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Impact of Cage Aquaculture on Water Quality Condition in Lake Maninjau, West Sumatera Indonesia

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Abstract

Water quality characteristic of Lake Maninjau related to the deterioration condition has been intensively reported, nevertheless research on water quality as an impact of cage aquaculture level has never been done. The aim of this research was to identify influence of cage density to water quality condition. The study was conducted at 11 stations in Lake Maninjau, by measuring 11water quality parameters at a depth of 4.5m and sediment organic content on locations that have soft substrate. Measurement periods were on June 2013, September 2013, December 2013, and March2014. Activity of cage aquaculture was distributed in all over the lake shore lines, with the highest density at 1226 units km^{-1}. Water quality measurement indicated similar condition based on spatial patterns (degree of similarity >85%) with tendency that the increase number of cages influence several parameters including increase concentration of chemical oxygen demand (COD), total nitrogen, and ammonium; and decrease concentration of dissolved oxygen.

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Although statistical analysis (*Test T*, for variant analysis) showed only COD on low to middle level cage density and ammonium on middle to highest level cage density were significantly different (P<0.5).

Keywords: Lake Maninjau; cage aquaculture; density of cage; water quality.

1. Introduction

Lake Maninjau is located in West Sumatera Province, and is one of the lakes in Indonesia which has a multi-purpose. The functions of Lake Maninjau are for tourism, a source of water for hydroelectric power plant (HEPP), fisheries activity and cage aquaculture, and as a source of raw material for drinking water

Production of cage aquaculture in Lake Maninjau has begun since 1992 and expanded in 1995 [1]. In 1997, the number of cage has reached 2000 units [2] and in 2000 the number of cages recorded 3,500 units [3].

Cage aquaculture has been reported to have negative impact on environment due to lose large amounts of organic material in the form of detritus suspended as waste [4,5], which primarily consists of unconsumed feed and excretion products of fish farming [6]. Severe alteration on the physical and chemical characteristics of the benthic environment resulted as impact of waste accumulated at the bottom around the cage area [4,7]. The presence of organic pollution cause local environmental damage and the impact on scale of space and time [8].

Lake Maninjau ($0^{o}19$'S, $100^{o}11$'E) area reach to 9737.5 ha, with a coastline of 52.7 km long, a maximum depth of 165 m, the water volume of 10 266 x 106 m^3, and has a water retention time up to 25 years [9]. Lake Maninjau is characterized by vertical temperature stratification, with termocline at depths between 10 - 40 m which varies seasonally [10]. Trophic state of Lake Maninjau is in eutrophic conditions, indicated by the level of Total Phosphate (TP), Total Nitrogen (TN), and the Sechi depth [11,12,13]. Dissolved oxygen levels are already very low at 20 m depth [10] and anoxic conditions was detected at 25 m depth [12].

Density level of cage is predicted to give an impact on the environmental condition differently, particularly on water quality. The purpose of this study was to determine the influence of the distribution and density of cage to environmental conditions in Lake Maninjau.

2. Materials and Methods

Study of cage density was conducted by observing cages distribution in 14 stations (S) and the observation of water quality was represented by 11 stations (Table 1; Figure 1). Water quality measurement was carried out in June 2013, September 2013, December 2013 and March 2014.

2.1. Activities cage aquaculture

Information about cage aquaculture activity was obtained from Fisheries and Marine Office of Agam District [14,15], and latest data of the number of cages were counted directly in the year 2013 based on the location of distribution and was characterized by coordinate points using Geological Positioning System (GPS) Garmin

GPSMAP 420S type. Cage distribution with density levels is displayed in a map.

Table 1: Location of cage aquaculture distribution for water quality measurement

Station number (S)	Locations	Coordinate	
		South	East
1	Muko-muko*	00^{o}17’10.6”	100^{o}09’13.8”
2	Rambay*	00^{o}16’14.5”	100^{o}09’43.5”
3	Muara (M) Tanjung*	00^{o}15’17.4”	100^{o}11’01.4”
4	Sawah (Sw) Lie	00^{o}15’26.6”	100^{o}12’17.1”
5	Lubuk (Lb.) Anyir*	00^{o}16’16.4”	100^{o}12’52.0”
6	Lubuk (Lb.) Kandang*	00^{o}17’02.8”	100^{o}13’26.8”
7	Bancah*	00^{o}19’04.3”	100^{o}13’27.7”
8	Sungai Batang*	00^{o}20’14.3”	100^{o}13’10.2”
9	Pandan*	00^{o}22’29.1”	100^{o}13’13.6”
10	Batu (Bt.) Nanggay*	00^{o}24’01.9”	100^{o}11’38.0”
11	Muko Jalan	00^{o}22’50.6”	100^{o}09’53.7”
12	Dalu-dalu*	00^{o}20’12.6”	100^{o}09’54.1”
13	Sungai (S) Tampang*	00^{o}18’49.0”	100^{o}09’50.3”
14	Batu (Bt) Anjing	00^{o}17’45.5”	100^{o}09’41.4”

*) Location of water quality measurement

2.2. Water quality measurement

Water quality was measured at a depth of 4.5 m water column, and Sechi depth measurement in waters with a depth of 10 m. Parameters measured on the locations (*in situ*) were temperature, pH, conductivity, and dissolved oxygen using Water Quality Checker (WQC) type YSI Professional Plus 605596. Other parameters were analyzed in the laboratory. Water sample was collected using Kamerrer Water Sampler.

Water sample were stored in bottles and preserved with H_2SO_4 for analysis of TP, TN, ammonium (NH_4) and chemical oxygen demand (COD). Water sample for hardness analysis were preserved with HNO_3. Chlorophyll a was taken by filtering 500 mL water sample with GFF paper and preserved with $MgCO_3$. Analysis of TP, TN, NH_4, and chlorophyll-a in the laboratory were done using spectrophotometric method [16].

2.3. Measurement of sediment organic materials

Sediment for organic content analysis was taken by core sampler from a depth of 1 m and 5 m in soft substrate in nine stations. Hard substrate sediment was not taken because the sediment consisted of gravel and rocks which make the organic materials in hard substrate low. Sediment samples were analyzed using the ash method by muffle furnace [17].

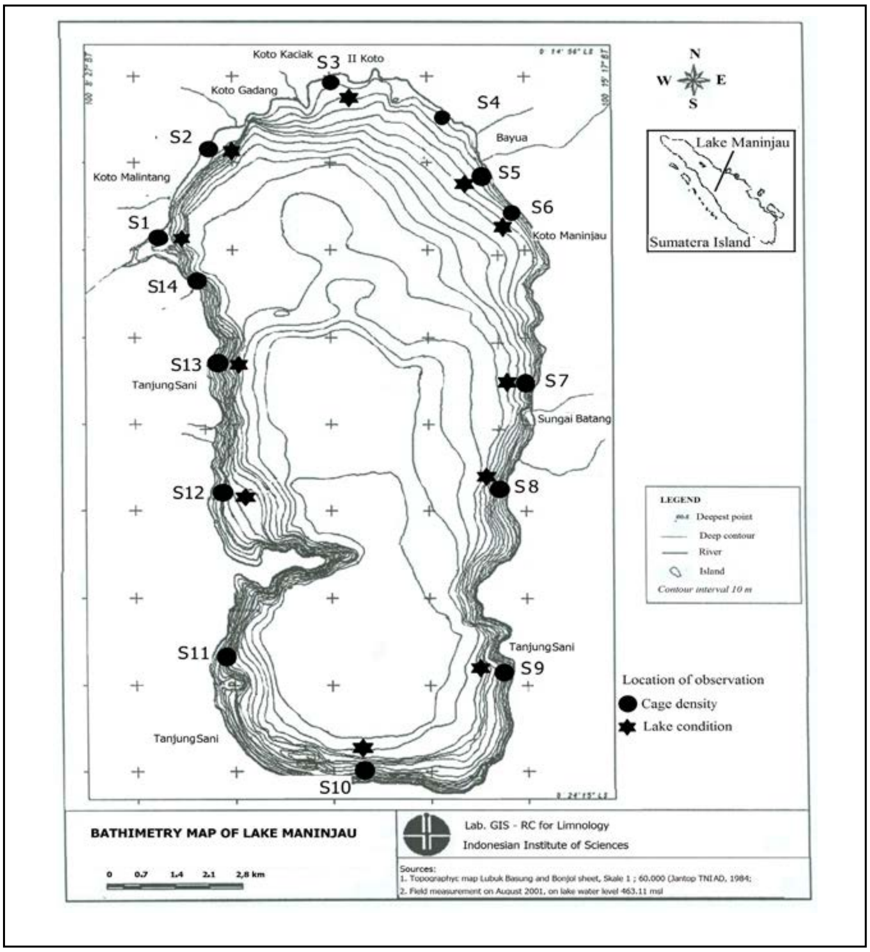

Figure 1: Water quality sampling station (S.; Station), Map source [9].

2.4. Analysis of the water quality condition

Water quality parameters were analyzed by clustering using Multivariate Statistical Package (MVSP). Parameters associated with anthropogenic impacts of the cage density level were displayed in graphical form and each parameter was compared using statistical analysis by variance test (*T test*).

3. Results

3.1. Cage aquaculture activity

Cage aquaculture activity in Lake Maninjau has wide contribution on the economy of local population (Table 2).

Cage aquaculture activity is distributed evenly in a long coast of Lake Maninjau, mostly in Nagari (Village) Tanjung Sani (5292 units). In the last two years, cage number has increased rapidly, from 14341 units in 2012 to 18630 units in 2013 and the highest were in Nagari Sungai Batang and Tanjung Sani (Table 3).

The highest cage density (1226 units.km^{-1}) was found in Nagari Bayua, precisely in Lubuk Anyir area. Nagari Tanjung Sani had the highest number of cages (6324 units), however this village has the longest coastline so that the density levels were relatively low (Figure 2; Table4).

Table 2: Characteristic of cage aquaculture activity in Lake Maninjau on 2013

No.	Characteristic	Volume
1	Number of cage (units)	14341
2	Owner of cage (people)	1341
3	Aquaculture farmer (people)	9119
4	Fish production (ton/day)	40 – 60
5	Seed requirement (fish/culture seasons)	100000000
6	Hatchery (units)	342
7	Feed shop (units)	26
8	Feed demand (ton/day)	70
9	Transporter (units)	57
10	Area of markets	Province of Riau, Kepulauan Riau, North Sumatera, Jambi, and South Sumatera

Source: [1]

Table 3: Distribution of cages number (units) in Lake Maninjau

No.	Villages	1997[2]	2000[3]	2009[14]	2012[15]	2013*
1	Koto Malintang	2000	3500	1934	2537	3352
2	Koto Gadang			84	321	356
3.	Koto Kaciak			659	983	1558
4	II Koto			503	1055	248
5	Bayua			878	2302	2650
6	Maninjau			679	1959	1842
7	Sungai Batang			1318	1582	2310
8	TanjungSani			4188	3602	6324
Total				10243	14341	18630

Sources: [2; 3; 14; 15]; *) This research.

3.2. Water quality condition

Water temperature was in the range of 27.9 – 28.4^{o}C; dissolved oxygen was still quite good, from 4.6 to 6.3 mg. L^{-1}; pH was slightly alkaline (7.7 to 8.9); the conductivity was between 121.7 to 128.4 mS.cm^{-1}; and hardness was between 46.8 to 58.5 mg.L^{-1}. Level of COD was quite high (35.1 to 75.1 mg.L^{-1}), TN was between 0.66 - 1.48 mg.L^{-1}, TP was between 0.02 to 0.06 mg. L^{-1}, NH_4 was from 0.14 - 0, 35 mg. L^{-1}, content of chlorophyll was between 14.4 to 23.7 mg. L^{-1}, and the Sechi depth was between 1.8 to 4.0 m (Table 5). Cluster analysis on anthropogenic-characterized parameters (dissolved oxygen, COD, TP, TN and ammonium) showed several cluster of water quality condition, however spatial patterns analysis showed similar water quality condition (degree of similarity > 85%) on the observation sites (Figure 3).

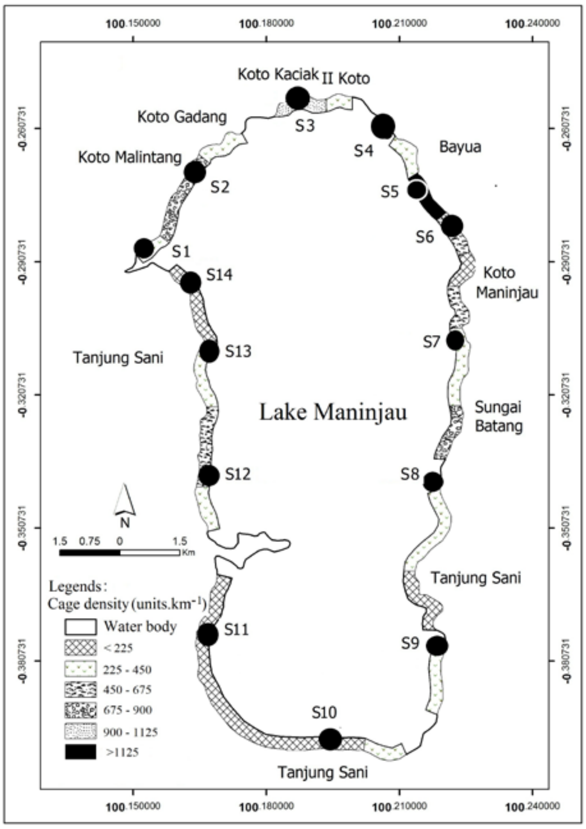

Figure 2: Distribution of cage density in Lake Maninjau

Table 4: Distribution of cages in the surrounding of LakeManinjau

Villages	Coordinate of observation border		∑Cage (units)	Distance (km)*	Density (units.km^{-1})
	I	II			
Koto Malintang	00°17’17.7” S 100°09’20.1”E	00°16’57.2” S 100°09’27.5” E	410	1.0	410
Koto Malintang	00°16’57.2”S 100°09’27.5” E	00°15’52.8”S 100°10’12.7” E	2940	3.3	891
Koto Gadang	00°15’52.8”S 100°10’12.7” E	00°15’37.1”S 100°10’33.1” E	356	1.0	356

Koto Kaciak	00°15’39.8” S 100°11’06.0” E	00°15’20.9”S 100°11’49.0” E	1558	1.7	916
II Koto	00°15’20.9”S 100°11’49.0” E	00°15’23.3”S 100°12’02.5” E	248	0.7	354
Bayua	00°15’46.4”S 100°12’35.8” E	00°16’12.9”S 100°12’54.8” E	564	1.3	434
Bayua	00°16’12.9” S 100°12’54.8” E	00°16’41.9”S 100°13’16.1” E	2084	1.7	1226
Maninjau	00°16’41.9” S 100°13’16.1” E	00°17’08.1”S 100°13’35.5” E	892	1.7	525
Maninjau	00°17’08.1” S 100°13’35.5”E	00°17’48.4”S 100°13’27.4” E	224	1.3	172
Maninjau	00°17’48.4” S 100°13’27.4”E	00°18’18.4” S 100°13’30.8” E	724	1.3	557
Sungai Batang	00°18’18.4” S 100°13’30.8” E	00°19’22.1” S 100°13’24.1” E	896	2.6	345
Sungai Batang	00°19’22.1” S 100°13’24.1” E	00°20’16.8” S 100°13’13.3” E	1414	2.0	707
TanjungSani	00°20’43.2” S 100°13’16.8” E	00°21’31.4” S 100°12’46.9” E	1022	2.3	444
Tanjung Sani	00°21’31.4” S 100°12’46.9”E	00°22’24.2” S 100°13’03.2” E	422	2.0	211
Tanjung Sani	00°22’29.1” S 100°13’13.6” E	00°23’31.1” S 100°13’15.5” E	664	2.6	255
Tanjung Sani	00°24’02.3” S 100°12’42.1” E	00°24’06.1” S 100°12’17.7” E	204	0.7	291
Tanjung Sani	00°24’06.1” S 100°12’17.7” E	00°23’57.8” S 100°10’51.7” E	344	4.0	86

Tanjung Sani	00°23'57.8" S 100°10'51.7" E	00°21'26.6"S 100°10'10.6" E	776	6.0	129
Tanjung Sani	00°21'13.4"S 100°10'08.2" E	00°20'41.2"S 100°09'54.1" E	268	1.0	268
Tanjung Sani	00°20'41.2"S 100°09'54.1" E	00°19'32.2"S 100°10'02.0" E	1266	2.6	487
Tanjung Sani	00°19'32.2"S 100°10'02.0" E	00°18'34.4"S 100°10'02.2" E	720	2.3	313
Tanjung Sani	00°18'34.4"S 100°10'02.2" E	00°17'31.5"S 100°09'28.1" E	634	3.0	211

*) *parallel dinstance to coast stright line*

Table 5: Water quality on 11 observation sites in Lake Maninjau

	Locations										
Parameters	Muko-muko	Ram-bay	Muara Tanjung	Lubuk. Anyir	Lubuk Kan-dang	Bancah	Sungai . Batang	Pandan	Batu Nang-gay	Dalu-dalu	Sungai Tam-pang
Temperatu-re (°C)	27.9	28.0	28.1	27.9	28.3	28.1	28.2	28.2	28.4	28.2	28.5
pH	8.2	8.3	8.1	8.4	8.2	7.9	8.2	8.6	8.9	8.9	9.2
DO ($mg.L^{-1}$)	5.68	5.43	4.60	4.9	4.95	4.71	5.26	5.69	6.03	6.24	6.30
Conducti-vity ($\mu S.cm^{-1}$)	123.4	121.7	125.5	122.5	124.2	124.0	128.4	123.2	124.1	123.1	126.2

Hardness ($mg.L^{-1}$)	50.15	46.81	50.71	54.0	46.25	50.15	46.81	49.04	49.04	47.68	53.0
COD ($mg.L^{-1}$)	43.41	48.60	69.92	75.23	46.85	43.41	35.08	44.92	58.41	49.19	54.13
Total N (mg/L)	0.656	0.775	1.283	1.081	0.947	1.476	1.061	0.985	0.799	1.014	1.03
Total P ($mg.L^{-1}$)	0.037	0.029	0.036	0.030	0.030	0.043	0.063	0.053	0.019	0.041	0.025
Ammoni-um ($mg.L^{-1}$)	0.201	0.216	0.351	0.179	0.206	0.221	0.172	0.142	0.162	0.208	0.177
Chlorophyl ($mg.L^{-1}$)	14.72	21.68	19.99	18.97	17.23	16.42	19.67	14.40	14.43	22.32	23.7
Sechi depth (m)	2.3	1.8	1.9	2.4	3.0	4.0	2.4	2.4	2.1	2.4	2.9

Note: Data is the average value from measurements in June 2013, September 2013, December 2013, and March 2014

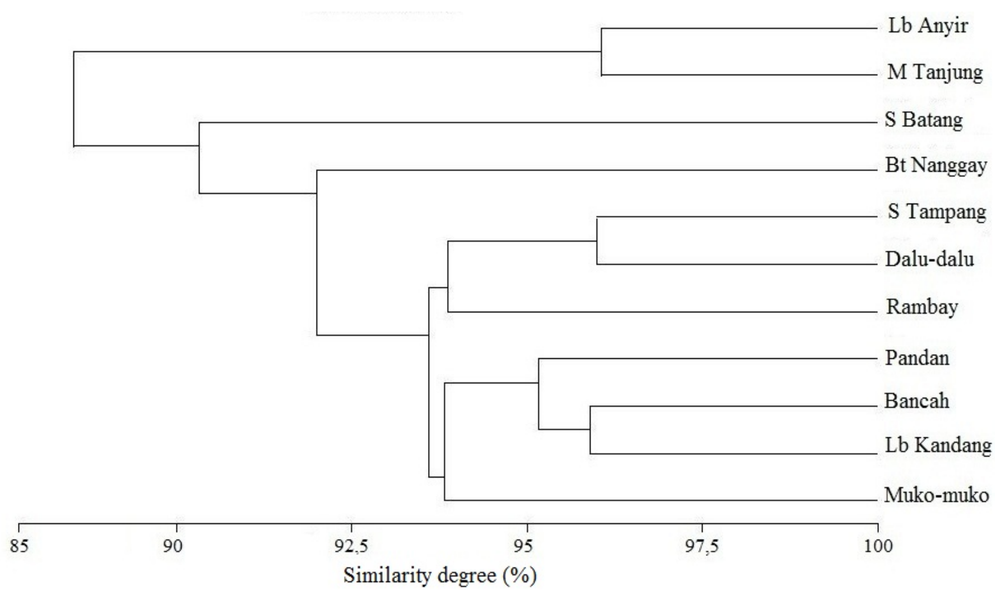

Figure 3: Cluster analysis of water quality condition of anthropogenic related parameters between locations

Components of organic materials on a substrate depth of 1 m were generally lower (ranged from 10.1 to 50.9 $mg.g^{-1}$ dry weight (*dw*) of sediment) compared to organic materials components on a substrate depth of 5 m (between 18.6 to 77.6 $mg.g^{-1}$*dw* of sediments) (Figure 4).

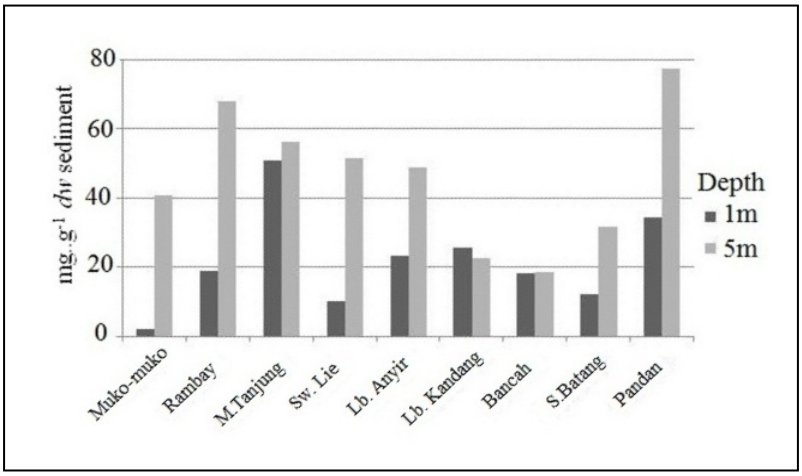

Figure 4: Organic material content on sediment in the depth 1 m and 5 m from several observation sites

4. Discussion

4.1. Cage aquaculture activity

Based on fish production data (40 – 60 ton) and feed requirement (70 ton) per day (Table 2), the potency of pollution especially from organic waste of fish culture activity in Lake Maninjau is about 10-30 ton per day. Organic pollution in lake tend to increase year to year parallel to the increase number of cages.

High number of cage density especially on the east side of the lake is associated with dominancy of population development on those areas. Condition of lake contour is quite slope in the eastern part which facilitate the access to the waters, while in the southern and western part of the lake the contour is relatively steep [9]. Distribution of cage density around Lake Maninjau based on the observed stations showed (Table 4; Figure 2) that the highest density (>675 $units.km^{-1}$) were in Rambay, Muara Tanjung and Lubuk Anyir (S2; S3; S5), which located commonly in the northern side of the lake. More to the south, in eastern part of lake, cage density were decreased as shown in Lubuk Kandang and Bancah (225-675 units. km^{-1}) and low cage density (<225 $units.km^{-1}$) was distributed in the south and west part of the lake (Table 6).

4.2. Water quality condition

Temperature and pH of the water were still in the same range as observed previously [10; 11; 12; 13]. Dissolved oxygen levels at a depth of 1-5 m was still quite good for aquatic fauna (> 2 $mg.L^{-1}$), while at 10 m depth the dissolved oxygen was low (<2 $mg.L^{-1}$) as observed in Muara Tanjung (Figure 5). The oxygen content was relatively good at 1 – 5 depths and such depth indicate photic zone, as can be seen from the Sechi depth on the same area. Low concentration of oxygen at depths of 10 m has previously been observed at several locations on the cages area in Lake Maninjau [13].

Table 6: Level of cage density on observation sites

		Cage density level (units.km^{-1}*)		
No.	Stasion	I (<225)	II (225-675)	III (>675)
1	Muko		+	
2	Rambay			+
3	M.Tanjung			+
4	Sw. Lie	+		
5	Lb. Anyir			+
6	Lb. Kandang		+	
7	Bancah		+	
8	S.Batang	+		
9	Pandan	+		
10	Bt. Nanggay	+		
11	Mk.Jalan	+		
12	Dalu		+	
13	S.Tampang		+	
14	Bt.Anjing	+		

*) *parallel dinstance to coast stright line*

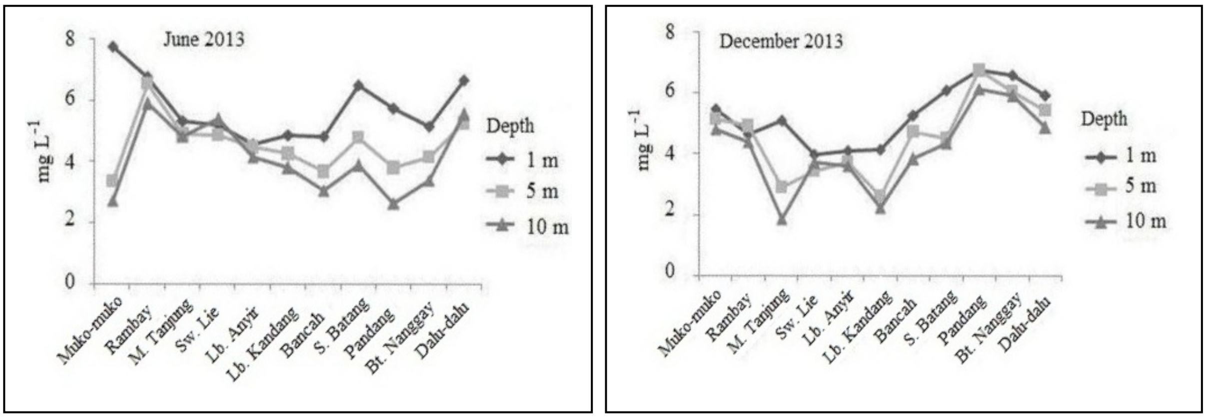

Figure 5: Dissolved oxygen on three depth level (1 m; 5 m; 10 m)

According Ibarra et al. (2005) [18] water conductivity level of lake Maninjau was still in very good condition (<400 mS.cm^{-1}). Explained by Hakanson (2005)[19] that the conductivity of lake water tend to be conservative and can be predicted very well from the hydrological parameters in the catchment area. Level of hardness of Lake Maninjau water was soft water (<75 mg. L^{-1}) as criteria of Sawyer & McCarty 1967 in [20].

Levels of TP and TN may be an indication of anthropogenic influence to the lake water. Levels of TP (0.019-0.063 $mg.L^{-1}$) and TN (0.656 to 1.476 $mg.L^{-1}$) were already quite high and indicated eutrophic conditions. According to Vollenweider & Karekes (1980) [21], level of TP in the range of 0.03 to 0.09 $mg.L^{-1}$ and levels of TN in the range of 0.393 to 6.1 mg. L^{-1} indicate that the water is in eutrophic condition.

The existence of cages in Lake Maninjau is a major factor of anthropogenic influence which contribute to water quality. The same condition occured on Lake Rupanco in Chile, that the salmon (*Oncorynchusmykiss*; *O. salar*) farming activities, which continually increased in the last two decades has led to the change in water environment. The level of salmon production between August 2008 and July 2009 has reached to 1626 tons. By using the rate of TN and TP (solid and dissolved) loss, it was estimated that cage aquaculture (unconsumed feed, feces, and urine) contributed annually to the loss of 76.4 tons of TN and 12.1 tons of TP [22].

By taking the proportion of TN and TP loss from cage activities as in Lake Rupanco, Chile [22], the potential loss of TN and TP in lake Maninjau can be calculated. The fish production of cages in Lake Maninjau recorded in 2011 has reached 36 217 tones [15], the potential loss of TP and TN into the Lake Maninjau water were about 269.5 $tons.year^{-1}$ and 1701.7 $tons.year^{-1}$, respectively. Base our calculation the loss of phosphor [P] into the waters of Lake Maninjau can reach 387 $ton.year^{-1}$, consist of [P] as wasted through feces (130.5 $ton.year^{-1}$) and wasted as dissolved with greater proportion (256.6 $ton.year^{-1}$) (Table 7).

Table 7: Estimation the loss of phosphor [P] from cage aquaculture in Lake Maninjau

Fish production	Total production (ton)[15]	Feed used estimation (ton)[23]	[P] content on feed (ton)[24]	[P] retention in fish (ton)[25]	Loss of [P] via feces (ton)[25]	Loss of [P] by diluting (ton)[25]	Loss of [P] total (ton)
Nile	23 947.0	29 454.9[a]	353.4[c]	133.3[d]	74.2[e]	146.0[f]	220.2
Carp	12 269.8	22 331.0[b]	268.0[c]	101.0[d]	56.3[e]	110.0[f]	166.9
Total	36 218.8	51 785.9	621.4	234.3	130.5	256.6	387.1

Source: [15; 23; 24; 25] ; a) Food conversion ratio (FCR) of nile 1.23; b) FCR of carp 1.23; c) 1.2% of feed weight; d) 37.7% of [P] on feed; e) 21,0% of [P] on feed; f) 41.3% of [P] on feed

Limited nitrogen component (N) in tropical water region is more common than the phosphorus (P), possibly due to a greater supply of P from chemical weathering of rocks whereas loss of N component internally is due to higher temperatures [26]. The presence of cage aquaculture in Lake Maninjau contributes to higher supply of N compare to P which was characterized by large TN:TP ratio (16.9 to 42.0).

The TN:TP ratio is known as "Redfield ratio" (N: P ≈ 16: 1 atom; or 7: 1 mass) which is a characteristic of plankton and sea water in the ocean around the world as stated by Redfield (1958) [27]. Ratio of TN:TP can be characteristic of lake trophic state, whereas the range of TN:TP ratio on oligotrophic and eutrophic is 200 and 5, respectively [28]. Lake Maninjau was eutrophic as characterized by high TN:TP ratio.

Organic content of Lake Maninjau water were indicated by average content of COD (35.08 to 75.23 $mg.L^{-1}$). Level of COD was the highest in Lubuk Anyir (75.23 $mg.L^{-1}$) and MuaraTanjung (69.92 $mg.L^{-1}$), and both of these locations are known to have the highest cage density (Table 6). High level of total organic content (15.9 - 98.7 $mg.L^{-1}$) is also found in some cage areas of Lake Maninjau with uniform vertical pattern [10]. Ammonium level was in the range from 0.351 to 0.142 $mg.L^{-1}$, and the highest level was found at the site of MuaraTanjung, indicated high pollution load from the cage.

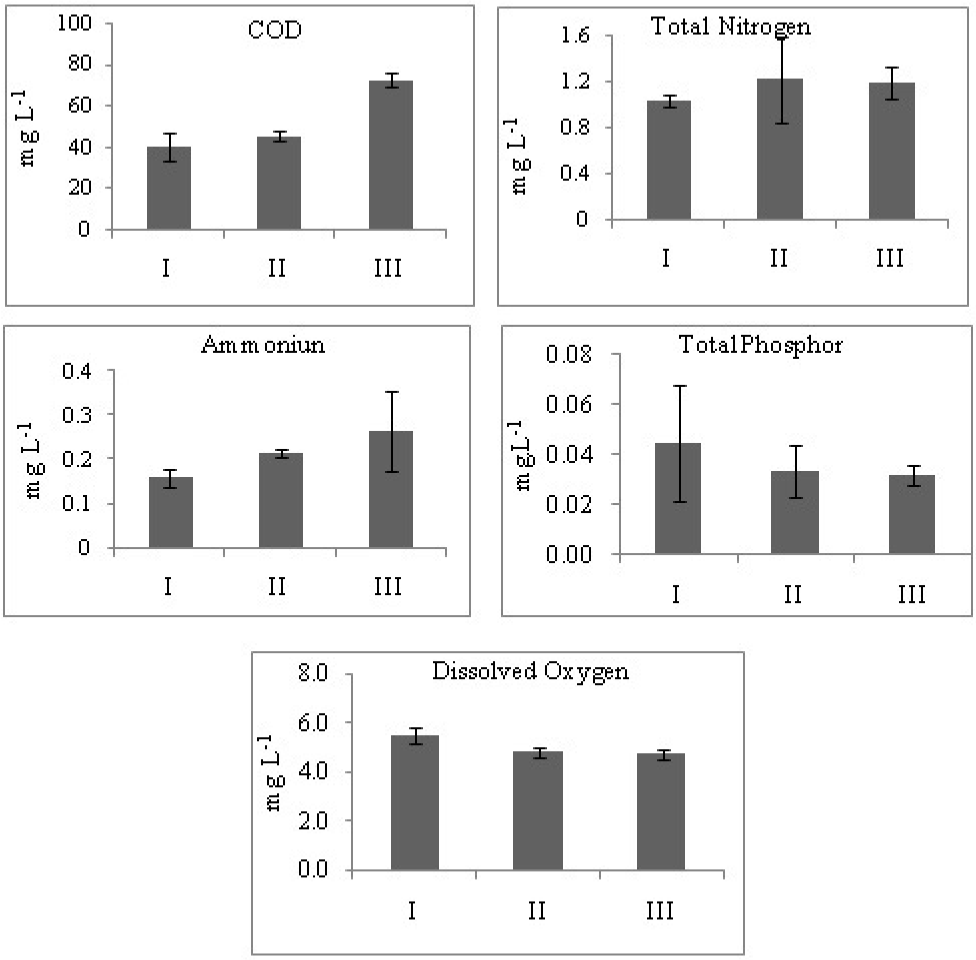

Figure 6: Average value of anthropogenic character parameters on different cage density (I, II, III) location

Chlorophyll a content in Lake Maninjau was in the range of 14.72 to 22.32 $mg.m^{-3}$. According to criteria of Wetzel (2001)[28], the content of chlorophyll in oligotrophic lake less than 3$\mu g.L^{-1}$ (<3 $mg.m^{-3}$) and in eutrophic has more than 11 $mg.L^{-1}$ (>11 mg. m^{-3}), therefore Lake Maninjau was on eutrophic. Huszar et al mentioned (2006) [30] that the relationship between (log) TP and (log) TN with (log) of chlorophyll in tropical lakes was lower (r^2 = 0.42 and r^2 = 0.39, respectively). Even thoughHuszar et al [30]stated that high level of chlorophyll is associated with high level of nitrogen and phosphorus found in the tropic lakes as in subtropical. Therefore it can not be denied that the high levels of chlorophyll in Lake Maninjau was actually associated with high TP and TN.

High content of chlorophyll in Lake Maninjau was also reflected by the low of the Sechi depth, which range from 1.8 to 4.0 m. Sechi depth may indicate the depth of the photic zone and further the depth of littoral zone. Following the formulation of Koening & Edmunson (1991)[31] that the ratio between Sechi depth (SD) to euphotic zone (EZD; Euphotic Zone Depth) in the clear water is 2.4.the range of EZD of Lake Maninjau was only between 4.2 - 9.6 m. Consequently, extensive dissolved oxygen availability from phytoplankton photosynthetic activity will be limited until 10 m depth.

Based on several water quality parameters of anthropogenic character, the increase of cage density tend to increase COD, TN, ammonium but decrease the oxygen content, whereas TP did not show any change (Figure 6). The comparison of COD, TN, ammonium, TP and dissolved oxygen base to cage density by statistical analysis (*T test*, variant analysis) showed that the difference was found only between cage density II and III ($P<0.05$) for COD and between cage density level I and II ($P<0.05$) for ammonium.

Levels of organic material in the sediment seemed to be not related to the cage density level. Sediment organic content in cage density I was higher than II, both on 1 m and 5 m sediment depth (Figure 7). One location of cage density I was Pandan had the highest levels of organic sediment (Figure 4). Pandan is located in bay area which allows the accumulation of organic material.

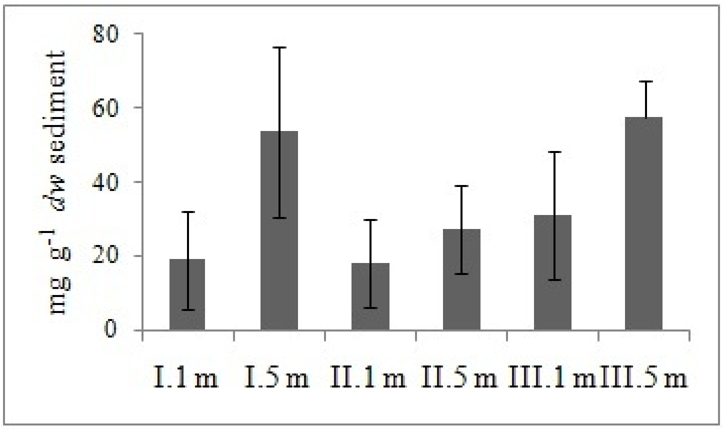

Figure 7: Organic sediment content on different substrate depth (1m; 5m) and cage density (I; II; III)

Organic content of Lake Maninjau sediment was in the range of 10.1 to 50.9 mg.g^{-1}dw sediment (1 m substrate) and from 18.6 to 77.6 mg. g^{-1}*dw*.sediment (5 m substrate) (Figure 4), or for each cage density level, the average was ranged from 18.9 to 57.8 mg,g^{-1}*dw* sediment (Figure 6). Such result was still lower than the result from organic content levels measured on sediment in Cirata reservoir, West Java, Indonesia where there were 150.5 to 188.6 mg.g^{-1}*dw* sediment [32] but higher than the sediment organic content of Lake Limboto which was in the range of 11.5 to 20.9 mg.g^{-1}*dw* sediment [33]. According to Entz (1977)[34], sediment organic content less than 17% (*dw* of sediment; or < 170 mg.g^{-1}dw sediment) indicates the oligotrophic lake while the organic matter content more than 30% (*dw* of sediment; or > 300 mg.g^{-1}dw sediment) characterizes eutrophic lake. Based on the organic content of Lake Maninjau sediment, the trophic status of Lake Maninjau is still in oligotrophic condition.

Sediment organic measured in Lake Maninjau was low, because the location of the measurement was at 1 m and 5 m depth. Accumulation of organic material from the waste of cage aquaculture activity generally occurs in the deepest sediment. According to Karaksassis et al. (2000) [4] and Rosenberg et al. (2001)[7], the accumulation of organic materials, which generally occurs around the cage, can also occur just below the cage area.

5. Conclusion

In this study, the water quality measured were similar based on spatial patterns (degree of similarity >85%), but there was a tendency that the increase of cage density influence the water quality of anthropogenic character which are the increase of COD, Total Nitrogen, ammonium and the decrease of dissolved oxygen. Even though statistical analytic (Test T, for variant analysis) showed only COD on cage density level from low to middle and ammonium on cage density level from middle to highest were significantly different ($P<0.5$.)

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