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Environmental Study on Phytoplankton in Garang Watershed, Central Java, Indonesia and Its Water Quality

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Abstract Phytoplankton can be used as an indicator for water environment quality in the watershed area. This research was conducted in Garang Watershed, Central Java, Indonesia. The aims of this research are to study the environmental assessment of Garang Watershed Central Java, Indonesia using phytoplankton diversity and their relationship to water quality. Sampling location was determined based on the Governor Regulation of Central Java Provincial No. 156/2010 about the segmentation of Garang Watershed. Plankton Net No.25 was used for collecting phytoplankton in Garang Watershed. Phytoplankton density ranged from 13 to 53 ind/L. The number of species in the range of 4-8. Diversity index in the range 1.07-2.06. The result of diversity index shown that this rivers is lightly polluted. Phytoplankton stabilization was moderate while phytoplankton evenness was spread. Water quality index in this research are: Phosphate, Nitrate, Nitrite, Ammonia and Fe.

1. Introduction

Garang watershed located at Central Java Province, Indonesia. Upstream Garang watershed is located in the area of Mount Ungaran, Central Java, Indonesia. Downstream is located at the mouth of the Java Sea. The distance of the river on the Garang watershed is 35 km. Garang watershed is divided into 3 zones, namely the upper zone, the middle zone, and the lower zone. Upper zone has a topography of the mountains with the slope of the river bottom is very steep. The flow velocity includes a supercritical flow type. The hydraulic characteristic in the upper zone is the high flow rate so that sediment transport and erosion are also high. Sediment transport is a complex phenomenon associated with nature, randomness and spatial-temporal discontinuity [2]. The middle zone has a hilly topography. The slope of the slope is not as sharp as the upper zone. The lower zone exists in urban areas. This zone has a very sloping riverbed. The symptoms that occur are sedimentation or sedimentation at the bottom of the channel.

Three districts of Garang Watershed are Semarang City, Kendal Regency, and Semarang Regency. The characteristic of the estuary of Garang watershed is a muddy area, and it used for aquaculture of Tilapia Fish. Aquaculture is a beneficial activity to provides economic benefits for the community. Aquatic waste comes from domestic, industrial waste [13], port activities [23], and anthropogenic activities [14]. Waste from anthropogenic activities can be caused by overpopulation.

IOP Conf. Series: Earth and Environmental Science **246** (2019) 012070 doi:10.1088/1755-1315/246/1/012070

In 2015 the population of the 3 regions (Semarang City, Kendal Regency, and Semarang Regency) is 1.284.967 people, the year 2016 is 1.370.906 people. Thus, that has increased the population of 85.939 people/year. Large population needs of settlements areas, so the changes in upstream land use into settlements. Land use change has an impact on water quality in the estuary/downstream [5]. Close to the estuary, there are residents who defecate directly in the river or dispose of stool waste directly into the river without processing.

Environmental feasibility for aquaculture can be estimated through quantitative and qualitative measurement of the biota that inhabits these aquatic environment. Plankton used its ecological studies cheaply in cost, and easily. Knowledge of the abundance, diversity and environmental conditions of the resource can be used for the determination of water productivity for aquaculture. Phytoplankton in aquatic systems requires nitrogen and phosphorus as a limiting factor for its growth, in addition to other factors [16]. The purpose of this study was to analyze the relationship of phytoplankton biodiversity with water quality in order to manage the sustainable river. Good water quality for the river is very important because it affects humans, plants, animals and all the elements that utilize the river [22]. Futhermore, they need research about water quality and plankton biodiversity to maintain the watershed ecosystems.

2. Research Method

2.1. Study Area

Garang watershed stretches across 3 districts. Upstream is located in Semarang, Central Java, Indonesia, downstream and centered in Semarang City, and Kendal Regency Central Java, Indonesia. The upper of Garang watershed is a super priority watershed. Upstream is a location to water supplier for Semarang and surrounding areas. Futhermore, it is very important to preserve the function of the environment. The upstream part of Garang Watershed there is many springs. Springs are used as water providers for household and industrial needs. (Figure 1).

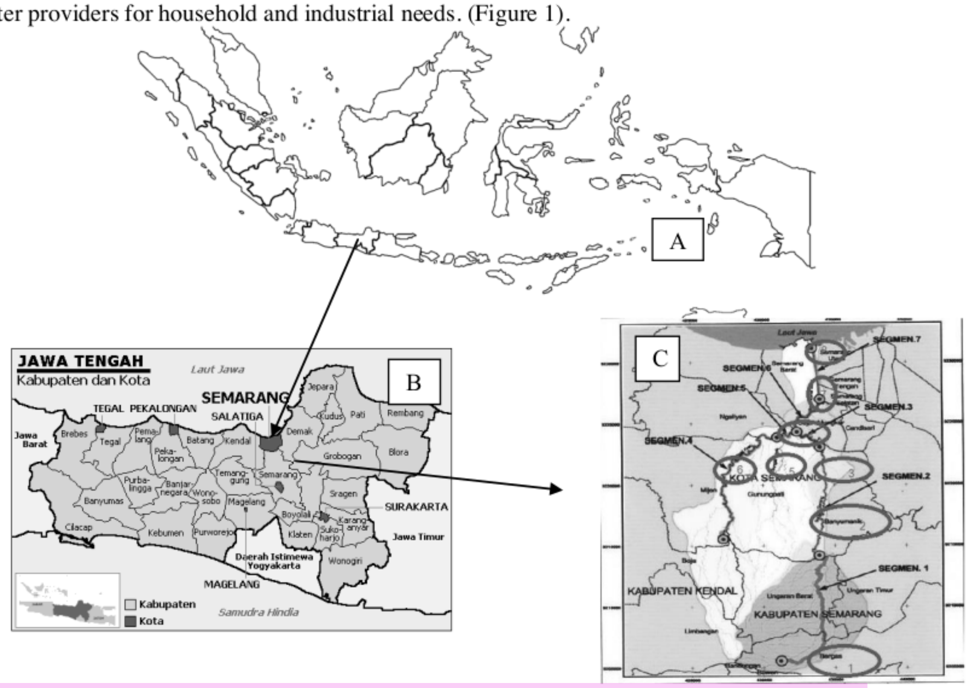

Figure 1. Study area: the map of the Indonesia (A), Central Java Province (B), Location of Garang Watershed Sampling Station 1-8, coordinate 6˚59'32,5" S and 110˚24'10,0" E (C)

IOP Conf. Series: Earth and Environmental Science **246** (2019) 012070 doi:10.1088/1755-1315/246/1/012070

2.2. Sampling techniques

Plankton collects in Garang watershed, with 8 sampling station with 7 segments area based on Governor Regulation of Central Java Provincial No. 156/2010. The purpose of this regulation is to manage the river segmentation based on utilization. Segment 1 is an upstream area used for: agriculture area, coffee plantation, settlement, and industries (biscuit, soft drink, textile, and tofu industry). Segment 2 is used for: settlement, agriculture, and industry (iron smelting industry). Segment 3 is used for settlement. Segment 4 is used for: agriculture, settlement, fishery, fishing, and forest. Segment 5 is used for settlement, fisheries. Segment 6 is used for settlement, fishery, industry, and agriculture. Segment 7 is watershed downstream is used for settlement, estuary, fishery, and port. The sampling location is 8 points. Sampling station 1 is a river in the downstream area at Gebugan Village, Bergas sub-district, Semarang Regency. Sampling station 2 is Garang River (Pramuka Street), Banyumanik sub-district near plantations and settlements. Sampling station 3 is Garang River in Tinjomoyo Village, this area near the plantation. Sampling station 4 called Tugu Suharto river, this area is confluent zone between Kreo river and the Garang river. In this area, there is an influence between sediment transport, flow dynamics and river morphology [18]. Waste comes from domestic and industry, thus affecting the water quality of the river [24]. Sampling station 5 is Garang river near fishing pond Sikopek Village, Gunung Pati Sub-district, this area near the plantation. Sampling station 6 is Garang river near Gisik Sari Village, Gunung Pati Sub-district near plantations and settlements. Sampling station 7 is Garang river, they river called Banjir Kanal Barat River, this river near settlements and downstream area. Sampling station 8 is the downstream area, estuary Laut Jawa. Sampling Station is shown in Figure 1(b).

Sampling used Plankton net No 25, with materials: alcohol, lugol, sampling bottles (1 liter) [21], and keep the sample in a cool box to the laboratory for analyzing the sample [16]. Filtered water is 10 liters using a 10-liter tube. Phytoplankton abundance is calculated by the following formula [20].

$$N = nx\frac{V1}{Vs}x\frac{1}{V}$$

where:
N: the amount of all phytoplankton
V: volume of filtered water
Vt: the initial sample volume
Vs: sub-sample volume (fraction)
N: number of phytoplankton in sub-sample Water

2.3. Biodiversity Index

Shannon-Wiener index (H′) is used to summarize the functional diversity of the ciliate communities, and is computed following the equation:

$$H' = -\sum_{i=1}^{s} Pi(\ln Pi)$$

where
H′ = observed diversity index;
Pi = proportion of the total count arising from the ith functional group;
S = total number of functional group

2.4. Evennes Index

Evenness Index J′ [29], which is expressed by the Shannon information scaled by the maximum information, to measure species evenness for each community:

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$$J' = \frac{H'}{\ln(S)'}$$

where
H′ = observed diversity index
S = total number of species observed

3. Result and Discussion

3. 1. Result

3.1. 1. Diversity index

Total Individu, Total Species, Diversity Index, Eveness Index and Dominance Index in Sampling Location shown in Figure 2.

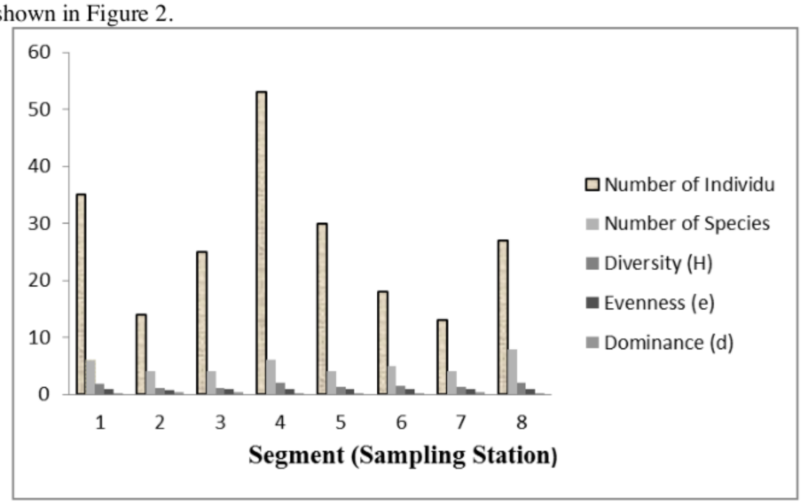

Figure 2. Total individu, total species, diversity index, evenness index and dominance index in sampling location

The number of individuals, species, diversity index, evenness Index, and phytoplankton dominance in Garang watershed of Central Java, Indonesia are shown in Figure 1. The number of individuals of phytoplankton in Garang watershed was about of 13-53 ind/L. The number of species of phytoplankton in Garang watershed was about 4-8. The diversity index of phytoplankton Garang watershed was about 1.07 - 2.06. The evenness index of phytoplankton in Garang watershed was about 0.77 - 0.99. The dominance index of phytoplankton in Garang watershed was about 0.17 - 0.43.

Table 1. Types of phytoplankton found in Garang Watershed, Semarang, East Java Indonesia

Class	Name of Spescies	Average
Chlorophyceae	*Arthrodesmus* sp.	0-5(0.63±1.65)
	Pediastrum sp.	0-1(0.13±0.33)
Bacillariophyceae	*Biddulphia* sp	0-8(3.00±3.46)
	Chaetoceros sp	0-9(2.88±3.79)
	Coscinodiscus sp	0-9(4.86±2.29)
	Cyclotella sp	0-7(0.88±2.32)
	Grammatophota sp	0-4(0.50±1.32)
	Guinardia sp.	0-8(2.71±3.24)
	Nitzschia sp	0-8(2.63±3.04)

IOP Conf. Series: Earth and Environmental Science **246** (2019) 012070 doi:10.1088/1755-1315/246/1/012070

Class	Name of Spescies	Average
	Pleurosygma sp	0-12(3.5±3.94)
	Rhizosolenia sp	0-4(1.13±1.54)
	Synedra sp.	0-2(0.25±0.66)
	Thalasiothrix sp	0-8(1.88±3.26)
	Triceratium sp	0-2(0.25±0.66)
Cyanophyceae	*Oscillatoria* sp.	0-3(0.38±0.99)
Dynophyceae	*Ceratium* sp	0-6(1.88±2.47)
	Dinophysis sp.	0-3(0.38±0.99)

Table 1. shown that data types of phytoplankton found in Garang Watershed. Semarang. East Java Indonesia. there are four classes found in Garang watershed are: Chlorophyceae, Bacillariophyceae, Cyanophyceae and Dynophyceae. The most phytoplankton was found in Garang watershed is *Chaetoceros* sp.

3.1.2. Water Quality Analysis

In this sampling area. they are 5 water quality samples. such as Phospate, Nitrate, Ammonia Nitrite and Fe (Table 2.)

Table 2. Variety of water quality in Garang Watershed

Sampling Station	Phospate	Nitrate	Ammonia	Nitrite	Fe
1	0.562	0.010	0.010	0.002	0.000
2	4.185	0.120	0.510	0.066	0.450
3	0.283	0.110	0.510	0.008	0.350
4	0.366	0.060	0.130	0.016	0.120
5	2.177	0.020	0.370	0.017	0.820
6	0.687	0.530	0.970	0.283	0.040
7	0.366	0.140	0.470	0.078	0.280
8	0.464	0.220	2.030	0.101	0.420
Average	1.14	0.15	0.63	0.07	0.31
Deviation Std	±1.38	±0.17	±0.64	±0.09	±0.27

Table 2 show that the study of water quality in Garang Watershed are: Phosphate, Nitrate, Ammonia, Nitrite and Fe. Phosphate range in a research study is 0.366–2.177 mg/L. Nitrate range in a research study is 0.010-0.530 mg/L. Nitrate is affected by rainwater runoff, industrial waste and domestic waste [15]. Nitrite range in a research study is 0.002-0.283 mg/L. Faeces of grazing animals carry pathogenic bacteria, protozoa and can be contaminated with nitrites and nitrates. This is an environmental problem for people who only use groundwater for their lives [4]. At sampling station 6 there are residents who have chicken farms, this is thought to have an effect on the high content of nitrate and nitrite. Ammonia range in a research study is 0.010–2.030 mg/L. Suspended solids affect ammonia in the waters. It is important to know the abundance of ammonia-oxidizing microorganisms and their response to the environment [27]. Fe range in the research study is 0.04-0.82 mg/L.

3.2. Discussion

3.2.1. Diversity index. evennees index and dominance index

When phytoplankton diversity (H'), if H'<1 then the community of biota is declared unstable [16]. H' ranges from 1-3 then the stability of the biota community is moderate (moderate). H'> 3 means the stability of the biota community is in a prime (stable) condition. In all sampling area, H' is moderate stable criteria. The waters condition is good if it has an increasing H value [16]. The evenness of the number of species is not the same and there is a tendency of dominance in the phytoplankton community. The diversity index on phytoplankton ranges from 0.90 to 1.52. The evenness index was calculated to find out how big the equality of the spread of the number of individuals at the community level both at each location and season. The evenness index close to 1 indicates evenness among species is evenly distributed when close to 0 indicates evenness among species is low [1]. The evenness index on phytoplankton ranged from 0.38 to 0.71.

The dominance in each location indicates the dominance of a certain species in an ecosystem. The dominance index close to 0 indicates that there are no dominant species, whereas close to 1 indicates the dominance of certain types within the community [1]. This dominance index indicates that there is no tendency of the dominance of certain phytoplankton type. The number of individuals and species of phytoplankton found in this study is relatively lower compared to previous studies in the waters of Semarang Bay which is the mouth of the Garang watershed (downstream/estuary area) by the research [1]. This research has shown that the dominance index on phytoplankton ranged from 0.38 to 0.62. The dominant index of zooplankton ranges from 0.08 to 0.16

The dominant phytoplankton species are *Pleurosygma* sp., *Coscinodiscus* sp., *Biddulphia* sp. and *Chaetoceros* sp. Algae blooms can be caused by algae from the genus Chaetoceros and Ceratium. blooming algae harmful to fish life. Red tide is caused by plankton *Chaetoceros* sp. [23]. Diatom *Coscinodiscus* sp. lives in a turbulent environment. not in calm waters that contain low nutrient concentrations [3]. The morphology of diatom that was protected by the cell walls was an important factor to tolerate the environmental changes. This factor also enabled diatom to win the competition in occupying the living space and obtaining nutrients. The diatoms living in tropical areas had structures (spicules, seat, and hard cell walls) and chemical defense beneficial to survive in the environment that has numerous predators. The chemical defense was used to survive from the smaller predators while the structural defense was used to survive from the bigger predators. Even the cell wall structure could absorb 30% of UVB radiation. It could survive from high light exposure [19].

3.2.2. Water quality

Household wastewater containing auxiliary residues and cleaning agents, agricultural runoff containing fertilizers and industrial waste from fertilizer, detergent, and soap industries are the main sources of phosphates in aquatic environments. Most sources of industrial waste and domestic waste in urban areas [9]. Phosphate can be caused by detergent concentration. Detergent affects the aquatic environment, caused by foam, limit oxygen production, and cause eutrophication [12]. Foam on the surface can limit oxygen production, inhibit aeration in the aquatic environment which causes an increase in oxygen demand which causes the dissolution of dissolved oxygen. High concentrations affect the life cycle of the organism: ovum and larval phase [12]. Overall, the detergent effect reduces oxygen concentration, changes in watercolor, increases turbidity and sedimentation, and decreases biological activity [12]. The highest concentration of phosphate in the sampling station 2, they are many industrial and domestic settlement in the near river. Nitrate is the main form of nitrogen in the water. Nitrate is a major nutrient for plant growth. Nitrate concentrations of more than 0.2 mg/L may result in the occurrence of eutrophication (enrichment) of the aquatic environment. The oligotrophic waters have a nitrate content between 0-1 mg/L [7]. Upstream of Garang watershed used for corn and cassava agriculture, furthermore they are many pesticides in this area. In the aquatic environment receiving runoff from agricultural areas containing fertilizers and pesticides, nitrate levels can reach 1.000 mg/L. Nitrate levels for drinking water are not allowed to exceed 10 mg/L [7]. These compounds are transferred to the environment through different sources including by-products of waste decomposition. The effects of high nitrate and phosphate can increase the toxic phytoplankton severely in waters near the waters around the world [10]. Ammonia concentrations in the aquatic environment above 0.2 mg/L can be harmful to many aquatic organisms [8]. In sampling station 8 which is an area of aquaculture [25], is thought to have an effect on the amount of ammonia waste derived from fish feed. This can cause a bad influence on the aquatic environment. Nitrite in the sampling area: 0.002-0.28, good condition in the watershed area of nitrite is from 0.4 to 0.8 mg/l [16]. Fe as a nutrient for life processes in plants and microorganisms but becomes toxic at higher concentrations. Fe range in fish at sampling station 7-8 is 15.86 mg/kg to 306.3 mg/kg. Concentration limit Fe according to World Health Organization is 0.3 mg/kg.

3.2.3. Relationship between phytoplankton and water quality

Abiotic factors can cause dominance of *Ceratium* sp. [21]. In sampling station 6. the decomposition process releases mineral elements. Nitrogen, phosphorus, and other important nutrients, this causes high phosphate concentrations [21]. Several research has shown that the ecological features of planktonic silica, such as species diversity, taxonomic uniqueness, and diversity of sizes/uniqueness, can be used as potential bioindicators of water quality status [28]. Plankton biomass is influenced by nitrogen, phosphorus, silica, and eutrophication. *Nitzschia* sp and *Dinophysis* sp can be caused dinoflagellate blooms. It is a bad condition for the aquatic environment [14].

The most dominating phytoplankton are *Rhizosolenia* Sp., *Chaetoceros* Sp., and *Bacteriastrum* Sp. this phytoplankton is natural foods for fish that live in the sea [1]. Cyanobacteria, for example, *Oscillatoria* Sp. is is a plankton that can photosynthesize. Morphology of *Oscillatoria* sp. is in the form of filaments. An abundance of *Oscillatoria* sp. affect DO concentrations in the aquatic environment, the habitat in fresh water and calm water area [19]. Increases of green algae (*Pediastrum* Sp., *Scenedesmus* Sp., *Coelastrum* Sp. etc.) can be caused harmful algal blooms (HABs) in coastal waters, and open sea. *Synedra* Sp is algae are bioindicators showing that aquatic ecosystem has high nitrate and phosphate levels. *Ceratium* sp is non-toxic but requires high O_2, furthermore, it can reduce dissolved oxygen. It can be concluded, land degradation has encouraged the use of inorganic fertilizers by farmers, which is finally washed out of the land through surface runoff and residual irrigation water. Residues from inorganic fertilizers, in the form of nitrate and phosphate solutions, are carried to the water flow in the river, which ultimately impacts on water quality [26].

4. Conclusion and Recommendation

This research has described the physical, chemical and biological variables of aquatic ecosystems to assess water pollution and ecological status. The results showed that the aquatic environment was moderately polluted with a phytoplankton diversity index of 1.07-2.06. This research needs to be continued because it is useful for maintaining the ecological status of aquatic environments. Pollution of the aquatic environment by domestic and industrial waste is a problem that needs to be soluted by the relevant government in collaboration, with the purpose of reducing the risk of disease in the community.

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