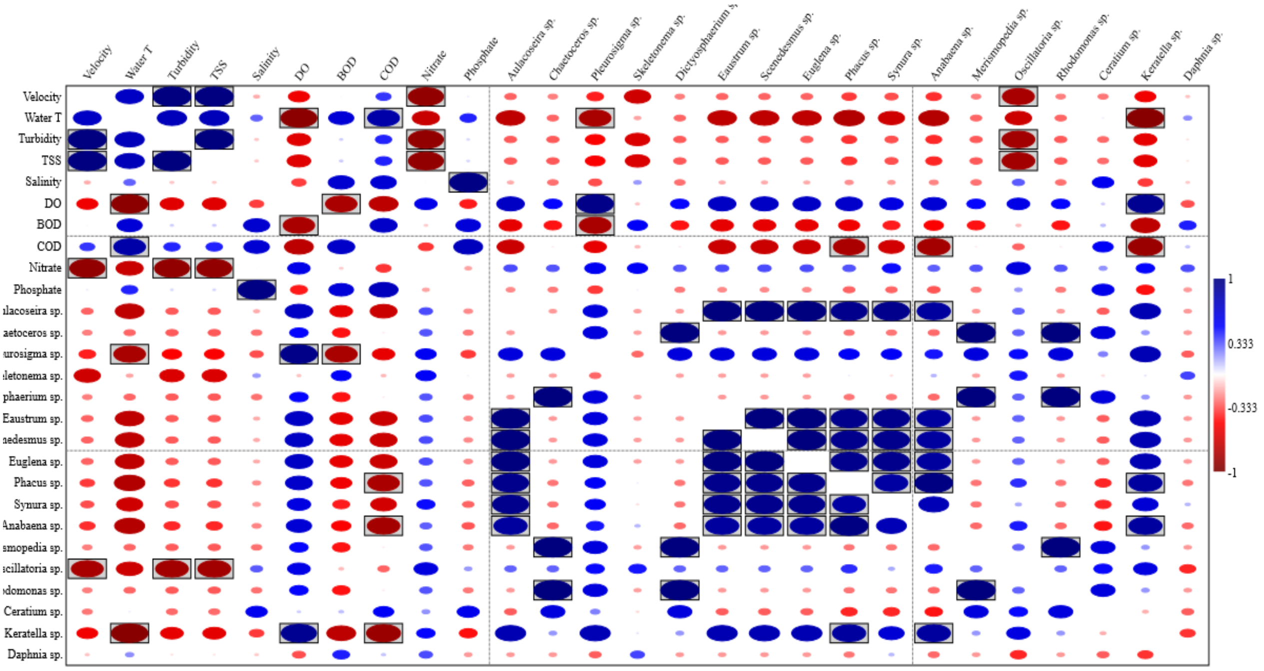

Figure 4. The Pearson correlation plot among aquatic physico-chemistry, and the population of plankton with a significance of $p < 0.05$ (note: a rectangular shape indicates a strong correlation between two variables).

The presence of *Skeletonema* sp. in water is influenced by several factors, including DO, phosphate, salinity, COD, water temperature, and BOD. Of these six factors, phosphate, COD, and DO levels had a strong positive relationship with *Skeletonema* sp. (Figure 4). This illustrates that as phosphate, COD, and DO levels increased, *Skeletonema* sp. also increased in the waters. Several abiotic factors influence *Dictyosphaerium* sp., *Eaustrum* sp., *Euglena* sp., *Merismopedia* sp., *Rhodomonas* sp., *Daphnia* sp., *Chaetoceros* sp., *Pleurosigma* sp., *Scenedesmus* sp., *Aulacoseira* sp., and *Ceratium* sp. in the water, including turbidity, TSS, COD, phosphate, and DO. The correlations between these species and abiotic factors are shown in the Pearson Correlation table (Figure 4).

Dictyosphaerium sp. had a strong positive relationship with COD. The relationship between *Eaustrum* sp., salinity, and phosphate was strong and positive. The correlation between *Merismopedia* sp. and COD was very strong and positive. *Rhodomonas* sp. showed a strong positive relationship with COD. *Daphnia* sp. had a strong positive relationship with velocity, turbidity, TSS, salinity, and COD. *Chaetoceros* sp. had a strong positive relationship with COD. *Pleurosigma* sp. had a very strong and negative correlation with water temperature and BOD, and a very positive and strong correlation with DO. The relationship between *Ceratium* sp., water temperature, and DO was strong and positive. *Euglena* sp., *Aulacoseira* sp., and *Scenedesmus* sp. showed strong positive correlations with phosphate levels. This condition shows that, along with the increase in turbidity, TSS, COD, phosphate, and DO factors, the presence of these species also increases in water.

Using the clustering method of biotic and abiotic factors at six stations along the Rangkui Watershed, the dendrogram shows that Station 6 is closer to stations 4, 2, and 5 than to stations 1 and 3 (Figure 5). The proximity between stations showed similarities based on abiotic and biotic factors. According to the data, Station 3 was the most problematic area for aquatic life. This location is situated near tin mining activities and exhibits the highest levels of turbidity (408 NTU) and TSS (15.9 mg/L) compared with the other five stations. Additionally, it had the lowest levels of dissolved oxygen (2.9 mg/L) and acidic pH (5.5), whereas the pH levels at the other five stations were above 6.45. Due to such unfavorable conditions, phytoplankton cannot do photosynthesis or survive in this environment.

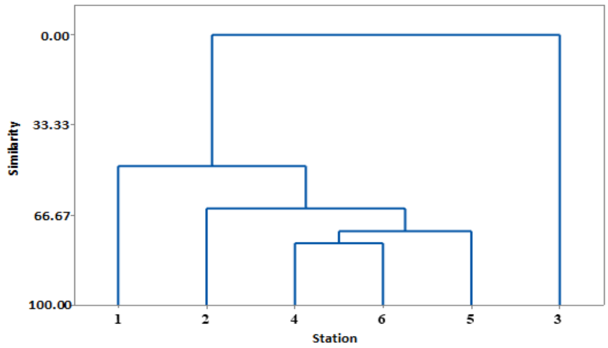

Figure 5. Dendogram using the Neighbor Joining Cluster method based on abiotic and biotic factors (notes: from upstream to downstream, Station 1 (pepper plantation), Station 2 (pepper and pineapple plantations), Station 3 (tin mining activities), Station 4 (housing and office), Station 5 (traditional market and fishermen pier), Station 6 (hydrophytes)).

Conclusions

Pollution around the Rangkui watershed affected plankton abundance. The pollution level with a saprobic coefficient ranged from light upstream to heavier downstream, with Station 4 being moderately polluted, which is suspected to be due to domestic waste. The study found 15 species from 15 families and six phytoplankton classes, namely Bacillariophyceae, Chlorophyceae, Euglenophyceae, Cyanophyceae, Cryptophyceae, and Dinophyceae, and two species of zooplankton from classes Eurotatoria and Branchiopoda. The total abundance of phytoplankton and zooplankton was highest upstream (721 ind/L) and gradually decreased downstream, except that there was no plankton at the station near tin mining activities. Nitrate had a positive correlation with phytoplankton at different correlation levels, whereas other abiotic environments responded differently to phytoplankton and zooplankton. The best water quality occurs upstream of the pepper plantations and decreases downstream. Stations near tin mining sites are the worst aquatic environments.

Author Contributions

TN: Methodology, Investigation, Writing - Review; **EN**: Conceptualization, Methodology, Software, Writing - Review & Editing, Supervision; **LL**: Methodology, Writing – Review, Supervision.

Conflicts of Interest

There are no conflicts to declare.

Acknowledgements

The authors would like to acknowledge the local government and community of the Rangkui Watershed who facilitated the research in the field, and Eka Sari, who reviewed the correlation analyses.

References

1. Sahidin, A.; Nurruhwati, I.; Riyantini, I.; Triandi, M. Structure of plankton communities in Cijulang River Pangandaran District, West Java Province, Indonesia. *World News of Natural Sciences* **2019**, *23*, 128–141.
2. Ding, J.; Jiang, Y.; Fu, L.; Liu, Q.; Peng, Q.; Kang, M. Impacts of land use on surface water quality in a subtropical river basin: A Case study of the Dongjiang River Basin, Southeastern China. *Water* **2015**, *7*, 4427–4445.
3. Yuagustini, R. Analisis Pengaruh Perubahan Tata Guna Lahan Terhadap Debit Banjir Sungai Rangkui. Thesis, Universitas Bangka Belitung, Bangka, ID, 2021.

4. Arsyadi, A. A Short Review: Water Environment of Rangkui River. 2019. Available online: https://www.researchgate.net/publication/332935303 (accessed on 20 June 2023).
5. Ferdiansyah R. Air Rangkui Tidak Seperti Dulu Lagi. 2011. Available online: https://www.ampl.or.id/digilib/read/air-rangkui-tidak-seperti-dulu-lagi/20951 (accessed on 12 February 2017).
6. Maghfiroh, M.; Novianti, H.; Lukman; Nurtjahya, E. Bacterial indicators reveal water quality status of Rangkui River, Bangka Island, Indonesia. *IOP Conf. Ser.: Earth Environ. Sci.* **2019**, *389*, 012008.
7. Pemerintah Indonesia. *Peraturan Pemerintah Republik Indonesia Nomor 82 Tahun 2001 Tentang Pengelolaan Kualitas Air Dan Pengendalian Pencemaran Air*; Sekretariat Negara Republik Indonesia: Jakarta, ID, 2001;
8. Meisaputra, D. Keanekaragaman Plankton di Aliran Sungai Rangkui Kota Pangkalpinang. Undergraduate Thesis, Universitas Bangka Belitung, Bangka, 2013.
9. Yusuf, Z.H. Phytoplankton as bioindicators of water quality in Nasarawa reservoir, Katsina State Nigeria. *Acta Limnologica Brasiliensia* **2020**, *32*, e4, doi:https://doi.org/10.1590/S2179-975X3319.
10. Saifullah, A.S.M.; Kamal, A.H.M.; Idris, MdH; Rajaee, A.M.; Bhuiyan, MdKA. Phytoplankton in tropical mangrove estuaries: role and interdependency. *Forest Science and Technology* **2016**, *12*, 104–113.
11. Suhadi, M.; Gustomi, A.; Supratman, O. Struktur komunitas plankton sebagai bioindikator kualitas air di Sungai Upang Desa Tanah Bawah Kecamatan Puding Besar. *Akuatik* **2020**, *4*, 26–32.
12. Parmar, T.K.; Rawtani, D.; Agrawal, Y.K. Bioindicators: the natural indicator of environmental pollution. *Frontiers In Life Science* **2016**, *9*, 110–118.
13. Aryawati, R.; Ulqodry, T.Z.; Isnaini; Surbakti, H. Fitoplankton sebagai bioindikator pencemaran organik di perairan Sungai Musi Bagian Hilir Sumatra Selatan. *J. Ilmu dan Teknologi Kelautan Tropis* **2021**, *13*, 163–171.
14. Kamilah, F.; Rachmadiarti, F.; Indah, N.K. Keanekaragaman plankton yang toleran terhadap kondisi perairan tercemar di Sumber Air Belerang, Sumber Beceng Sumenep, Madura. *LenteraBio* **2014**, *3*, 226–231.
15. SNI (Standar Nasional Indonesia). Air dan air limbah – Bagian 57: Metode pengambilan contoh air permukaan. 2008. Available online: www.547-sni-69857-2008.ac.id (accessed on 23 March 2017)
16. Pratiwi, D.E.; Koenawan, C.J.; Zulfikar, A. Hubungan kelimpahan plankton terhadap kualitas air di perairan Malang Rapat Kabupaten Bintan Provinsi Kepulauan Riau. 2015. Available online: http://jurnal.umrah.ac.id (accessed on 12 March 2017).
17. Faza, M.F. Struktur Komunitas Plankton di Sungai Pesanggrahan dari Bagian Hulu (Bogor, Jawa Barat) hingga Bagian Hilir (Kembangan, DKI Jakarta). Thesis, Universitas Indonesia, Depok, ID, 2012.
18. Bellinger, E.G.; Sigee, D.C. *Freshwater Algae: Identification and Use as Bioindicators*; Wiley-Blackwell: Chichester, 2010;
19. Bridgewater, L.; American Public Health Association; American Water Works Association; Water Environment Federation. *Standard Methods for The Examination Water and Wastewater*, 22nd ed.; American Public Health Association: Washington DC, USA, 2012; ISBN 9780875530130.
20. Odum, E.P. *Fundamentals of Ecology*, 3rd ed.; WB Saunders Co., Philadelphia, 1971; 574 p.
21. Dresscher, T.G.N.; van der Mark, H. A simplified method for the biological assessment of the quality of fresh and slightly brackish water. *Hydrobiologia* **1976**, *48*, 199–201.
22. Awaludin, A.S.; Dewi, N.K.; Ngabekti, S. Koefisien saprobik plankton di perairan embung Universitas Negeri Semarang. *Jurnal MIPA* **2015**, *38*, 115–120.
23. Powley, H.R.; Dürr, H.H.; Lima, A.T.; Krom, M.D.; Cappellen, P.V. Direct discharges of domestic wastewater are a major source of phosphorus and nitrogen to the Mediterranean Sea. *Environmental Science and Technology* **2016**, *50*, 8722–8730.
24. Hariyati, R.; Putro, S.P. Bioindicator for environmental water quality based on saprobic and diversity indices of planktonic microalgae: a study case at Rawapening lake, Semarang district, Central Java, Indonesia. *J. Phys.: Conf. Ser.* **2019**, *1217*, 012130.

25. Muslih, K.; Adiwilaga, E.M.; Adiwibowo, S. Pengaruh penambangan timah terhadap keanekaragaman ikan sungai dan kearifan lokal masyarakat di Kabupaten Bangka. *J Limnotek*. **2014**, *21*, 52–63.

26. Chapman, P.M.; Hayward, A.; Faithful, J. Total suspended solids efects on freshwater lake biota other than fish. *Bull Environ Contam Toxicol* **2017**, *99*, 423–427.

27. Dembowska, E.A. The use of phytoplankton in the assessment of water quality in the lower section of Poland's largest river. *Water* **2021**, *13*, 1–13, doi:https://doi.org/10.3390/w13233471.

28. Hasan, Z.; Syawalludin, I.N.; Lili, W. Struktur komunitas plankton di Situ Cisanti Kabupaten Bandung, Jawa Barat. *J Akuatika* **2013**, *4*, 80–88.

29. Yun, S.M.; Joo, H.M.; Jung, S.W.; Choi, C.H.; Ki, J.S.; Lee, J.H. The relationship between epilithic diatom communities and changes in water quality along the lower Han River, South Korea. *Journal of Freshwater Ecology* **2014**, *29*, 363–375.

30. Supriyantini, E. Pengaruh salinitas terhadap kandungan nutrisi Skeletonema costatum. *Bull Oseanografi Marina* **2013**, *2*, 51–57.

31. Sun, J.; Xu, H.; Pei, H.; Jin, Y.; Li, H.; Ma, C. Worse than cell lysis: The resilience of Oscillatoria sp. during sludge storage in drinking water treatment. *Water Research* **2018**, *142*, 405–414.

32. Nascimento, M.N.; Bush, M.B.; Bicudo, D.C. Water quality and spatial and seasonal dynamics in the largest water supply reservoir in Brazil and implications for diatom assemblages. *Acta Limnologica Brasiliensia* **2021**, *33*, e7, doi:https://doi.org/10.1590/S2179-975X7120.

33. Greeson, P.E. *An Annotated Key to the Identification of Commonly Occuring and Dominant Genera of Algae Observed in the Phytoplankton the United States*; United States. Government Printing Office: Washington DC, USA, 1982.

34. Yin, L.; Ji, Y.; Zhang, Y.; Chong, L.; Chen, L. Rotifer community structure and its response to environmental factors in the Backshore Wetland of Expo Garden, Shanghai. *Aquaculture and Fisheries* **2018**, *3*, 90–97.

35. OBIS (Ocean Biogeographic Information System). Chaetoceros Debilis. 2023. Available online: http://www.iobis.org (accessed on 29 June 2023).

36. Rogozin, A.G. Materials on the fauna and ecology of rotifers in the Urals, family Brachionidae (Rotifera, Eurotatoria, and Ploima), genera Kellicottia, Plationus, and Platyias. *Biology Bulletin* **2021**, *48*, 950–958.

37. Aprillia, T.; Rachmatiah, I. Uji Toksisitas Akut Limbah Cair Industri Pulp dan Kertas Terhadap Daphnia Magma (Studi kasus: PT Aspex Kembong). 2013. Available online: www.publikasi.ftsl.itb.ac.id (accessed on 4 March 2018).

38. Tundisi, J.G.; Tundisi, M.T. *Limnology*; CRC Press: London, UK, 2011;

39. Iswanto, C.Y.; Hutabarat, S.; Purnomo, P.W. Analisis kesuburan perairan berdasarkan keanekaragaman plankton, nitrat dan fosfat di Sungai Jali dan Sungai Lebeng Desa Keburuhan, Purworejo. *J Maquares*. **2015**, *4*, 84–90.

40. Morales, M.; Aflalo, C.; Bernard, O. Microalgal lipids: A review of lipids potential and quantification for 95 phytoplankton species. *Biomass and Bioenergy* **2021**, *150*, 106108.

41. Fox, J.; Behrenfeld, M.J.; Haëntjens, N.; Chase, A.; Kramer, S.J.; Boss, E.; Karp-Boss, L.; Fisher, N.L.; Penta, W.B.; Westberry, T.K.; et al. Phytoplankton growth and productivity in the Western North Atlantic: Observations of regional variability from the NAAMES Field Campaigns. *Front. Mar. Sci.* **2020**, *7*, 1–15, doi:https://doi.org/10.3389/fmars.2020.00024.

42. Sulawesty, F.; Rahayu, S.Y.S.; Yustiawati; Chrismadha, T. Phytoplankton response to differences in light and the addition of phosphorus in Lake Cikaret. *Journal of Natural Resources and Environmental Management* **2023**, *13*, 27–36, doi:http://dx.doi.org/10.29244/jpsl.13.1.27–36.

43. Zohary, T.; Flaim, G.; Sommer, U. Temperature and the size of freshwater phytoplankton. *Hydrobiologia* **2021**, *848*, 143–155.

44. Takarina, N.D.; Nurliansyah, W.; Wardhana, W. Relationship between environmental parameters and the plankton community of the Batuhideung Fishing Grounds, Pandeglang, Banten, Indonesia. *Biodiversitas* **2019**, *20*, 171–180, doi:https://doi.org/10.13057/biodiv/d200120.