INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 9, No. 5, p. 66-77, 2016

RESEARCH PAPER OPEN ACCESS

The dynamics of phytoplanktonic community in relation to water quality regimes, In flood plain of Bangkau Swampy lake, South Kalimantan, Indonesia

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Key words: Phytoplankton, Flood plain, Swampy lake, Water quality

http://dx.doi.org/10.12692/ijb/9.5.66-77 Article published on November 21, 2016

Abstract

This research aims to investigate the the effect of the dynamic of water physico-chemical changes to structural community of phytoplantonic creatures in swampy flood plain. Water samples were taken in May to November 2015 in Bangkau swampy flood plain. Multivariate analysis non-metric multidimension scaling (NMDS) was used for statistically analysis the relationship of biotic and water physico-chemical data. *Oscillatoria*, *Gonatozygon* and *Thallasiossira* are three of twenty species, which they always present in each observations. Abundance of phytoplanktonic ranges between 148 to 23,740 cell L^{-1}. The presence of phytoplanktonic mainly abundance in November (16 to 20 genera) and very rare in May. Identified 20 genera, there 6 genera have a correlation to the dynamic of water quality parameters. *Binuclearia* and *Cryptomonas* have positiey correlated to parameters of depth, SO_4 and PO_4. Both *Binuclearia* and *Cryptomonas* were present dominantly in May and June. In the other hand, *Oscillatoria* (Cyanophyta), *Sphaeroplea* (Chlorophyta), *Diatoma* and *Nitszchia* (Chrysophyta) shows negatively correlated to the dinamic water quality.

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Introduction

Bangkau swampy lake is siatuated at western part of South Kalimantan, Indonesia. It is a monotone swamp which is bordered by flooding swampy plain. The change of surface water create high variation of lake width. In the dry season, the depth of surface water droops and is collected in the middle of lake, while in the rainy season the width of lake expands in larger area.

The dynamic of water depth is the most important environmental parameter in aquatic environment of flood plain (Mihaljevi´c *et al.,*2010), because of as a hub of energy, material and organisme between theriver and flood plain (Tockner and Stanford, 2002).

The different of water depth between dry and rain season can possibly interact between hidrology and ecology (Junk *et al*., 1989; Junk and Wantzen, 2004) that it differenciates physico-chemical aquatic characteristic and biological adaptation.

The different of water fluctuation may affect to the change of behavior and pattern of local fish migration (Lowe-McConell, 1989; Schagerl *et al*., 2009). During flooding, aquatic environmental diversity is reduced (Cardoso *et al*., 2012).

As a natural flood plain ecosystem, such as Bangkau Swampy Lake is the ecosystem which has high productivity and biodiversity (Mihaljević *et al*., 2013). However it is the most threated and sensitve ecosystem. It's degradation will affect to reduction of biodiversity and aquatc productvity.

Trend of reducing of fishing yield has been detected by local fisherman since the last five years. Therefore, management and habitat conservation of flood plain must be revitalized for sustaining the ecosystem (Abdullah-Al Mamun, 2010).

The success of management and conservation of flood plain swamp will be determined by the understanding to environmental aquatic condition, which consists of quantity and physico-chemical fluctuation of water (Alam *et al*., 2016), and biological communty in this ecosystem. Planktonic organisms is the first biological comunity that will gives dinamically response to the aquatic changes(Kozak *et al*., 2015; Yu *et al*.,2016). Thus, planktonic organism presence in aquatic environment can be used to be an indicator for aquatic condition and water producivity level.

Materials and methods

Study area

Bangkau swampy lake is located in western part of Meratus highland with plain topographic lowland. According to hydrological processes maintaining the wetland, this lake is categorised to be a basin landform type (Semeniuk, 2011). Almost al of surface water is covered by emergen

t and free-floating plants.Administratively, Bangkau lake has been registered in Hulu Sungai Selatan District of South Kalimantan, Indonesia. Geographycally, it is located at 2°37'30"S - 2°40'18"S dan 115°11'06"E - 115°13'02"E., with area covers of 65 Ha. This lake has flooding area which increases in rainy season dramatically.

Sampling site and sample processing

The dynamics of phytoplankton community and physical-chemical features of Danau Bangkau swampy flood plain waters were observed from May 2015 to November 2015.

The data of phytoplankton and water quality were taken regularly every monthin every last week. Three sampling sites were chosen to be evaluated for featuring of phytoplanktonic community and water quality parameters (Fig.1).

Planktonic samples weretaken by filtering water from (0 – 30 cm) depth from the surface using plankton net No. 20. About 15 ml of concentrated filtered water was added by 4 drops of 48% formaldehide. Phytoplanktonic creatures were identified and counted at 400x magnification using Binocular microscope.

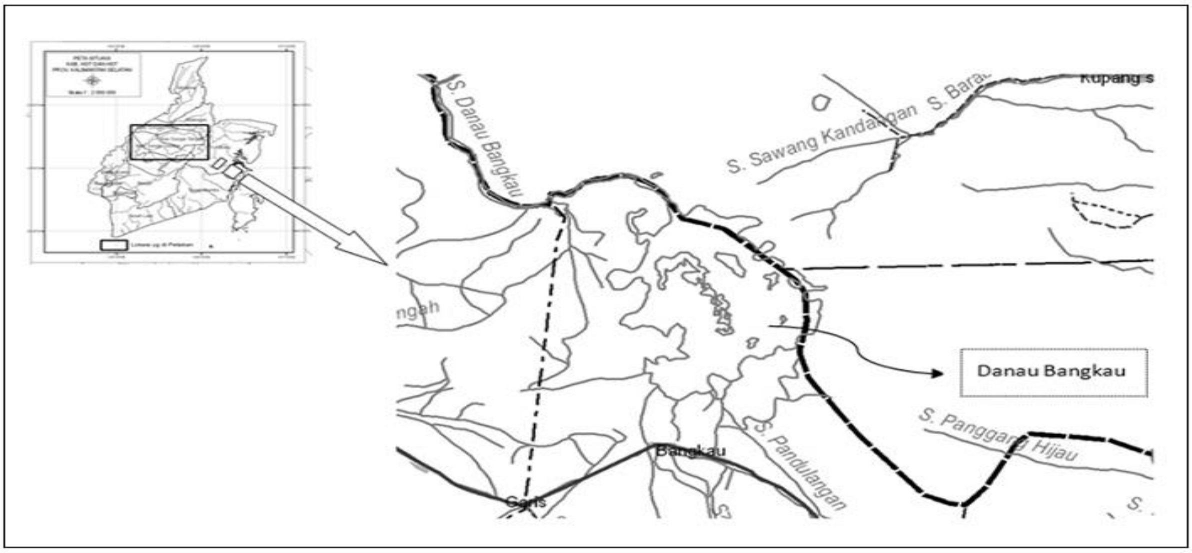


Fig. 1. Sampling location at Bangkau swampy.

In laboratory, phytoplanktonic sample was poured into sedimentation-flask, kept in the dark compartment for 3x magnification to let phytoplanktonic cells completely settle to the flask bottom. Identifying phytoplanktonictaxa were doneat species level with refering to Edmonsond (1964); Prescott (1970); Entwisle, *et al.* (1997); Wehr and sheath, (2003); Peerapornpisal (2005). Recent systematic synonym and validity of the taxa were checked from the www.algaebase.org. (Guiry, 2014). Water samples were taken from euphotic zone, 0 – 30 cm depth from water surface using Van Dorn Water Sampler (APHA, 1998). Water quality was directly measured, *in situ* on the foeld and in laboratoium, which is consist of Water temperature, depth, transperancy, total dissolved solid (TDS). Total suspended solid (TSS), electric conductivity (EC), pH and dissolved oxygen (DO) were measured in site using Horiba U-10 water checker. The measurement of other parameters (BOD, COD, NH_3-N, NO_3-N, NO_2-N, PO_4-P, Fe dan SO_4.) had been done in laboratory used Horiba U-25 spectrophotometric. Water samples were preserved in flexiglass for laboratory analyses as described by the American Public Health Association (APHA, 1998).

Data analysis

Phytoplankton community

Phytoplanktonic community structure were analysed, which includes abundance, biodiversity, similarity, dominance indices was calculated by rational method. The abundance of phytoplankton was calculated as:

$$N = \frac{1}{p} \sum_{n=1}^{p} \left(n \times \frac{a}{s} \times \frac{1}{v} \right)$$

where: *N* = abundance ofplanktonic organisme per liter; *n* = number ofphytoplanktonic cellsin observation at i; *a* = volume of concentrated water (ml); s = volume of water sampled (ml); v = volume of filtered water(liter); p = number of observation.

Shannon's diversity index (H) (Maguran, 2004) as measure of the abundance and evenness of species present in a sample was calculated at each sampling site. The index is difined as:

$$H = \sum_{i=1}^{s} Pi \times \ln Pi$$

where: *Pi* is the number of individuals of each species divided by the total number of individuals of all species in each sample and *S* is the total number of individuals of all species.

Shannon's evenness index (E) (Maguran, 2004) was calculated as:

$$E = \frac{H}{\ln Pi}$$

Where: H = shannon's diversity index. This indexs lies between 0 and 1, with 1 being complete evenness.

Relation of water quality and phytoplanktonic community

Non-Metric Multidimensional Scaling (NMDS) with env.fit to ordination (scalling) was used to summarize phytoplanktonic data variation in relation to extract environmental factors, which is affecting phytoplanktonic community. Statistical program of R ver.2.8.0., especially the vegan package for NMDS was used to analyze data and drawing figure (RDCT, 2008). Independent variables consist of physico-chemical parameters of water and dependent variables areabundance (N), diversity (Div), Eveness (Eve) dan dominancy (Dom). Especially for the data matrix abundance of phytoplankton species (dependent variable, Y) transformation with the function Log (x + 1) prior to analysis, to reduce the abnormal data. NMDS analysis of the matrix dependent variable (Y) using the Bray-Curtis dissimilarity, double standardization

Results and discussion

Phytoplanktonic organism diversity

There are 20 genera of 3 phylum were found, such as Cyanophyta (3 genera), Chlorophyta (9 genera) and Chrysophyta (8 genera). Genera of phytoplanktonic organisms that were frequently found in each observation are *Oscillatoria* (Cyanophyta), *Gonatozygon* (Chlorophyta) and *Thallasiossira* (Chrysophyta)with abundance of 8 – 5,994 cells L^{-1}, 8- 667 cells L^{-1}dan 13 – 180 cells L^{-1}repectively.

Table 1. Phytoplanktonic structural community indices and abundance (May 2015 – Nov 2015).

No.	Genera	Code	Phyllum	May	June	July	August	Sept	Oct	Nov
1	*Oscillatoria*	*Osc*	Cyanophyta	8	20	4,686	2,450	1,670	1,466	5,994
2	*Coelosphaerium*	*Coe*								8,970
3	*Lingbya*	*Ling*			320	32		32		
4	*Gonatozygon*	*Gona*	Chloropyta	12	30	8	25	8	27	667
5	*Ankistrodesmus*	*Anki*					7		7	333
6	*Spirogyra*	*Spiro*				2,480	1,367	480	1,367	
7	*Trichodesmus*	*Trich*				160		155		
8	*Sphaeroplea*	*Sph*			17	80	17	75	17	
9	*Binuclearia*	*Binu*		45	120		7		7	648
10	*Netrium*	*Netr*		14						245
11	*Rhizosolenia*	*Rhiz*			6					256
12	*Cryptomonas*	*Cryp*			364					333
13	*Dytilium*	*Dyti*	Chrysophyta				13		13	333
14	*Diatoma*	*Dia*			7	32	50	19	50	2,333
15	*Coscinodiscus*	*Cosc*								665
16	*Thallasiossira*	*Thall*		25	13	16	60	13	60	180
17	*Streptotheca*	*Strep*		8	3		13		13	450
18	*Brebissonia*	*Breb*		8						333
19	*Nitszchia*	*Nits*				3	17	3	17	1,000
20	*Gyrosigma*	*Gyro*		28						1,000
	Number of genera			8	10	9	11	9	11	16
	Abundance (cells L^{-1})			148	900	7,497	4,025	2,454	3,043	23,740
	Dominacy Index			0.18	0.31	0.50	0.49	0.51	0.43	0.22
	Eveness Index			0.90	0.60	0.39	0.38	0.46	0.43	0.71
	Diversity Index			2.71	2.01	1.24	1.33	1.46	1.48	2.82

The highest abundance of genera belong to *Oscillatoria* which is found in November and the lowest is in May. *Gonatozygon*found highest figure in November andthe lowest in Julyand September, while *Thallasiossira*in November andthe lowest at June and September.

Variation of abundance shows wide range, between 148 – 23,740 cells L^{-1}. The highest figure is in May and the lowest in November

(Fig. 2).

Phytoplanktonic organisms in Bangkau swampy lakeis fluctuating which follows of water level and tends to increase during flooding.

The highest figure of abundance were occured in October – November, while the lowest was in May – June and September – October. The highest value may caused by the increase simultaneously of lake and river watervolume. Swampy–river interconnection during the rainy season would increase the quality of aquatic environment, brings and spreads nutritions into swampy flood plain (Alam *et al.*, 2016; Nabout *et al.*, 2007; Yu *et al.*, 2016). Water brings nutrition from allochonous materials and pushes autochrotonus (autochthonous) to mix simulaneously, which finally triggers the increase the growth of phytoplanktonic organisms and thus increase productivity of zooplankton (Okogwu, 2010; Liu *et al.,* 2010).

Table 2. Water quality regimes in Bangkau swampy lake (May 2015 – Nov 2015).

No.	Parameter	unit	Sampling Period						
			May	June	July	August	Sept	Oct	Nov
1	WT	°C	30.25	30.50	30.10	29.93	29.83	33.68	29.15
2	Depth	M	3.57	3.17	2.97	2.47	1.87	1.67	1.77
3	Transparancy	Cm	151.5	148.3	144.0	128.5	130.5	128.3	97.3
4	TDS	Mg L^{-1}	31.88	35.00	36.55	37.55	31.25	342.88	49.75
5	TSS	Mg L^{-1}	6.25	6.75	7.93	8.83	10.23	11.25	7.25
6	EC	µmhos.cm^{-1}	66.93	69.15	72.95	75.45	64.30	271.68	326.53
7	pH	-	6.45	6.73	6.55	6.45	6.50	4.94	6.70
8	DO	Mg L^{-1}	7.25	7.53	7.15	6.83	7.05	4.30	4.05
9	BOD	Mg L^{-1}	8.86	9.69	9.56	9.57	9.22	8.45	8.33
10	COD	Mg L^{-1}	12.40	13.22	12.85	12.30	12.91	15.07	13.11
11	NH_3-N	Mg L^{-1}	0.002	0.126	0.024	0.032	0.008	0.113	0.083
12	NO_3-N	Mg L^{-1}	0.235	0.274	0.233	0.242	0.212	0.150	0.125
13	NO_2-N	Mg L^{-1}	0.019	0.022	0.014	0.017	0.018	0.138	0.488
14	PO_4-P	Mg L^{-1}	0.0793	0.0453	0.0773	0.0353	0.0165	0.0200	0.0233
15	Fe	Mg L^{-1}	2.05	1.40	1.26	1.20	1.86	0.86	0.49
16	SO_4	Mg L^{-1}	25.60	17.53	16.10	16.95	25.65	19.52	19.46

Abbreviation explanation : WT = water temperature; TDS = total dissolved solid; TSS = total dissolved solid; EC = electric conductifity; DO = dissolved oxygen; BOD = biological oxygen demand; COD = chemical oxygen demand;

The number of phytoplankton species varied during observation time ranged between 8-16 genera.The smallest amount of genera in May and the highest in November. Diversity, eveness and dominance indices moderately vary along the change of observation times it is about 1,241 – 2,823; 0,385 – 0,903 and 0,181 – 0,507. Diversity indice has the highest value in November and ts in he lowest in July.

Table 3. The influence of Physico-chemical factors(independent variabels) to abundance phytoplankton speciesand diversity, evenessand dominancy indices as it is described by multiple linear regression (environmental fit onto ordination of NMDS).

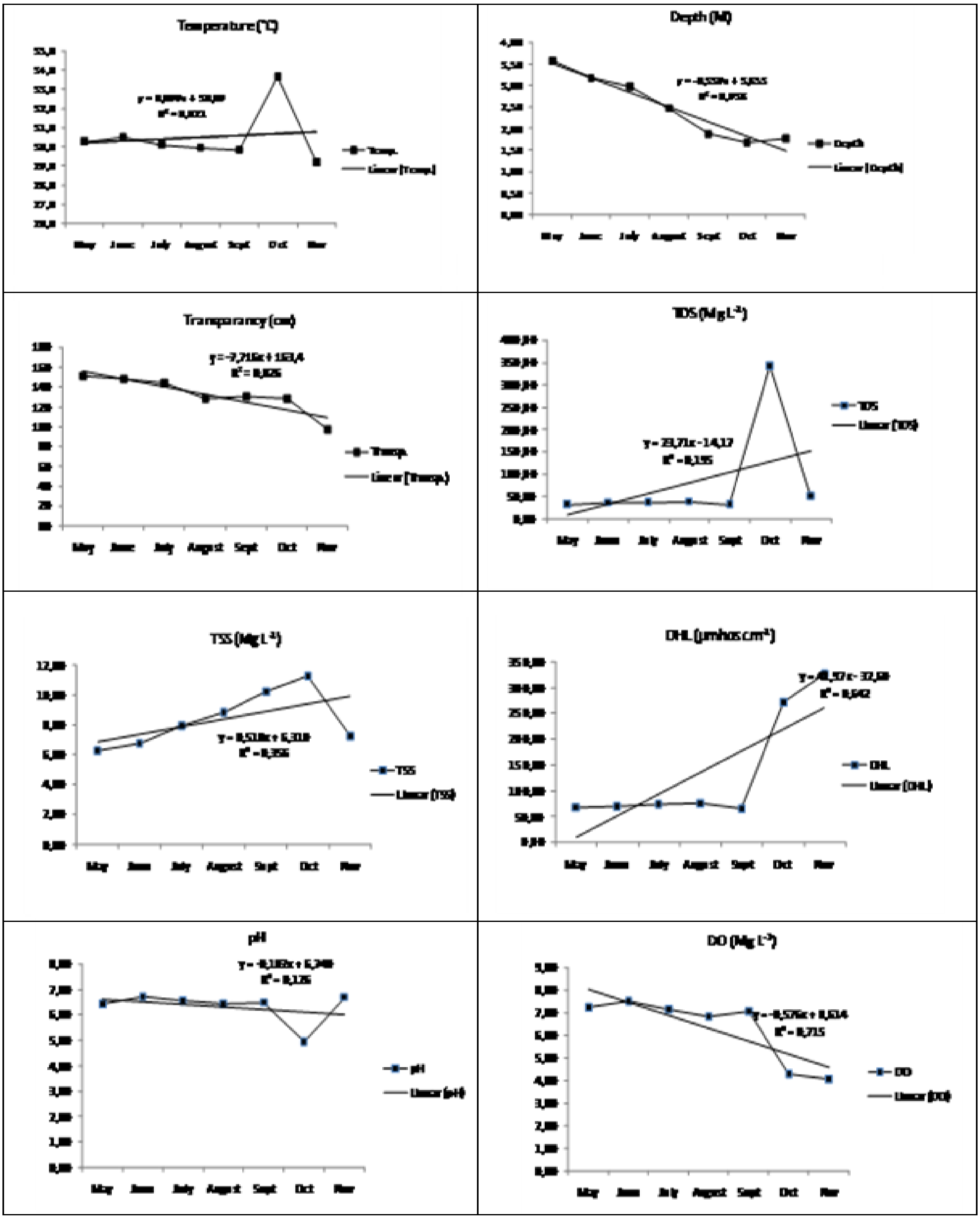
No.	Parameter	NMDS1	NMDS2	r2	Pr(>r)
1	Temp.	0.788880	0.614547	0.0104	0.994
2	Depth	-0.310484	-0.950578	0.5018	0.276
3	Transp	0.021723	-0.999764	0.6512	0.095.
4	TDS	0.164889	0.986312	0.1136	0.756
5	TSS	0.792088	0.610407	0.4429	0.309
6	EC	-0.177503	0.984120	0.6143	0.118
7	pH	-0.242225	-0.970220	0.0947	0.884
8	DO	0.116568	-0.993183	0.6597	0.122
9	BOD	0.413386	-0.910556	0.5757	0.210
10	COD	0.405444	0.914120	0.0654	0.912
11	NH_3-N	-0.644640	0.764486	0.0101	0.970
12	NO_3-N	0.091475	-0.995807	0.6294	0.150
13	NO_2-N	-0.274256	0.961657	0.6153	0.118
14	PO_4-P	-0.379083	-0.925363	0.1669	0.697
15	Fe	-0.058961	-0.998260	0.6053	0.180
16	SO_4	-0.586073	-0.810258	0.2198	0.589

Signif.codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

P values based on 999 permutations.

The eveness indice figure out the highest in May and the lowest value in August. Dominance indice shows the highest value in September and the lowest in May. The changes of structural community indices do not follow the change of planktonic abundance. It occurs due to an increase in certain species. Phytoplantonic community profile can be seen in Table 1.

Table 1 shows that the trend of reduction of diversity indice in July – October because of the increase in abundance of organism cells, such as *Oscillatoria* sp and *Spirogyra* sp. Therefore, diversity indice increases to be 0.501, 0.486 and 0,507. In addition to that, the presence of *Spirogyra* sp. with huge number is only resent in those months.



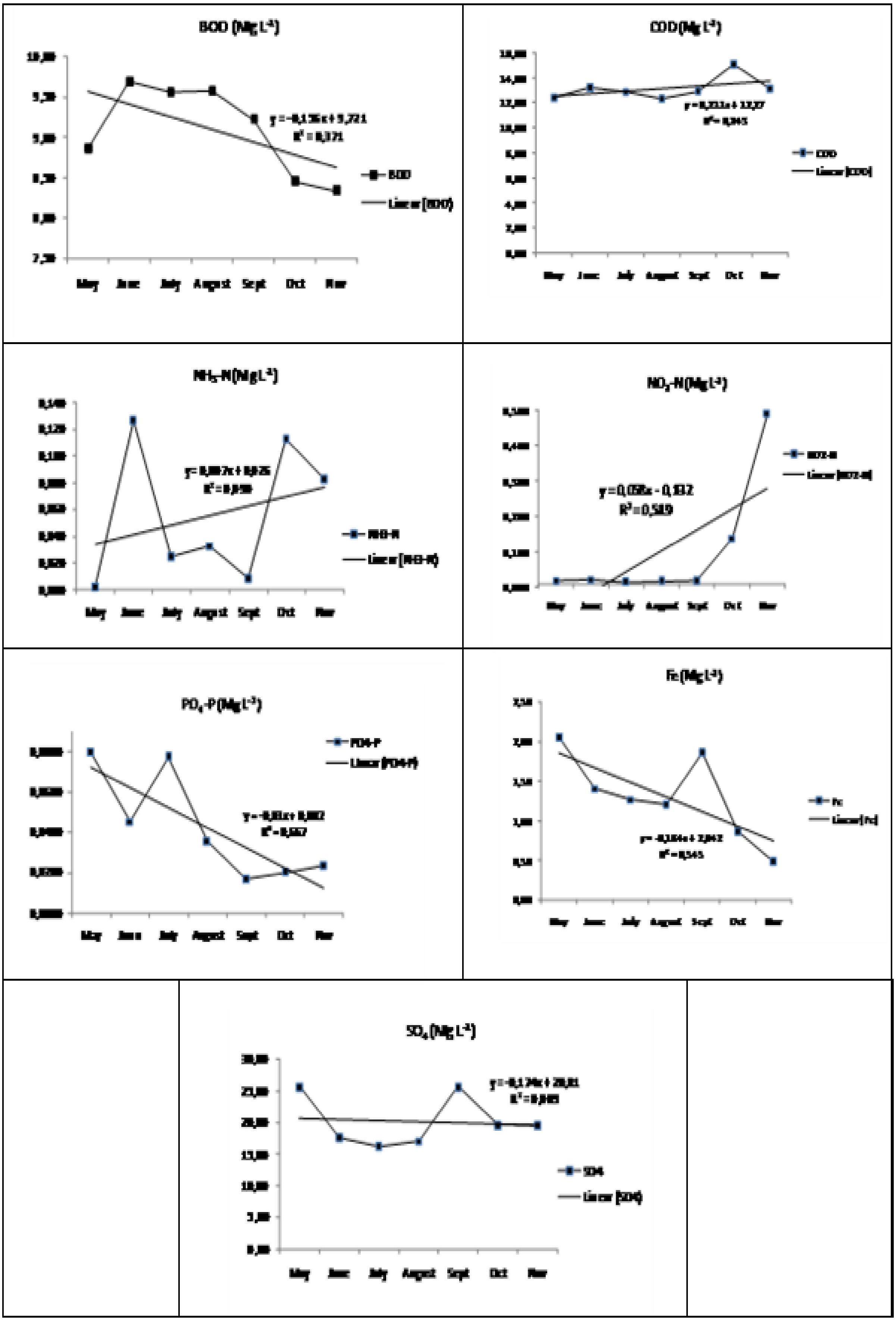


Fig. 2. The trend of water quality in Bangkau swampy.

The dynamic of water quality features

Measuring of water quality in Bangkau swampy lake in period of May to November showed fluctuation. This occure due to the change of volume and the depth of water which marely due to rainfall and river water. The change in water quality regime is shown in Table 2.

Additional water volume results in reducing concentration of diluted and suspended particles, and thus will reduce the concentration of water in the flood plain area. Therefore, the water quality in flood plain during flooding will be affected the quality of water from rivers which are connected to the flood plain areas (Agostinho *et al.*, 2009).

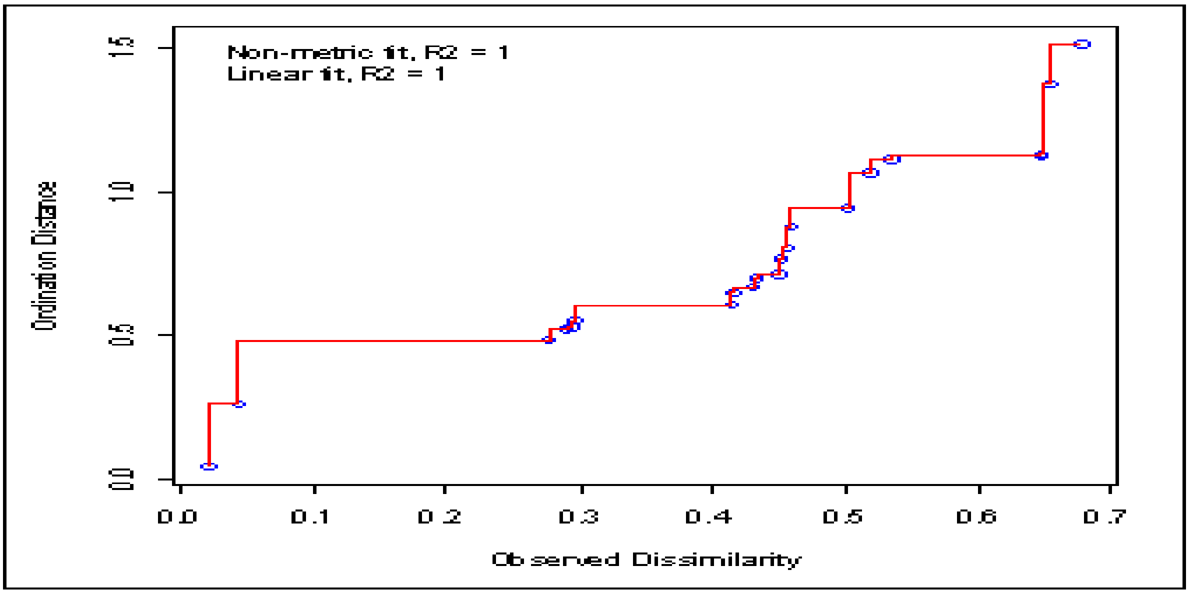


Fig. 3. Stressplot (Shepard) Ordination Distance-observed dissimilarity data dependent variable (Y).

The trend of water quality changes in Bangkau swampy lake during observation period is shown in Fig. 2.

From 16 parameters of water quality measured, there are 2 physical parameters tend to decrease along the observation, such as depth ($y = -0.339x + 3.853$; $R^2 = 0.938$) and transparency ($y = -7.716x + 163.4$; $R^2 = 0.826$). Chemical parameters which shows a similar relation pattern to physical parameters include NO_3-N ($y = -0.021x+0.295$;$R^2 = 0.749$), Do ($y = -0.576x + 8.614$;$R^2=0.715$),PO_4-P($y= 0.01x+0.082$; $R^2=0.667$), Fe($y=-0.184x+2.042$;$R^2=0.545$) and NO_2-N($y=0.058x-0.132$;$R^2 = 0.519$). In the other hand, other parameters, such as temperature, TDS, TSS, EC, pH, BOD, COD, NH_3-N and NO_2-N) have determination coeficient less than 50%.

Water temperature did not change significantly during observation, it just has range between 29.15 – 33.68 °C ($\bar{y}$ = 30.49 °C; SD ± 1.47).

The highest temperature was shown in October and the lowest were as recorded in November. This range reveals the ideal temperature for phytoplanktonic organism.

The change of temperature highly related to the intensity and peridiocity of sun light, and the depth of water coloum. The increase of the intensity and peridiocity of sun light will increase the water temperature, while an additian of water coloum will decrease gradually water temperature.

Increasing of water coloumn in swampy flood plain play importan role in determining the change of water quality, because dilution and the quality of additional water from the rivers has different to swampy water quality during dry period. Flooding also accelerate nutrition accumulation from detritus decomposition (Agostinho *et al.*, 2009). This process allows sustainability of water productivity.

The average of tranparency is about 97.3 – 151.5 Cm ($\bar{y}$ = 132.62 Cm; SD ± 18.34). The biggest feature is in May and the smallest in November. Photosynthetic Active Radiation is calculated base on depth reading of Secchi disk (SERM, 2002) and Beer-Lambert' s equation (Devlin *et al.*, 2008; Srifa *et al.*, 2016), it is about 2.3 of Secchi's depth. Base on this PAR value, photosynthetic depth in Bangkau lake is 42.3 – 65.9 cm. The increase of phytoplantonic abundance will reduce photosynthetic depth (Cardoso *et al.*, 2012) as it is occured in November.

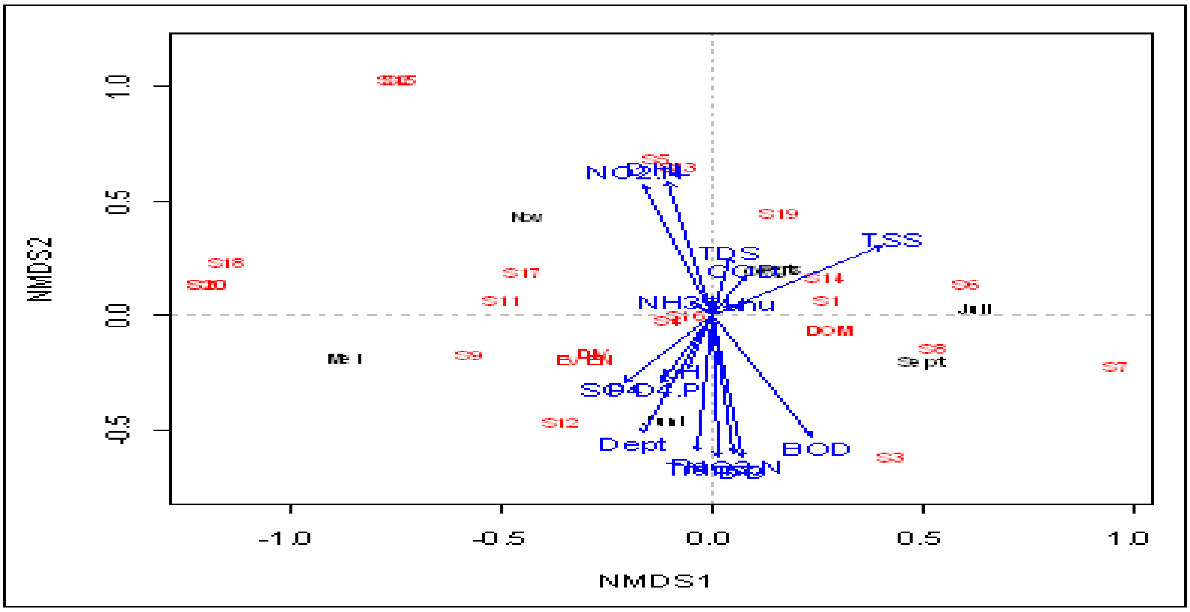


Fig. 4. NMDS Biplot of relation trend between abundance of phytoplanktonic species, diversity (DIV), domiancy (DOM) and eveness (EVEN) as Y, and Depth, Transparence, TDS, TSS, DHL, pH, DO, BOD, COD, NH_3-N, NO_3-N, NO_2-N, PO_4-P, Fe and SO_4 as X at NMDS$_1$line andlineof phytoplanktonic species codes (S1 s.d. S20) can be seen at Tabel 1. An object is time period of sampling from May to November.

TDS value from May to November tends to rise up at liitle fold from (31.25 – 49.75 mg L^{-1};$\bar{y}$ = 37.84 Mg L^{-1}; SD = 6.53). The smallest value was recorded in September and the (31.25 mg L^{-1}) and the biggest was in November (49.75 mg L^{-1}). Similar to TDS, TSS (6.25 – 11.25 Mg L^{-1}; $\bar{y}$ = 8.35 Mg L^{-1}; SD ± 1.85), but suddenly drops in November. EC (electro conductivity) is remarkable steady beween May to September (64.30 – 75.45 μmhos cm^{-1}), but suddenly jump up to (271.68 – 326.53 μmhos cm^{-1}) in September to November.

Acidity (pH), DO, BOD and COD, NH_3-N, NO_2-N, NO_3-N, phosphate (PO_4-P) and Fe are fluctative following the change of organic matters. All the figures during observation reveals in Table 2. Normaly the increase of BOD and COD will reduce DO, but it does not occur in Bangkau swampy flood plain open system.

This condition may happened due to a direct diffusion of oxygen from the air into the water, due to an involment of other environmental factors and oxygen induced by algal photosynthetic.

The relation of phytoplatonic and water quality

NMDS stress value to examine the relationship between objects is determined by Kruskal's Stress value (KSV). KSV measure "badness of fit", the smallest value indicates abetter match. Stress value as 2.91^{e-14}obtained is good value as shown in Shepard-plot of Ordination Distance-observed dissimilarity, with non-metric fit (R2) = 1.0 (Fig.3).

In general, the relation of phytoplankton species, such as *Binuclearia* (Chlorophyta) and *Cryptomonas* (Chlorophyta) are positively corelated to, and inflenced by Depth, SO_4, PO_4-P and Fe. They dominate the community in May and June.

In contrast to that *Nitszchia* (Chrysophyta), *Diatoma* (Chrysophyta), *Oscillatoria* (Cyanophyta), and *Sphaeroplea* (Chlorophyta) (Fig.4) is in opposite situation. Although statistically there is no correlation or significant influence on α = 0.05, as shown in Table 3.

Although there was no significant influence of environmental factors (physical and chemical parameters of water) to the presence of phytoplankton species, but of tendencies (brief tendencies) biplot NMDS in Fig. 4 can be explained relationship. From Fig. 2, NO_2 and DIN positively affect the presence or abundance of phytoplankton species: S5, S13 and S12, S15, S10, S20. Instead NO_2 and DIN negatively influence on the abundance S3, S7 and S8, and a third species is positively correlated to BOD, DO, NO_3 and Transp. Biplot MDS from Figure 4, the value of the diversity of phytoplankton species is characterized by high species richness S9 and S12 in May and June. In conclusion, The depth of water column (flooding) play an important role in determining dynamic of water quality in Bangkau swampy flood plain ecosystem. Critical condition of water quality occurs in May – September. Abundance of phyoplanktonic organisms in Bangkau swampy tends to increase following the increase of water depth. In May - June and September - October is the time for abundance value in lowest value. In general, the relation of phytoplanktonic, such as *Binuclearia* (Chlorophyta) and *Cryptomonas* (Chlorophyta) and physico-chemical factors, such as Depth, SO_4 and PO_4-P have positively correlation, when they are dominate in May and June, but it is in opposite to *Nitszchia* (Chrysophyta), *Diatoma* (Chrysophyta), *Oscillatoria* (Cyanophyta), and *Sphaeroplea* (Chlorophyta).

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