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Research Article

Evaluation of water quality in the swamp river border using water quality index

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Abstract: As a source of minerals, water must be continuously maintained, including in term of its quality. Meanwhile, swamps are wetlands that have the potential to experience a decline in water quality. The presence of river borders in swamps has been known to maintain their water quality. Vegetation cover of the river border is established through restoration activities in which it is expected, directly and indirectly, to improve water quality. This study aimed to investigate the water quality in swamp using the Water Quality Index (WQI). Surveys were carried out and samples were collected to determine the effect of restoration on river border in swamps. Samples were collected severally, namely prior to restoration (T0), first year (T1), third year (T3) and fourth year (T4) after restoration. The parameters for water quality of T0 and T1 include pH, DO, BOD, TDS, turbidity and nitrate, while for T3 and T4 include: pH, DO, BOD, TDS, temperature, phosphate, *E. coli* and nitrate. The findings indicated that the WQI of the swamp prior to restoration was greater than that at the first year of restoration due to the process of land clearing. Meanwhile, the WQI at the third year has improved compared to before the restoration and land clearing phase. It suggests that the presence of vegetation on river border is able to improve the water quality. At the fourth year, a fire in the upstream reached the area adjacent to the study site. It led to a decline in surface water quality and affected the water quality index. Furthermore, the abundance of aquatic biota was indicated by two taxa of zooplankton in the third year of restoration while none of them was identified in the fourth year. In overall, restoration activities on the river border improve the quality of water in swamps in a sustainable manner.

Keywords: *restoration, swamp, vegetation, water quality*

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Introduction

The quality of water is vital, considering the function of water as the source of all life. In general, water quality index reveals the quality of the environment around water bodies, including in peat swamps. Rasidah et al., (2017) found that despite the water in peatland has pH values in the range from 3 to 4, yellowish-brown color and high levels of organic, iron and manganese, it has the potential as raw water with certain processes. Meanwhile, peatland is a life support system (Irma et al., 2017) which sustainability must be prevailed. In fact, any damage may lead to a decline in water quality. Hence, potential damage must be overcome immediately considering the essential role of peat swamps for ecosystems and biodiversity (Sudrajat and Subekti, 2019).

River border is the parts located on the banks of the river in which its existence indicates the health of a river. According to Fachrudin and Lubis (2016), river border is capable of maintaining water quality. Similarly, Maryono (2009) suggested the direct influence of river border on the river including its physical, ecological, hydraulic and morphological changes. In general, a healthy river border is indicated by the condition of the vegetation cover. It is claimed to inhibit any possible contamination in the river. Moreover, vegetation on the river border also has an inhibiting effect on sedimentation and erosion, as well as a positive influence on aquatic organisms living in mud-free water (Jones et al., 1999).

The Water Quality Index (WQI) has been frequently employed for assessing water quality in swamps. This index expresses the water quality of rivers, which is very useful in devising any improvement plans (Bordalo et al., 2006). Nevertheless, the changes in vegetation covers on swamps are known to affect the values of WQI, both directly and indirectly. An effort to improve the swamp ecosystem is through restoration. It has been highlighted to improve an existing ecosystem (Menberu et al., 2017). Furthermore, revegetation is an activity of restoration plans (Waluyo and Nurlia, 2017). According to Anggana and Ahmadi (2018), such activity can involve local plants that is very useful for the restoration of swamps, particularly in river borders. This study aimed to investigate the values of WQI in swamps and compared the values after and before restoration.

Materials and Methods

P5 River or Sungai P5 is located in Pawalutan village, Banjang subdistrict, North Hulu Sungai Regency, South Kalimantan, Indonesia. Restoration has been done in this area, approximately 8.8 km in length and 5-7 m in width. Several native plants are used, including *Ketapang (Terminalia catappa* L.*), Sengon (Paraserianthes falcataria* (L) Nielsen*, Trembesi (Samanea saman), Meranti Rawa (Shorea balangeran), Galam (Melaleuca leucadendron)* and *Jelutung Rawa (Dyera costulata)* (Anggana and Ahmadi, 2018). The study site is specified in Figure 1.

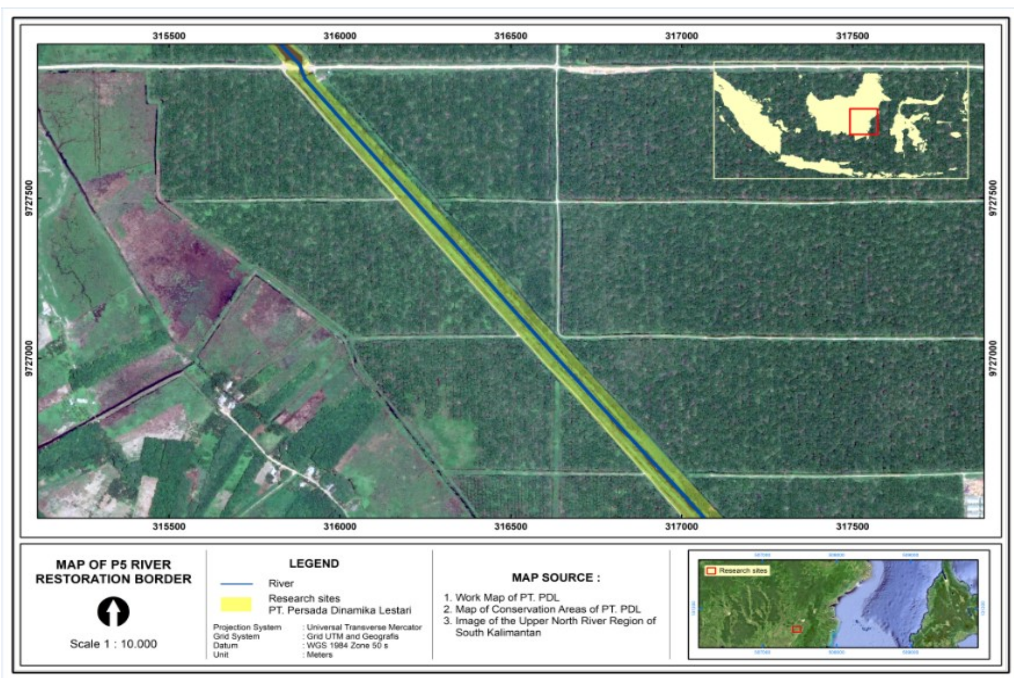

Figure 1. The study site.

In the present study, the survey method has been selected and samples of surface water have been collected to determine the effect of the restoration on the river border of swamp. Samples of surface water were collected prior to the restoration activities (T0), and first year (T1), third year (T3) and fourth year (T4) after restoration. Several parameters were examined for the water quality of T0 and T1, namely: *pH*, *DO (Dissolved Oxygen)*, *BOD* (*Biochemical oxygen demand)*, *TDS* (Total dissolved solids), *turbidity* and *nitrate*. Meanwhile, parameters for T3 and T4 include *pH*, *DO*, *BOD*, *TDS*, *temperature*, *phosphate*, *E. coli* and *nitrate*. In addition to the assessment on the water quality, the abundance of aquatic biota on T3 and T4 was also examined, particularly on the abundance of Plankton and Benthos.

Water Quality Index

The formula used to determine the WQI is based on the National Sanitation Foundation Water Quality Index (NSF-WQI) that can be noticed in the following expression:

NSF-WQI = $\sum_{i=0}^{n} Wi \times Li$………………….. (1)

where:

NSF-WQI	=	the water quality index,
Wi	=	the weight,
Li	=	the sub-index obtained from curves.

The results of water quality data analysis is further used to determine the criteria for each sample as presented in Table 1.

Table 1. Criteria of Water Quality Index

No	NSF-WQI Score	Criteria
1.	0 – 25	Very bad
2.	26 – 50	Bad
3.	51 – 70	Medium
4.	71 – 90	Good
5.	91 – 100	Excellent

Source: Water Research Center, 2019

Level of biodiversity

In this study to determine species diversity using the Shannon-Weaver Diversity Index (H') according to Gagan et al. (2018). The equation as follows:

$$H = -\sum [Pi \ln Pi] \qquad P = \frac{Ni}{N}$$

where:

H '	:	Shannon Index
Ni	:	Number of individuals
N	:	Number of all types

Results and Discussion

Water Quality Index

The analysis of the water quality index shows the changes in the quality of surface water in the study site. The results of data analysis are presented in Table 2. Based on the result, the quality of surface water prior to the restoration (T0) and in the first year of restoration (T1) have the same criteria, despite their different index values. T0 has a higher index than T1 allegedly due to the preparation on the river border for the restoration process. It leads to the higher content of both BOD and TDS. Nirtha (2014) suggests such preparation possibly causes erosion that eventually affects the TDS in water bodies. Based on the results of laboratory analysis, it can be seen an increase in the value of TDS caused by erosion on the banks of the river, in this case an increase in the value of TDS from 32 mg/L to 83 mg/L. Likewise, Salim and Dharmawan (2017) affirm that the increase in TDS is due to the addition of dissolved materials that influence the turbidity of the waters and inhibits light penetration, leading to the higher content of BOD. Syofyan (2019) claims that BOD is the oxygen needed by microorganisms to decompose organic matters; thus, the increase in TDS will affect aquatic life or water quality. The same results were also found in the water quality index of T3 and T4. Based on the results of the analysis, T3 has a higher index than T4. The values are 55.235 and 48.133, respectively, in which T3 is classified Medium while T4 is classified Bad. Based on the results of the data analysis, the WQI of T3 is higher than the index of T0 and T1. It shows that restoration activities on the river border could improve water quality. Land management and appropriate land-use have a positive effect on water quality (Ahmad, 2019) reaffirm the significance of vegetation cover on the amount of suspended solids in water bodies. The presence of plants around water bodies plays an important role in aquatic ecosystems (Ayu et al., 2017). Table 2 shows the decline in water quality of the fourth year after the restoration (T4) compared to the previous year (T3). The survey in the field revealed that this declined quality was allegedly caused by a fire in the upstream adjacent to the study site. It adversely impacted the surface water quality, leading to the lower WQI compared to the previous year. The results of water quality assessment disclose the decrease of several parameters, including pH, temperature, nitrate and TDS. It has been reported by Wasis et al. (2019) that fire can be devastating for the hydrological conditions of the land. Fire causes vegetation, litter and microorganisms to disappear so that it will damage the soil structure. Damage to the structure will hamper hydrological processes such as interception, evapotranspiration, infiltration and runoff (Depari et al., 2009).

Abundance of aquatic biota

The abundance of aquatic biota has been observed thoroughly after the restoration activities. This observation is substantial to signify the necessity of water quality as a source of a variety of life both for humans, flora and fauna (Rehnuma et al., 2016). The observation results of WQI Analysis on T3 and T4 are presented in Table 2.

Table 2. Result of WQI Analysis on T0, T1, T3 and T4.

No	Parameter (unit)	T0				T1				T3				T4			
		TV	**Qe**	**WF**	**Calc**	**TV**	**Qe**	**WF**	**Calc**	**TV**	**Qe**	**WF**	**Calc**	**TV**	**Qe**	**WF**	**Calc**
1	DO (mg/L)	4.21	3.5	0.23	0.805	5.52	4.25	0.23	0.978	6.300	5.060	0.180	0.911	6.410	5.125	0.180	0.923
2	pH	5.83	51.125	0.17	8.691	5.21	31.75	0.17	5.398	5.780	47.250	0.120	5.670	4.620	18.000	0.120	2.160
3	BOD (mg/L)	5.21	53.125	0.17	9.031	13.25	24.125	0.17	4.101	16.500	17.500	0.120	2.100	16.500	17.500	0.120	2.100
4	Nitrate (mg/L)	0.042	98	0.16	15.680	0.6	95.5	0.16	15.280	0.189	97.250	0.110	10.698	0.480	96.060	0.110	10.567
5	Turbidity (NTU)	52	37.75	0.14	5.285	70	28	0.14	3.920	-	-	-	-	-	-	-	-
6	TDS (mg/L)	38	87.31	0.13	11.350	82	86.72	0.13	11.274	40.000	88.120	0.080	7.050	408.000	45.820	0.080	3.666
7	Temperature (°C)	-	-	-	-	-	-	-	-	27.700	12.180	0.110	1.340	29.700	10.625	0.110	1.169
8	E. Coli (CFU/100ml)	-	-	-	-	-	-	-	-	0.000	98.000	0.170	16.660	0.000	98.000	0.170	16.660
9	Phosphate (mg/L)	-	-	-	-	-	-	-	-	0.034	98.250	0.110	10.808	0.003	99.000	0.110	10.890
	NSF-WQI Score				50.843				40.950				55.235				48.133
	Criteria				Bad				Bad				Medium				Bad

Remark: TQ = Tested Value, laboratory analysis result; QV = Q Value, Modified values based on Q value recommendations from Water Research Center (2019); WF = Weight Factor, modification of weights is based on recommended parameter values from Water Research Center (2019); and Calc = Calculation, water quality value per parameter.

Table 3. Identification of phytoplankton, zooplankton, and benthos.

No	Phylum	Genera	Year	
			T3	T4
Phytoplankton				
1	Cyanophyta	*Oscillatoria*	24	8
		Aphanozomenon	8	
		Spirulina		8
		Anabaenopsis		8
		Colothrix		8
2	Chlorophyta	*Gonatozygon*	100	
		Ankistrodesmus spiralis	24	
		Binuclearia w	16	
		Sphaeroystus schroctery		24
		Spirogyra	16	
3	Chrysophyta	*Rhizosolenia imbicata*		12
		Streptotheca	12	24
		Synedra	28	8
		Thallasiossira sp	32	8
4	Freshwater diatom	*Eunotia teetrodon*		40
Abundance (cells/liter)			260	96
Diversity Index (Shannon-Wiener)			2.7374	1.5397
Evenness Index			0.8636	0.8593
Dominance Index			0.2024	0.2245
Number of Taxa			9	5
Zooplankton				
1	Protozoa	*Dinobryon stipitatum*	0	
2	Aschelmintes	*Notholca*	4	
3	Crustacea	*Spongilla aspinosa*	22	
Abundance (Individual/liter)			26	
Diversity Index (Shannon-Wiener)			0.6194	
Evenness Index			0.6194	
Dominance Index			0.7396	
Number of Taxa			2	
Benthos				
1	Annelid	*Olligochaeta*		
2	Mollusca	*Vivipandae*	132	
3	Insect	*Gomphidae*	44	
Abundance (Individual/m^2)			176	
Diversity Index (Shannon-Wiener)			0.8113	
Evenness Index			0.8113	
Dominance Index			0.625	
Number of Taxa			2	

Phytoplankton, zooplankton and benthos on the third year (T3) and fourth year (T4) after the restoration are presented in Table 3. The identification reveals the changes in the abundance of aquatic biota in the third year (T3) and fourth year (T4) after the restoration, in which a fire occurred in the fourth year. The abundance of phytoplankton in T3 is 260 cells/liter with *Evenness index* (*E*) of 2.7374, and a total of nine taxa. Meanwhile, in T4, the abundance is 96 cells/liter, with *E* of 1.5397, and a total of five taxa. These changes are accompanied by changes in the abundance of zooplankton. The identification process reveals only two taxa of zooplankton in T4, and none on the subsequent year. The same phenomenon is also observed in the abundance of benthos. The fire adversely affected the abundance of benthos as indicated by none of them were found after the fire occurred or during the fourth year after the restoration. Meanwhile, two taxa were still observed within the third year after the restoration (T3). Specifically, the abundance of benthos in T3 is 176/m^2 and *E* of 0.8113, with a total of two taxa.

It suggests that fire has a huge destructive impact, including the deterioration of water quality and the reduction rate in the abundance of phytoplankton, zooplankton and benthos. It has been argued by Wasis et al. (2019) that forest fires cause tremendous damage to the ecosystems, both abiotic and biotic.

Conclusion

The assessment on the water quality of swamps before the restoration reveals that it has a higher water quality index (WQI) than the condition in the first year of the restoration due to the preparation phase or land clearing process. Furthermore, the value of WQI in the third year after the initiation of restoration activities is higher than the values obtained before and in the first year of the restoration. It suggests the vegetation cover on the river border can improve the water quality. In the fourth year after the restoration, a fire occurred in the upstream of the river adjacent to the study site. It caused a decline in surface water quality, leading to a lower value of WQI compared to previous observed years. Restoration activities are a constructive effort to improve the water quality, one of which is through the revegetation of native plants. Nevertheless, maintenance and monitoring on a regular basis are required to ensure the sustainable functions of the river border.

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