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STATE OF AQUATIC RESOURCES MANINJAU LAKE WEST SUMATRA PROVINCE, INDONESIA

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Abstract- Ecological state of inland waters is the condition of the balance of functional relationship between inland waters ecosystem component as abiotic and biotic. Ecological state of inland waters change because of external factors such as land use change in catchment area intensive utilization of lakes that indicated by the dominant of certain biota, water quality changing and food web disruption. Research on the state of the waters of Maninjau lake has been conducted from June until July 2013 in order to determine state of morphological and proportion of land use in the catchment area, state of fish communities, state of water quality and state of trophic. The results showed the elevation 463.12 m above sea level lake surface area is 9,996 ha. Catchment area is 13,260 ha with the largest proportion of land use for forest are 46.11%. Fish community in Maninjau Lake as 16 species, consists of ten species of native and six species of introduced with trophic level are 46.66% herbivorous, 20.00% omnivore and 33.33% carnivore. The dominant activity in Maninjau Lake is floating net cages with the number 16,210 units. The activity has an effect on water quality among others water temperature ranged from 27.5 to 28.5°C, pH ranged from 8 to 10.0, total dissolved suspension maximum 1.65 mg.l⁻¹ and brightness is very low at maximum of 1.5 m. Phosphorus ranged from 0.27 to 0.47 mg.l⁻¹, nitrogen in the ranged from 1.28 to 1.95 mg.l⁻¹ and chlorophyll-a ranged from 0.23603 to 0.28502 mg/m³. Trophic state index values ranged from 77.58 to 80.08, based on the value of Maninjau Lake classified state heavy eutrophic.

Keywords- Maninjau Lake, morphological lake, catchment area, fish community, water quality, state of trophic

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Introduction

Maninjau Lake is a tecto-vulcanic, located in the district of Tanjung Raya, Agam Regency, West Sumatra Province, Indonesia on geographical position E: 00°12'26.63" - S: 0°25'02.80" and E: 100°07'43.74" - E: 100°16'22.48", located at altitude of 461.50 m above sea level with the surface area 9737.50 ha. Based on the Schmidt-Ferguson climate classification, this lake has the characteristics of climate types A and annual rainfall around 3,490 mm. Maninjau Lake is a natural resource that has a very important role as a tourist destination, Hydroelectric Power Plants with a capacity of 64 MW, capture fisheries and floating net cages farming [1].

Fish aquaculture systems in cages culture at Maninjau Lake started in 1992 with the number of 16 units and managed to increased local people income [2]. In 2003 the number of floating net cages increased to 4,000 units [1] and in 2011 increased to 15,000 unit [3]. Whereas carrying capacity of floating net cages was estimate in this lake around 1,500 units [1], and recent data in 2012, there were 15,860 units and fish production are 23,790 tons [4]. It can also add phosphorus and nitrogen, orthophosfat so as to increased the trophic state of waters [5]. According Henny [6] keep the fish with floating net cages has led to the accumulation of organic matter,

which in turn created the conditions toxic to fish. Organic materials generally consist of three forms of coarse particles, fine and dissolved. The three types of organic matter will affect the energy flow in lake ecosystems and effect on biodiversity, water productivity and fish production [7]. It is therefore very important to do research on the state Maninjau Lake order management can be done in a sustainable.

Material and Methods

Morphological features data Maninjau lake ie surface area (A_0), long coastline, the maximum length and average depth and volume of water sourced from secondary data [8]. Land use data sourced from district of Tanjung Raya 2012 [13]. Relative depth (Z_r) and shoreline development index (D_L) [9] obtained using the formula:

$$Z_r = \frac{(50z_{\max}\sqrt{\pi})}{\sqrt{A_0}} \quad \text{and} \quad D_L = \frac{L}{(2\sqrt{\pi A_0})}$$

A_0 = surface area, Z_{\max} = maximum depth, L = length of coastline. The data of fish be obtained from the fishermen [enumerators], pelagic fish caught by gill net mesh sizes 0.5, 1.0, 1.5, 2.5, 3.5 and 4.5 inches. The fishing gear used for pelagic fish species. Longline

is used to catch the carnivorous fish species, and traps to catch specific of fish that live in the bottom waters. Sample of fish preserved in formalin 10% to be identified to species level [10]. At each observation site water quality monitoring study conducted in the littoral zone in Juni until July 2013 [Table-1], [Fig-1]. Water sampling

using a Kemmerer water sampler volume of five liters at a depth of 50 cm from the surface of the water. Kemmerer water sampler slowly lifted and opened the water faucets expenditure, then the water entered into the sample bottles of water and closed. Water samples were analyzed by the method of APHA [11].

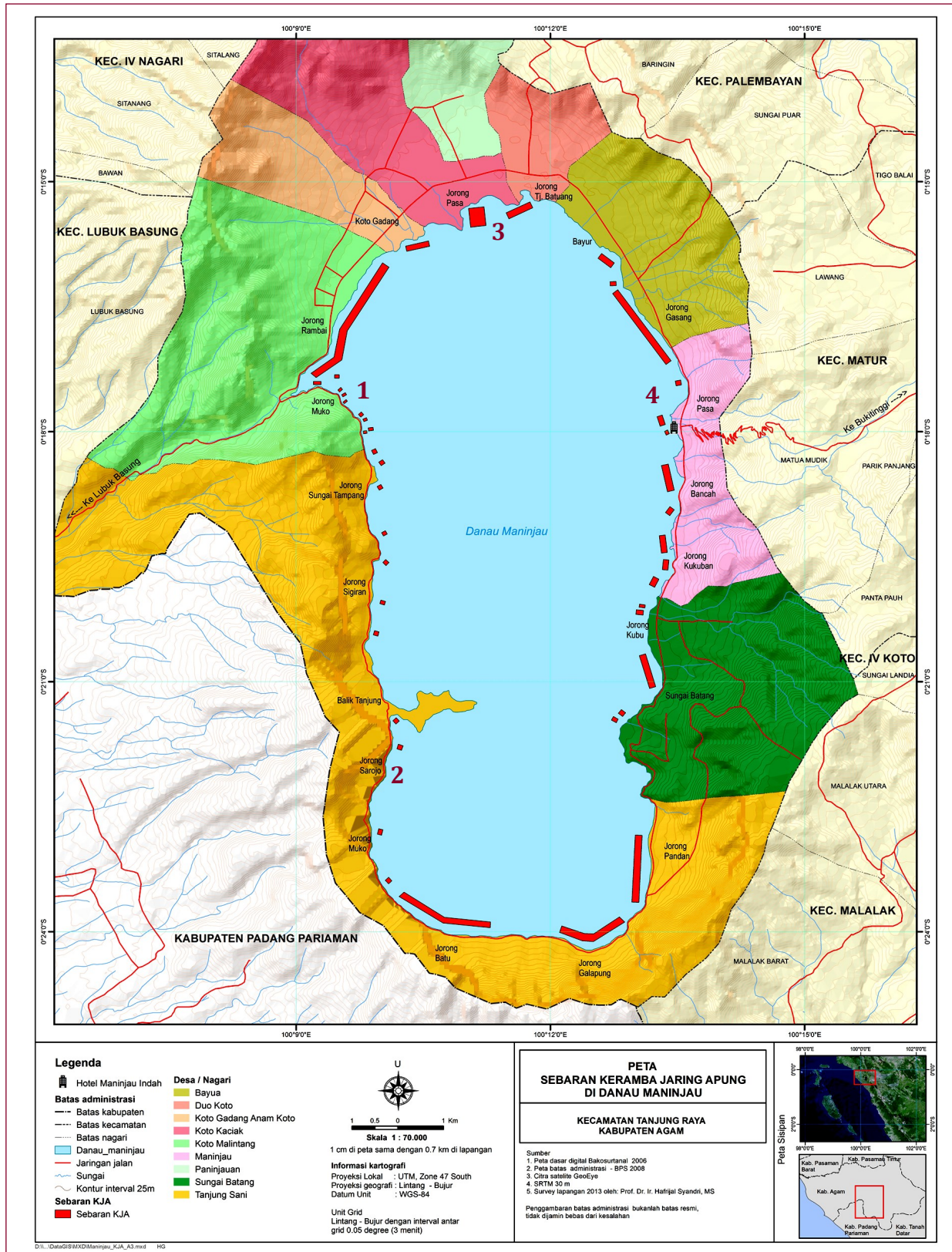


Fig. 1- Map of Maninjau Lake, West Sumatra Province

Table 1- Description of the water quality monitoring stations in Maninjau Lake

S No	Observation site	Geographical Position	Description
1	Muko-Moko	S: 00°17'58.5" E: 100° 09' 47.3"	An outlet of lake and there is a hydropower intake, and conservation area, sandy bottom substrate, tourist area.
2	Tanjungsani	S: 00°18'21.58" E: 100°11'18.98"	Littoral waters of steep, little aquatic vegetation and substrate dominated rocks, the area for floating net cages farming of tilapia, and human settlement area.
3	Koto Kaciek	S: 00°16'37.15" E: 100°12'07.41"	Littoral waters is ramps, the muddy substrate, the area for floating net cages farming of tilapia, overgrown by Eichhornia crassipes, riparian area is agricultural.
4	Bayur	S: 00°19'57.89" E: 100°12'39.85"	Littoral waters is ramps, mud and sand substrate, location on floating net cages farming of tilapia, in the riparian lakes, human settlement area and hotels.

Trophic state of the lake in the littoral zone were analyzed with the formula Carlson's trophic state index, TSI [12], i.e.:

Information : 1.2.3.4 = observation site

a. TSI for Chlorophyll-a (CA)TSI = $9.81 \ln \text{Chlorophyll-a (ug/L)} + 30.6$

b. TSI for Secchi depth (SD)TSI = $60 - 14.41 \ln \text{Secchi depth (Meters)}$

c. TSI for Total phosphorus (TP)TSI = $14.42 \ln \text{Total phosphorus (ug/l)} + 4.15$

where TSI is Carlson Trophic State Index and \ln is Natural logarithm.

Carlson's trophic state index (CTSI) = $[\text{TSI (TP)} + \text{TSI(CA)} + \text{TSI (SD)}] / 3$

TP and Chlorophyll-a in micrograms per litre, SD transparency in meters.

Result

State of Morphological

The morphology of the lake is important to know because it gives effect to the physical, chemistry and biology processes in the waters of the lake itself, among others depth relative, development of shoreline and patterns of lake basin. The lake bathymetry mapping results in October 2010 when the lake elevation reaches 463.1 m from sea level [8] and analyzes of data on relative depth, shoreline development and water retention time [Table-2].

Table 2- Morphological characteristics of Maninjau Lake

S No	Parameter	Unit	Value
1	The surface area	ha	9,996
2	The length of coastline	km	52.7
3	The maximum length	km	16.46
4	The maximum width	km	7.5
5	The maximum depth	m	168
6	The average depth	m	105
7	The relative depth (Z_r)	%	1.51
8	The volume of water	m ³	10,226,001,629.2
9	Development of shoreline	(D _L)	1.51
10	Water Retention Time	Year	25
11	Catchment area	Ha	13,260
12	Catchment area ratio: the surface area of the lake		01:01.3

Sources : Fakhruddin, et al [8] and analyzes of primary data.

Maninjau Lake water area covers 75.38% of the catchment area, and sizeable proportion. Land use in the catchment area is for rice fields, dry land, human settlements area, forests and etc. [Table-3]. Based on the relative depth of the lake level of 1.508%, showed that the stability of the lake water is low so easy mixing of water masses occur if high winds. Based on outflow an average of 12.86

m³/second and a volume of water 10,330,000,000 m³, then the lake water retention time Maninjau have for 25 years. The water retention time gives a significant role in the processes that occur in the lake, the longer water retention time, then the process of waste sediment geminating of floating net cages and domestic waste will be even greater.

Table 3- The proportion of land use in the catchment area (ha)

Village	Rice fields	Dry land	Human settlements area	Forest	Etc.
Maninjau	205	426	110	560	9
Bayur	526	435	138	692	8
III Koto	421	258	135	152	15
Koto Kociek	460	236	108	369	14
II Koto	390	199	144	2,037	12
Tanjungsani	126	1,773	154	2,421	27
Sungai Batang	390	279	180	1,223	11
Total	2,518	3,606	869	6,951	96
Proportion (%)	16.7	23.92	5.76	46.11	0.64

Source : Government of Tanjung Raya [13].

State of Fish Communities

Fish community in Maninjau Lake consists of native and introduced species, native species are *Osteochilus hasselti*, *Rasbora lateristriata*, *Psilopsis sp*, *Puntius schwanefeldi*, *Tor douronensis*, *Hampala macrolepidota*, *Hemibagrus nemurus*, *Channa striata*, and *Anabas tertudineus*. Introduced species are *Oreochromis niloticus*, *Osphronemus gourami*, *Pangasius hypophthalmus*, *Oxyeleotris marmorata*, *Leptobarbus hoeveni* and *Channa lucius*. Consists of trophic state are herbivorous 46.66%, omnivore 20.00%, and carnivore 33.33% [Table-4]. *Psilopsis sp* is an endemic species, small fish size of ranged from 20 to 40 mm and important fisheries commodity in Maninjau Lake with the price of 35,000 IDR /kg in off season.

State of Waters Quality

At the lake elevation 462.82 meters above sea level, water surface quality at each station research showed almost the same conditions, temperature ranged between from 27.5 to 28.5°C, pH of more than seven which characterizes the alkaline waters, low total dissolved suspension (maximum 1.65 mg/l) and brightness is very low at a maximum of 1.5 m. Phosphorus ranged from 0.27 to 0.47 mg/l, orthophosphate ranged from 0.30 to 0.40 mg/l, nitrogen in the range from 1.28 to 1.95 mg/l and chlorophyll-a range from 0.23603 to 0.28502 mg/m³ [Table-5].

State of Trophic

Total phosphorus values ranged waters Maninjau Lake 550-650 µg/l with average 605± 47,95 µg/l. brightness ranged from 1.1 to 1.5 m

with average 1.3 ± 0.18 m and chlorophyll-a ranged from 236.03 to 297.01 $\mu\text{g/l}$ with average 271.3 ± 2.65 $\mu\text{g/l}$. Based on the value the trophic state index (TSI) Maninjau Lake in July 2013 ranged from

77.82 to 80.08 with average 78.62 ± 1.15 [Table-6]. This value is matched with the following criteria according [12], the waters of the littoral zone Maninjau Lake state is heavy eutrophic.

Table 4- Trophic state of fish communities in Maninjau Lake

Trophic level	Family	Type of fish	Type of food	
			Main	Complement
Herbivorous	Cyprinidae	<i>Osteochilus hasselti</i>	Aquatic plant	phytoplankton, zooplankton
	Cyprinidae	<i>Rasbora lateristriata</i>	phytoplankton	zooplankton
	Cyprinidae	<i>Psilopsis sp</i>	phytoplankton	-
	Cyprinidae	<i>Puntius shwanefeldi</i>	Aquatic plant	phytoplankton, zooplankton
	Cyprinidae	<i>Tor douronensis</i>	Aquatic plant	aquatic insects
	Cyprinidae	<i>Leptobarbus hoeveni</i>	Aquatic plant	phytoplankton, detritus
	Osphronemidae	<i>Osphronemus gourami</i>	Aquatic plant	detritus
Omnivore	Anabantidae	<i>Anabas testudineus</i>	aquatic insects	floating aquatic plants
	Anabantidae	<i>Oreochromis niloticus</i>	aquatic insects	floating aquatic plants
	Pangasidae	<i>Pangasius hypophtalamus</i>	crustacea, insects and molusca	rotifera, larvae dan aquatic plant
	Cyprinidae	<i>Hampala macrolepidota</i>	fish	aquatic insects, bivalvae, mullusca
	Eleotridae	<i>Oxyeleotris marmorata</i>	fish, shrimp	aquatic insects, fry lobster
Carnivore	Bagridae	<i>Hemibagrus nemurus</i>	fish, shrimp	aquatic insects, bivalvae, mullusca
	Channidae	<i>Channa striata</i>	fish	aquatic insects, bivalvae, mullusca
	Channidae	<i>Channa lucius</i>	fish	shrimp, aquatic insects

Table 5- Water quality Maninjau Lake in July 2013

Parameter	Observation site			
	Muko-Muko	Tanjungsani	Koto Kaciek	Bayur
Temperature ($^{\circ}\text{C}$)	28	27.5	28.5	27.5
Brightness (m)	1.5	1.2	1.1	1.4
Total dissolved suspense (mg/l)	4.68	12.9	13.65	9.05
pH	8	8.0	10.0	8.5
Alkalinity (mg/l)	54.11	79.6	54.58	28.22
Dissolved oxygen (mg/l)	6.57	5.56	5.17	6
Total phosphorus (mg/l)	0.55	0.64	0.65	0.58
Ortofosfat (mg/l)	0.3	0.4	0.38	0.39
Total nitrogen (mg/l)	1.28	1.66	1.9	1.95
Klorofil-a (mg/m^3)	0.23603	0.2673	0.28502	0.27901

Discussion

State of Morphological

Maninjau Lake area of 75.38% of the catchment area, means that cathment area relatively small. But with the water volume 10,226,001,629.2 m^3 and outflow water on average 12.86 m^3/second , means that the role of groundwater is large enough in water supply Maninjau lake. There is a negative relationship between the ratio of the cathment area with the lake water surface, the higher the ratio of the cathment area with the lake water surface, so water retention time will be lower [14]. The water retention time give a significant role in the processes that occur in the lake, the longer of water retention time make process of sediment deposition and nutrient will be greater. Thus the waste sediment from floating net cages and domestic waste in the lake Maninjau the more trapped in the lake.

Based on the relative depth of 1.51% showed the nature of the waters is less stable, very easy to experience mixing water with the

outside influences, such as the presence of strong winds. Singkarak lake in Tanah Datar regency of West Sumatera Province has a relative depth value of 2.45% [4] and Limboto Lake in Poso Regency of Central Sulawesi Province has a relative depth value of 1.18% [15]. Most of the lake has a value of $Z_r < 2.0$ showed a low level of stability, while the lake with surface of the a narrow and high depth have high stability with a value of $Z_r > 4.0$ [9].

State of Fish Communities

Fish community in Maninjau Lake total 15 species consists of nine species of native fish and six fish species introduction, have a high diversity dominated by herbivorous fish species 46.66%. *Psylopis sp* is an endemic species and important fisheries commodity in Maninjau Lake. The *Psylopis sp* is an important fish to sustain the balance of food chain in Maninjau Lake [16]. Its is a prey for carnivorous fish such as *Hampala macrolepidota* and *Hemibagrus nemurus* [17] stated the fish community in Maninjau Lake many as ten species, means within the last seven years the addition of five species of fish communities are *Osphronemus gurami*, *Leptobarbus hoeveni*, *Pangasius hypophtalamus*, *Oxyeleotris marmorata*, *Channa lucius*. The existence of these species due to the development of cultured in floating net cages farming. So that fish farmers also cultured *Osphronemus gourami*, *Leptobarbus hoeveni*, *Pangasius hypophtalamus*, while *Oxyeleotris marmorata* and *Channa lucius* a followup fish with carp seed from Rao Pasaman Regency to be cultured in floating net cages. Changes in the composition of the fish community can cause native fish species threatened because *Oxyeleotris marmorata* and *Channa lucius* are predatory. But it economically profitable in rural communities because this species has a high price in the local market ranged between 50,000 to 75,000 IDR/kg.

Table 6- Trophic state index (Carlson's trophic state index, TSI, 1977) in July 2013

Observation site	Total Phosphorus ($\mu\text{g/l}$)	Brightness water (meter)	Chlorophyll-a ($\mu\text{g/l}$)	Average TSI (Score)	Trophic state
Muko-Muko	550	1.5	236.03	77.82	heavy eutrophic
Tanjungsani	640	1.2	267.2	77.58	heavy eutrophic
Bayur	580	1.4	285.02	79.03	heavy eutrophic
Koto Kaciek	650	1.1	297.01	80.08	heavy eutrophic
Average \pm SD	605 \pm 4.79	1.3 \pm 0.18	271.3 \pm 2.65	78.62 \pm 1.15	heavy eutrophic

State of Waters Quality

Water transparency of Maninjau Lake in July 2013 very low average of 1.3 ± 0.18 m, whereas in 2004 an average of 5.4 ± 0.63 m [1]. The reduced level of water transparency caused by the increasing number of particles residual feed and fish feces of floating net cages in the form phosphorus and nitrogen of loose into water bodies. Phosphorus plays a major role in the metabolism of biologically needed by aquatic organisms. Phosphorus in lake waters of which can take the form of orthophosphate which is the form of dissolved inorganic phosphate that can be used directly by the plant components such as phytoplankton. The content of chlorophyll-a ranged between 0.23603 to 0.28502 mg/m³, lower than the findings [18] which is ranged between 0.312 to 2.795 mg/m³. The reduced content chlorophyll-a caused since 2005 Weir door Hydroelectric Power Plant has been opened with the water discharge ranged ranged between 0.38 to 0.67 m³/second thus allowing *Mycrocystis* located on the surface of the water rapidly out of the lake.

State of Trophic

The waters Maninjau lake in July 2013 are the state of heavy eutrophic, caused by many nutrients such as nitrogen and phosphorus from sewage floating net cages are released into the water. Floating net cages in Lake Maninjau in 2012 amounted to 15,860 units and the contents of the fish were only 80% are 12,688 units, require as much feed 6,542.25 tons / year so that the feed conversion of 1.6 produced fish as many as 4,088.90 tons. Residual feed and fish feces is predicted to be as organic waste much as 18.17 tons/day [19]. Levels of total phosphorus and chlorophyll-a found highest at area a lots of water cages culture in Koto Kaciek village. This is because the waste feed and fish feces high containing organic matter and nutrients and into to water bodies. According McDonald et al [20] 30% of the amount of feed given not consumed by fish and 25% to 30% of the food eaten is excreted. Waste feed and fish faces is a form of pollution load of phosphorus, orthophosfat and nitrogen compounds which can change the trophic state of the lake [21, 5].

Conclusion

Maninjau lake, a tecto- volcanic type lake, occupies a considerable proportion of the catchment area, has a very long water retention time, with the nature of the waters is less stable. Inhabited by 15 species of economically important fish consists of native and introduced fish are classified as herbivorous, omnivore and carnivore. The phosphorus and Chlorophyll-a is very high, brightness level waters is very low caused by waste feed and fish feces from floating net cages were released into bodies of water so resulting state of water is heavy eutrophic.

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