Distribution of phytoplankton based on the water quality of Bengawan Solo River, Central Java

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Abstract. Bengawan Solo River is the longest river on the island of Java, and it has 548.53 km in length. The river has an important meaning for the community both for agriculture, tourism, plantations and fisheries, as well as for the life of aquatic organisms. Phytoplankton in rivers have a role in fishery resources, being a primary producer and can be used as an indicator of the quality of the aquatic environment. Distribution phytoplankton abundance in waters will be affected by water quality and physiology. This study aims to determine the abundance and diversity of phytoplankton in Bengawan Solo. The research was conducted in April and August 2020. The research stations selected to represent the upstream locations were Gajah Mungkur Wonogiri Reservoir and Bendung Colo Sukoharjo. Kampung Sewu Solo and Bison Karanganyar research stations represent locations where there are industries. Meanwhile, Tenggak Sragen, Ngawi, Kanor Bojonegoro stations are three locations which are located on the downstream sector. The results showed that during the dry season, distribution of abundance of phytoplankton was higher (259 cells L^{-1}) than during the rainy season (192 cells L^{-1}). During the rainy season, there are only two classes of phytoplankton, namely Bacilariophyceae and Chlorophyceae. During the dry season, there are three classes of phytoplankton, namely Bacilariophyceae, Chlorophyceae and Cyanophyceae class. The plankton diversity index at the pollution site in Bison Karanganyar village was lower (H=1.47) than in the upstream location, namely Bendung Colo Sukoharjo village (H=2.1).
Key Words: abundance, diversity, pollution zone.

Introduction. Bengawan Solo River is the longest river on the island of Java, with a length of 548.53 km. The Bengawan Solo River has benefits for the surrounding community and also for the life of aquatic organisms (Utomo et al 2008; Directorate General of Water Resources 2019). This river has undergone many modifications such as drains, reservoirs, dams and is also polluted from industrial waste (industrial alcohol for example), fish farming, livestock (cattle, pigs), and household waste (Utomo et al 2010; Dani et al 2015; Arif et al 2015; Darmawan et al 2018; Mudjib & Lasminto 2013).

The negative impact of water pollution are decreasing water quality and changes in the diversity of plankton. Plankton is a biological parameter that is closely related to nutrients. These organisms can be used as an indicator of water quality, in regard to their tolerances to various factors and have different responses to changes in water quality. The types of plankton that act as the main producers in the water are phytoplankton, while zooplankton, fish larvae, shrimp, crabs, and so on are consumer organisms (heterotrophs). The existence of phytoplankton is very important for fisheries because it is a natural food source for larvae of aquatic organisms and a source of oxygen in the water (Nontji 2008; Utomo et al 2011; Fachrul et al 2005).

The distribution of abundance and composition of phytoplankton will change in response to changes in environmental conditions, including water quality and physiology (Vallina et al 2014; Effendi et al 2016; Ridho et al 2019; Hastuti et al 2018). Based on the phytoplankton diversity index, the water quality of the Bengawan Solo River in

Bojonegoro Regency is in a good category (Wibowo et al 2014). Different results were found in the Pepe River (a tributary of the Bengawan Solo), which was categorized in a bad category due to environmental pollution (Fadhilatin & Roziaty 2016).

To support the management of aquatic resources, knowledge of toxic and dangerous phytoplankton species is needed. In highly polluted waters, there will be phytoplankton from the Cyanophyceae class (blue-green algae) and several genera that fish cannot eat because they are poisonous, including Anabaenopsis, Microcystis, Anabaena, Coelosphaerium, Oscillatoria, Nostoc, Hapalosiphon, and Lyngbya (Lindon & Heiskary 2009; Rochelle-Newall et al 2011). Phytoplankton research in the Bengawan Solo River has been carried out a lot but it is only a piece of the area and does not represent the dry and rainy season, among others: Wibowo et al 2014 and Sulistiowati et al 2016 state that the phytoplankton diversity (H) in the Bengawan Solo River Bojonegoro Regency is 2.35 and included in the good category. Safitri (2016) research only on the Pepe river (a tributary of the Bengawan Solo river), states that the phytoplankton in Solo City is dominated by Cyanophyceae. Darmawan et al (2018), researched only in Solo City and states that the rivers around Solo City have been polluted with organic matter, and there is a positive linear relationship between phosphate levels and phytoplankton abundance, the higher the phosphate content the higher the phytoplankton abundance. Meanwhile, the phytoplankton research carried out by the author is starting from the upstream zone that has not been polluted, the middle zone which is heavily polluted to the downstream zone where the pollution has recovered and is carried out to represent the dry and rainy seasons. This study aims to determine the diversity index and abundance of phytoplankton in the Bengawan Solo river which has been heavily polluted, so it can be seen whether the pollution in the Bengawan Solo river has an impact on the phytoplankton that live in the river. It is hoped that information can provide input for the management of water resources in the Bengawan Solo River.

Material and Method

Description of the study sites. The study was conducted in April 2020 to represent the rainy season and August 2020 represented the dry season. The research station start from upstream to downstream of Bengawan Solo River, namely Gajah Mungkur Reservoir in Wonogiri district, Bendung Colo in Sukoharjo district, Kampung Sewu in the city of Solo, Bison in Karanganyar District, Tenggak in Sragen District, Ngawi District, and Kanor in Bojonegoro District. Gajah Mungkur Reservoir and Bendung Colo research stations are two stations chosen to represent the upstream location, that have no industry. Kampung Sewu Solo and Bison Karanganyar are research stations chosen to represent middle stream locations, there are many industry. Whereas Ngawi, and Bojonegoro are research stations are located downstream (Figure 1).

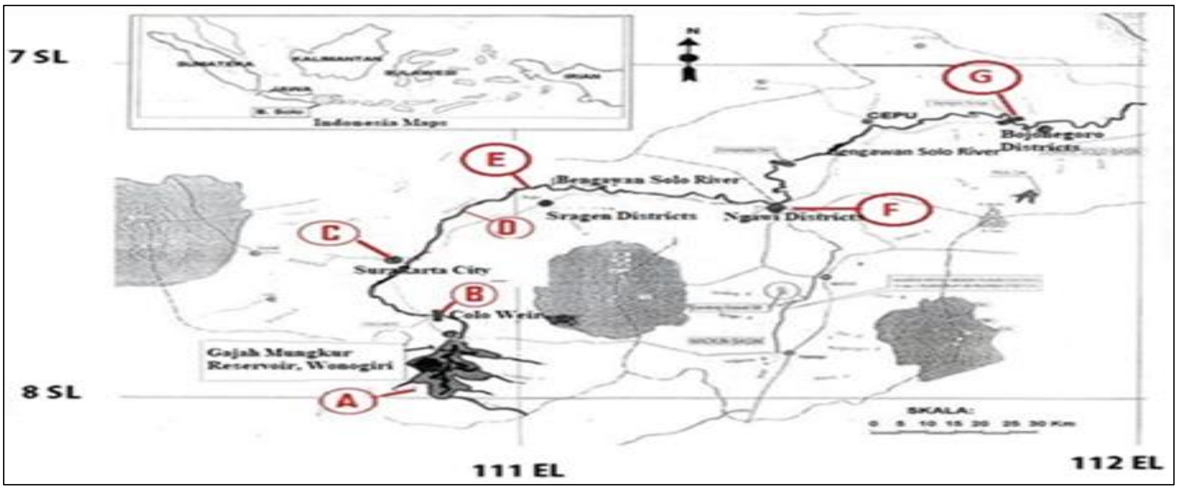

Figure 1. Map of research location (QGIS programe).

Note: Upstream zone: This zone is an area that is not much affected by industrial areas.

- (A) = Research Station in Gajah Mungkur Reservoir, Wonogiri Regency; there is no industry, but many aquaculture floating cages.
- (B) = Bendung Colo Village, Sukoharjo Regency research station; there is no industry,

Middle Stream zone: This zone has several industries, the location is downstream of zone I.

- (C) = Kampung Sewu Village, Solo City research station; there is a textile industry.
- (D) = Bison Village, Karanganyar Regency research station; there is the alcohol industry.
- (E) = Tenggak Village, Sragen Regency Research Station, there is no industry, but is near Bison Village (which has many industries).

Down Stream zone**:** This zone is located far downstream from the Industrial area (zone II)

- (F) = Ngawi Purba Village, Ngawi Regency research station. It's estimated that the effect of industrial waste from upstream will begin to decrease.
- (G) = Kabalan Village, Bojonegoro Regency Research Station, is located far downstream from the industrial area.

Water quality. Research on water quality parameters which was carried out insitu are temperature (T^{o}C) and pH. While the research for nitrate (NO_3), phosphate (PO_4), and ammonia (NH_3), was carried out in the laboratory. Water quality analysis method was based on APHA 2012 protocol (Table 1).

Table 1

Parameters and analysis methods (according to APHA 2012)

Parameters	*Unit*	*Methods and equipment*
Temperature	^{o}C	Insitu. Thermometer
pH	pH unit	Insitu. pH universal indicator
PO_4	mg/L	Exsitu. Vanadate molybdate methods, spectrophotometry.
NO_3	mg/L	Exsitu. Nessler methods, spectrophotometry.
NH_3	mg/L	Exsitu. Nessler methods, spectrophotometry.

Phytoplankton. Plankton was taken by filtering water with Plankton-net No. 25 on the surface layer, the volume of filtered water is 50 L. The phytoplankton net used is conical with a diameter of 35 cm and a height of 120 cm. The filtered phytoplankton is then placed in a vial bottle (100 ml), then lugol was added as a preservative solution. For examination of phytoplankton in the laboratory, 1 ml sample is taken into a Sedgwick rafter (SR), then an observation of phytoplankton under a microscope is done. The identification and abundance of phytoplankton refer to Needham and Needham (1963), Mizuno (1966), Edmonson (1966), and Pennak (1978).

1) Plankton abundance

Calculation of plankton abundance as follows (Wiadnyana & Wagey 2004):

$$N = n \times \frac{Vr}{Vo} \times \frac{1}{Vs} \times 1000$$

Information:

N = Number of cells per liter.

n = Number of individuals or cells based on observations.

Vr = Volume of filtered water (100 ml).

Vo = Observed volume of water (1 ml).

Vs = Volume of filtered water (50 L).

2) Diversity

Diversity index (H') is an index that shows the level of diversity of types of organisms that exist in a community. The calculation of the diversity index using the Shannon index equation is as follows (Bengen 2000).

$$H' = -\sum_{n=1}^{s} pi \ln pi$$

Information:

H' = Diversity index.

S = Number of plankton species.

pi = $\frac{ni}{N}$.

ni = Number of individuals of type i.

N = Total number of individuals.

Results. Water quality in the upstream zone (zone I) of Sukahardjo Regency is relatively better when compared to other locations with indications that ammonia (NH_3), phosphate (PO_4) and nitrate (NO_3) levels are still relatively low: ammonia content 0.07 mg L^{-1} during the rainy season and 1.319 mg L^{-1} during the dry season. Phosphate content 0.039 mg L^{-1} during the rainy season and 0.249 mg L^{-1} during the dry season. Nitrate content 0.164 mg L^{-1} during the rainy season and 1.10 mg L^{-1} during the dry season. This is because the upstream zone is an area that is not much affected by industrial estates so that organic matter pollution is relatively small.

Whereas in the middle zone (zone II) there is a decrease in water quality, especially during the dry season. In Kampung Sewu Village Solo City, ammonia content during the rainy season is 0.825 mg L^{-1} and during the dry season 7.38 mg L^{-1}; phosphate content during the rainy season is 0.392 mg L^{-1} and 1.487 mg L^{-1} in the dry season; nitrate content during the rainy season is 1.257 mg L^{-1} and 1.75 mg L^{-1} in the dry season. In Bison Village Karanganyar Regency, ammonia content during the rainy season is 1.31 mg L^{-1} and in the dry season is 9.87 mg L^{-1}; phosphate content during in rainy season is 0.8 mg L^{-1} and 3.48 mg L^{-1} in the dry season; nitrate content during the rainy season is 1.56 mg L^{-1} and 3.48 mg L^{-1} in the dry season. In Tanggak Village Sragen Regency, ammonia content during the rainy season is 0.15 mg L^{-1} and 5.58 mg L^{-1} during the dry season; phosphate content during the rainy season is 0.193 mg L^{-1} and 1.362 mg L^{-1} during the dry season. This is because the middle zone is an area that is heavily influenced by industrial areas so that organic matter pollution will be more.

In the downstream zone (zone III) the water quality is getting better because it has undergone self-purification in Ngawi Purba Village (Ngawi Regency): ammonia content during the rainy season was 0.031 mg L^{-1} and during the dry season 0.422 mg L^{-1}, phosphate content during the rainy season was 0.158 mg L^{-1}, and 0.98 mg L^{-1} in the dry season; nitrate content during the rainy season was 0.212 mg L^{-1} and 1.66 mg L^{-1} in the dry season. In Kanor Village, Bojonegoro Regency during the rainy season ammonia content was 0.018 mg L^{-1} and during the dry season 0.841 mg L^{-1}, phosphate content during the rainy season was 0.03 mg L^{-1} and during the dry season 0.99 mg L^{-1}, nitrate content during the rainy season was 0.094 mg L^{-1} and 0.094 mg L^{-1} in the dry season.

Table 2

Water quality in Bengawan Solo River during the rainy season, April 2020

Parameter	*Zone I*	*Zone II*			*Zone III*	
	Bendung Colo, Sukoharjo	*Kampung Sewu, Solo*	*Bison, Karanganyar*	*Tenggak, Sragen*	*Ngawi Purba, Ngawi*	*Kanor, Bojonegoro*
T°C	28.55	29.8	29.93	28.78	28	28
pH	7.62	7.75	7.38	7.37	8	8
NO_3 (mg L^{-1})	0.164	1.257	1.56	0.831	0.212	0.094
NH_3 (mg L^{-1})	0.07	0.825	1.31	0.15	0.031	0.018
PO_4 (mg L^{-1})	0.039	0.392	0.81	0.193	0.158	0.03
S	07°45'4"	07°34'37"	07°31'16"	07°23'58"	07°22'28"	07°45'4"
E	110°54'06"	110°50'38"	110°52'56"	110°57'03"	111°21'30"	111°54'06"

Table 3

Water Quality at Bengawan Solo River during the dry season, August 2020

Parameter	*Zone I*		*Zone II*		*Zone III*	
	Bendung Colo. Sukoharjo	*Kampung Sewu, Solo*	*Bison, Karanganyar*	*Tenggak, Sragen*	*Ngawi Purba, Ngawi*	*Kanor, Bojonegoro*
T°C	26	29,8	29,56	27	29,5	28-30
pH	7	7.66	7.9	7	8	7.5
NH_3 (mg L^{-1})	1.319	7.38	9.87	5.58	0.422	0.841
PO_4 (mg L^{-1})	0.249	1.487	3.294	1.362	0.98	0.99
NO_3 (mg L^{-1})	1.1	1.75	3.48	1.34	1.66	0.094
S	07°45′4″	07°34′37″	07°31′16″	07°23′58″	07°22′28″	07°45′4″
E	110°54′06″	110°50′38″	110°52′56″	110°57′03″	111°21′30″	111°54′06″

Distribution of phytoplankton. During the rainy season, the phytoplankton abundance in Bengawan Solo River ranges from 142-260 cells L^{-1} with an average of 191.7 cells L^{-1}. There are two classes of phytoplankton found, namely the Bacillariophyceae class which has six genera dominated by *Cyclotella* and *Synedra*, while the Chlorophyceae class has nine genera dominated by *Mougeotia, Pediastrum*, and *Staurastrum* (Table 4).

Compared to the rainy season, the abundance of phytoplankton in the dry season (August) was quite high, ranging between 198–1498 cells L^{-1} with an average of 844.57 cells L^{-1}. There are three classes of phytoplankton identified, namely the Bacillariophyceae class which has ten genera dominated by *Diatoma* and *Tablellaria*, the Chlorophyceae class has twelve genera dominated by *Chroococcus* and *Botryococcus* and the Cyanophyceae class has five genera dominated by *Oscillatoria* and *Anabaena*.

Table 4

Phytoplankton in April 2020 in the Bengawan Solo River (cells L^{-1})

Class	*Genera*	*Location*							
		A	*B*	*C*	*D*	*E*	*F*	*G*	*(%)*
1. Bacillariophyceae	1.*Cyclotella*	8	0	12	124	64	0	12	39.31
	2.*Diatoma*	8	16	0	6	0	24	14	12.14
	3.*Navicula*	12	10	4	0	4	6	18	9.64
	4.*Synedra*	46	34	8	0	8	10	0	18.92
	5.*Surirella*	8	0	6	12	16	8	0	8.92
	6.*Tabellaria*	0	0	8	0	8	24	22	11.07
	Sub total	82	60	38	142	100	72	66	
2. Chlorophyceae	1.*Closterium*	12	0	10	0	16	8	14	7.67
	2.*Chodatella*	10	10	0	0	16	0	0	4.60
	3.*Cosmarium*	0	14	16	6	0	10	14	7.67
	4.*Mougeotia*	82	10	0	84	0	42	0	27.87
	5.*Pediastrum*	0	24	16	14	64	0	0	15.14
	6.*Scenedesmus*	46	0	24	0	0	10	10	11.50
	7.*Selenastrum*	0	10	0	0	6	8	0	3.06
	8.*Staurastrum*	10	8	24	0	46	16	24	16.36
	9.*Tetraedron*	14	6	0	14	0	0	14	6.13
	Sub total	174	82	90	118	148	94	76	
Total		256	142	128	260	248	166	142	
Total species		11	8	10	7	7	11	9	
Diversity Index		2	2.1	2.1	1.3	1.9	2.1	2.1	

Note: A = Gajah Mungkur Reservoir at Wonogiri districts; B = Bendung Colo at Sukoharjo districts; C = Kampung Sewu at Solo city; D = Bison at Karanganyar districts; E = Tenggak at Sragen districts; F = Ngawi Purba at Ngawi districts; G = Kabalan at Bojonegoro districts.

Table 5

Phytoplankton in August 2020 on the Bengawan Solo River (cells L^{-1})

Class	*Genera*	*Location*							
		A	*B*	*C*	*D*	*E*	*F*	*G*	*(%)*
1.Bacillariophyceae	1. *Coscinodiscus*	0	0	0	6	0	0	0	2.81
	2. *Diatoma*	14	0	42	10	24	106	34	26.43
	3. *Navicula*	0	12	0	24	10	12	0	6.66
	4. *Nitzschia*	0	0	12	0	64	0	32	12.41
	5. *Pinnularia*	0	0	0	4	0	0	0	0.45
	6. *Surirella*	0	0	0	26	0	0	0	2.98
	7. *Synedra*	0	18	14	12	0	22	42	12.41
	8. *Cymbella*	0	0	6	0	24	0	10	4.59
	9. *Cyclotella*	24	10	0	0	24	22	46	14.48
	10. *Tabellaria*	64	0	12	0	42	28	0	16.78
	Sub total	102	40	86	82	188	190	164	
2. Chlorophyceae	1. *Chroococcus*	0	0	0	624	0	0	0	25.01
	2. *Closterium*	0	8	12	42	0	8	0	2.40
	3. *Coelastrum*	0	0	0	32	0	0	0	1.09
	4. *Cosmarium*	0	24	0	4	0	0	0	0.96
	5. *Cyclotella*	0	0	0	44	0	0	0	1.51
	6. *Mougeotia*	0	0	0	8	0	0	0	0.27
	7. *Pediastrum*	68	0	0	152	16	12	46	10.1
	8. *Scenedesmus*	46	0	0	8	0	0	0	1.85
	9. *Sphaerocystis*	0	0	0	42	0	0	0	1.44
	10. *Spondylosium*	6	44	0	16	0	0	0	2.26
	11. *Staurastrum*	0	24	0	0	0	0	0	0.82
	12. *Tetraedron*	8	0	0	14	0	0	0	0.75
	13. *Botryococcus*	0	0	0	0	286	220	420	31.82
	14. *Spirogyra*	0	0	46	0	0	0	28	2.54
	15. *Ulothrix*	0	0	150	0	54	0	86	9.96
	16. *Ankistrodesmus*	6	0	0	0	0	0	0	0.2
	17. *Actinastrum*	22	0	0	0	0	0	0	0.75
	18. *Cladophora*	122	6	0	0	0	0	0	4.39
	19. *Chodatella*	0	42	0	0	0	0	0	1.44
	20. *Selenastrum*	0	10	0	0	0	0	0	0.44
	Sub total	278	158	208	986	356	240	580	
3. Cyanophyceae	1. *Anabaena*	0	0	126	64	108	0	18	17.42
	2. *Gomphosphaeria*	0	0	64	64	0	0	124	13.89
	3. *Microcystis*	0	0	0	60	0	0	0	3.3
	4. *Oscillatoria*	642	0	0	224	192	86	24	64.38
	5. *Spirulina*	18	0	0	0	0	0	0	1.01
	Sub total	660	0	190	412	300	86	166	
Total		1040	198	484	1480	844	516	910	
Total Species		12	10	10	21	11	9	12	
Diversity Index		1.43	2.10	1.80	1.65	1.80	1.86	2.08	

Note: A = Gajah Mungkur Reservoir at Wonogiri districts; B = Bendung Colo at Sukoharjo districts; C = Kampung Sewu at Solo city; D = Bison at Karanganyar districts; E = Tenggak at Sragen districts; F = Ngawi Purba at Ngawi districts; G = Kabalan at Bojonegoro districts.

Discussion. Water quality of the rainy season is relatively better than in the dry season, with an indication that the content of nitrate, phosphate, and ammonia in the rainy season is lower than the dry season (Table 2 and Table 3). This is because the high volume of water in the rainy season will further dilute the pollutants in the river. The opposite occurs in the dry season, where a low volume of water will cause pollutants to be more concentrated.

The content of ammonia (NH_3), nitrate (NO_3), and phosphate (PO_4) is quite high in the dry season, especially in polluted areas (zone II). The content of ammonia in the water can come from the decomposition of organic pollutants and their high content in the water. This indicates the presence of organic matter pollution in these waters, where levels of free ammonia exceeding 0.2 mg L^{-1} can cause the death of several types of fish (Sawyer & McCarty in Effendi 2000). According to Novotny and Olem (1994), the total nitrogen content is eutrophic if the total nitrogen content is >0.5 mg L^{-1}. High nitrogen content can be caused by organic waste from industry. High phosphate levels are also an indicator that the waters have been polluted by organic matter. Phosphate levels in natural waters only range from 0.005-0.02 mg L^{-1}. Excessive levels of phosphate will cause the development of algae which can inhibit the penetration of sunlight into the water so that the aquatic ecosystem is disturbed (Boyd 1988).

According to Utomo et al (2010), the water quality in the Bengawan Solo River during the dry season is worse than during the rainy season, especially in the Solo–Sragen area. During the dry season, the oxygen content is 0–1.94 mg L^{-1}, while during the rainy season it is 4–4.7 mg L^{-1}. When high temperatures are above 30^{o}C, oxygen consumption will increase (Schmittou 1991). The temperature in the waters of the Bengawan Solo River ranges from 27-30^{o}C, this range is still feasible for freshwater fish life. The pH in the waters of the Bengawan Solo River is still suitable for fish, which ranges from 7-8. Most of the freshwater organisms live in the pH range 7-8.5 (Novotny & Olem 1994).

The abundance of phytoplankton in the dry season was higher (average 844.57 cells L^{-1}) than in the rainy season (average 191.7 cells L^{-1}) (Table 4 and Table 5). Because the volume of water in the dry season is lower and more concentrated than the volume of water in the rainy season which is higher and dilutes. Heavily polluted waters will cause eutrophic (high fertility) which has the potential to increase the development of blue algae, *Cyanobacteria*, and Microcystin. Blue algae can produce toxins that are harmful to aquatic organisms and humans, the types of toxins include microcystin, anatoxin, saxitoxin. Microcystin is produced by several genera of blue algae, namely *Anabaena*, *Coelosphaerium*, *Lyngbya*, *Microcystis*, *Oscillatoria*, *Nostoc*, *Hapalosiphon*, and *Anabaenopsis* (Lindon & Heiskary 2009).

Cyanophyceae class was not found in the Bengawan Solo River during the rainy season, but in the dry season where the abundance of Cyanophyceae was on average 259 cells L^{-1} and dominated by *Anabaena* and *Oscillatoria* (Table 5). Phytoplankton from the Cyanophyceae class is a blue-green algae that is generally disliked by fish because it has a thick cell wall that is difficult to digest and poison. Some blue-green algae produce toxins that can cause death to aquatic organisms and harm human health (Chorus & Bartram 1999; Lindon & Heiskary 2009; Retnaningdyah et al 2011; Huang & Zimba 2019).

The highest phytoplankton abundance at Bison Karanganyar Station (Station D) is in the range of 260-1480 cells L^{-1} with an average of 870 cells L^{-1} because in Bison there is a lot of organic material input from the industry around it (especially alcohol industry) (Utomo et al 2006; Utomo 2007). Furthermore, the second-highest phytoplankton abundance is at Gajah Mungkur Reservoir station (Station A) between 256-1040 cells L^{-1} with an average of 648 cells L^{-1}, and this is due in the Gajah Mungkur reservoir there are approximately 1100 plots of floating net cages. Feed that escapes from floating net cages into water will cause nutrient enrichment (eutrophication) in reservoir waters (Garno 2002; Utomo 2013). The importance of nutrient content in the waters is closely related to the phytoplankton abundance, where the higher the nutrient content in the waters, the higher the phytoplankton and vice versa. The abundance of phytoplankton class Bacillariophyceae and class Cyanophyceae in waters is very high due to the presence of organic waste, which is the main supply of phosphorus and nitrogen needed by phytoplankton for growth (Maresi et al 2015; Sari et al 2021).

Organic pollution in the waters of Bison Karanganyar District and Gajah Mungkur Reservoir also caused the diversity of phytoplankton to shrink. The lowest phytoplankton diversity index (H) at Bison Karanganyar station is 1.3-1.65. Furthermore, at the Gajah Mungkur Reservoir research station (station A) the phytoplankton diversity index was

1.43-2. This is by the research of Setyowati and Roziaty (2017), which states that based on the phytoplankton diversity index, the water quality of the Karanganyar river is classified as heavily polluted and the quality of biota is unstable.

Bendung Colo research station, station B (control location, no industry, and no floating cages); which is a station in the upstream of the industrial pollution area, the lowest phytoplankton abundance compared to other stations that are 142-198 cells L^{-1} with an average of 170 cells L^{-1} and the highest phytoplankton diversity index is 2.1, this is due to the fact that there is less input of organic pollution from outside than other research stations.

Furthermore, sequentially starting from the station in the industrial area (D) which has the highest phytoplankton abundance and the lowest phytoplankton diversity index, after heading downstream Tenggak Sragen (E) to Kanor Bojonegoro (G) phytoplankton abundance decreases and phytoplankton diversity increases, this is due to the downward recovery of pollution (self-purification). Naturally, aquatic ecosystems can overcome the problem of pollution. The ability of water bodies to conduct self-purification from the effects of pollution can be carried out by biological activities that live in these water, oxidation of pollutants by aerobic organisms, and diffusion of oxygen from the air into the waters. In rivers, because the water is flowing self-purification will be faster, because the diffusion of oxygen from the air to the waters is faster (Bogdał et al 2016; Policht-Latawiec et al 2015; Effendi et al 2016; Zubaidah et al 2019). Even though Bengawan Solo River flows, however the volume of water is small because it is widely used for agriculture, high pollution, and slow currents especially during the dry season, so that the process of self-purification of organic material pollution in waters is very slow (Aida et al 2019; Utomo et al 2019). Based on the diversity and abundance of phytoplankton, it can be assumed that the recovery of pollution from Karanganyar Districk in Central Java will end in the Bojonegoro East Java Kanor area, which is estimated to reach 260 km.

Conclusions. Phytoplankton abundance during the dry season is higher than during the rainy season. In the rainy season no Cyanophyceae, while during the dry season Cyanophyceae begin to exist, and is dominated by *Anabaena* and *Oscillatoria*. The highest phytoplankton abundance is in the village of Bison, which is a polluted area, but has the lowest phytoplankton diversity index. Based on the species, diversity, and abundance of phytoplankton, it can be assumed that the recovery of the impact of pollution originating from Bison Village, Karanganyar Regency, Central Java will end in the Kabalan village, Bojonegoro Regency, East Java, which is an estimated distance of 260 km.

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