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# Fishery activities and environmental condition of Maninjau Lake, West Sumatra

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**Abstract.** Maninjau Lake is located in Tanjung Raya Subdistrict, Agam Regency, West Sumatra Province, with the surface area 9,737.50 ha. Maninjau Lake has one major outlet through the Batang Antokan river flows to the west coast of Sumatra Island. The excessive number of floating net cages, those are upper of carrying capacity, is the biggest problem in Maninjau Lake. Mass fish kills happened frequently due to deterioration of water quality in this lake. This study is aimed to observe the current fishery activities and environmental conditions in Maninjau Lake. The data were collected by survey using interview methods and record statistic data from the government. The results showed that Maninjau Lake has three functions as ecologies, social and economic. The capture fisheries are still using the traditional fishing gears, while the fish culture is using the floating net cages. There were 18 species inhabited in Maninjau Lake, consists of native and introduced species. Moreover, invasive species have been found, namely *Pteryglichtys pardalis* (Amazon sailfin catfish) and *Amphilophus trimaculatus* (flowerhorn). Nowadays, it is difficult to catch the native fish, *Tor* sp (gariang), and the endemic fish, *Psilopsis* sp (rinuak). Maninjau Lake is in the eutrophic state with quite good waters conditions, but it could become worse since the lake is steadily changing naturally and also anthropogenic activity. The fisheries management in Maninjau Lake should involve the stakeholder groups that have a different degree of interest, the role of management, and related institutions.

## 1. Introduction

West Sumatra Province has five big lakes, i.e., Singkarak Lake (10,908 ha), Maninjau Lake (9,737.5 ha), Diatah Lake (3,500 ha), Dibawah Lake (1,400 ha), and Talang Lake (500 ha) [1]. Those lakes are the primary producer of freshwater fish in West Sumatra, besides being a tourist destination. Maninjau Lake is located in Tanjung Raya Subdistrict, Agam Regency, about 140 kilometers north of Padang City.

Maninjau Lake is a techno volcanic lake formed by volcanic activity around 52,000 years ago. This lake is located on geographical position E: 00012'26.63 " - S: 0025'02.80" and E: 100007'43.74" - E: 100016'22.48 ", at altitude of 461.50 m above sea level. The surface area of the lake is 99.5 km<sup>2</sup> with an average depth of around 105 m and can reach 495 m as a maximum depth [2][3]. Maninjau Lake has one major outlet through the Batang Antokan river flows to the west coast of Sumatra Island.



Maninjau Lake is one of the priority management lakes in Indonesia. This lake has the sulfur tubo phenomenon that occurs 3-4 times per year from November 2016 to the present. The residence time of water mass (retention time) is very long, 25 years with a volume of 10.26 billion m<sup>3</sup>. The damage of the Maninjau Lake environment is caused by the number of floating net cages that exceed the carrying capacity (more than 20,000 units), and they were also too closed between with others. The maximum of floating net cages are 6000 units. The floating net cages in Maninjau Lake produced 178,889 tons of sediment. Fish mass killed from floating net cages are dumped into the lake. Until now, there were 11 times fish killed happened and increased in 2016. The revenues from the floating net cages were 43.3 billion every year. This business was exciting and caused the amount of floating net cages was overgrown. To save the Maninjau Lake, it needs to manage seriously. Maninjau Lake needs the management for the conservation to keep the fish resources sustainability of Maninjau Lake.

This paper is to determine the fishery activities and environmental conditions of Maninjau Lake, West Sumatra, in order to keep the sustainability of fish resources.

## 2. Data and Methods

The research was conducted in 2017 in Maninjau Lake, Agam Regency, West Sumatra (*Figure 1*). The primary data were collected by direct survey and interview the fishers, whereas secondary data were obtained from the related institution and previous studies. Data collection from the field survey was carried out by stratified sampling methods [4] [5].



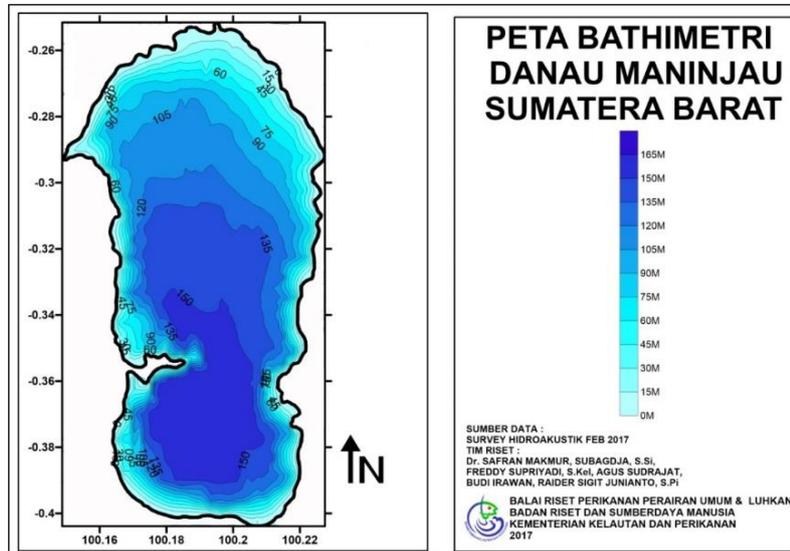
**Figure 1.** Location of research site

## 3. Results and Discussions

### 3.1. Features of Maninjau Lake

Maninjau Lake has a form of extending from north to south with a maximum length of about 17 km and a width of about 8 km. This lake has one natural outlet, Batang Antokan, a river that flows to the westward towards the Indian Ocean. The higher area with the steeper slope is the area towards the southern part of the lake. In general, the lake's hydrological condition is influenced by surface water and groundwater. Most of the surface water flows through established distribution patterns. The water sources mainly come from rivers that flow along the water catchment area, therefore stream down into the lake, as well as from rainwater. Eighty-eight large and small rivers flow into the lake. Maninjau Lake has a depth ranging from 0-165 m, with an average depth of 104 m (*Figure 2*). According to the Research Center for Limnology, Indonesian Institute of Sciences, the Maninjau Lake physical characteristics

showed in Table 1. The deep part of the lake finds in the southern region, such as the area of Galapuang and Pandan areas.



**Figure 2.** Bathymetric of Maninjau Lake (Makmur *et al.* 2017)

**Table 1.** Maninjau Lake physical characteristics [8]

Characteristics		
Elevation (above sea level)	463	m
Luas Permukaan	99.5	km <sup>2</sup>
Maximum of lake length	16.7	km
Maximum of lake width	8.5	km
Maximum of lake depth	169	m
Average of lake depth	109	m
Circumference	48.8	km
Volume	10.4	km <sup>3</sup>
Retention time	47	year
Water Catchment Area	248	km <sup>2</sup>

### 3.2. Maninjau Lake Roles

The ecological function of Maninjau Lake is the habitat for organisms, the balance control of groundwater, and as a control of microclimate. Presently, the utilization of Maninjau Lake is a primary source of water, hydroelectric power, tourism, and fisheries. The people who live surrounding the lake, get clean water sources. Over time, various activities have taken places, such as the existence of power plants, fisheries in floating net cages, captured fishery, tourism destination, and irrigation for agriculture [7]. The livelihood of the people surrounding the lake depends on the lake condition. By constructing hydropower, the water throughout the lake is diverted, so the natural flushing system becomes disrupted. The existence of hydropower development caused a change in the lake's hydrological system. Initially, the surface layer of waters turned into a subsurface layer or at a height of 6-10 m. Since the hydropower plant constructed, the water has no longer throughout the natural channel of Batang Antokan. The water was through from the intake to the hydropower plant because it was needed to drive the turbine. The reduced area of forest cover in the catchment area in the upper of Maninjau Lake caused significant water level differences between the rainy season and the dry season. In the dry season, the water level becomes lower, and the hydropower operation is getting disrupted.

### 3.3. Floating Net Cages

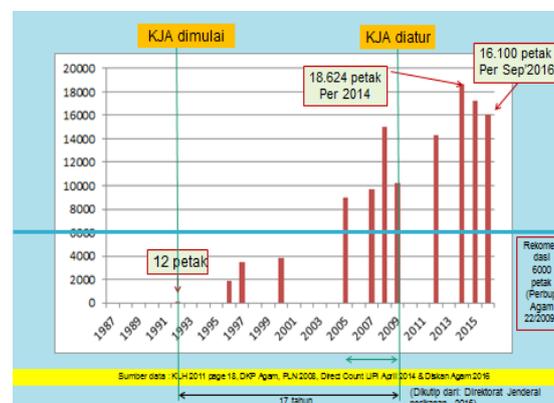
The people who lived surrounding the lake informed that the first time of floating net cages development was in 1991. The number of cages increased rapidly to thousands from year to year. Indonesian Institute of Science conducted a study in 2001-2009 and reported that the closure of the Batang Antokan River due to leftover food and metabolic waste from fish rearing activities in floating net cages. The number of floating net cages in Maninjau exceeded the carrying capacity of the environment [9]; its domestic waste was the leading cause of the lake ecosystem function declining [10]. For instance, the number of floating net cages in 1996 was only 1,886 units; then, in 2000, it became 3,856 units; in 2008, it reached 15,051 units, and in 2014 became 18,000 units. According to the Limnology Research Center study, this lake can only support 6,000 units (*Figure 3*).

The rapid development of floating net cages with overfeeding has caused a lot of leftover food to accumulate at the bottom of the lake. It is estimated that around 50-70 tons of feed is spread per day through floating net cages activities. Besides that, fish feces also accumulate at the bottom of the lake. The organic materials are then broken down by microbes that expose a lot of oxygen and brought in the bottom of the lake to run out of oxygen (anoxic) and contains toxic sulfides (sulfur). If the weather change was changed, it causes the hydrological conditions changes. It will turn the inner layer to be lifted (overturn), the fish on the surface will die massively because of depleted of oxygen and poisoned. The mass fish kills have repeatedly occurred in Maninjau Lake, and cause enormous economic losses.

The water quality of Maninjau Lake was decreasing due to the inclusion of organic and inorganic pollutant loads from various pollutant sources. The primary source of pollution came from activities around the lake, such as from housing, agriculture, animal husbandry, as well as floating net cages [11]. [12] reported that environmental problems are indeed complex because they cover various aspects. Ever since the Maninjau Lake pointed as one of the examples of lake management, it is necessary to study various aspects of fisheries and other factors such as environmental changes in the waters. Moreover, it needs to pay attention to industrial and household pollution factors, which also pose a severe threat to the existence of fish resources and water quality of the lake.

Currently, the economic condition of the people around Maninjau Lake is not good as well as previous, when floating net cages became the best success. At that time, Maninjau Lake was a center for freshwater fish production in West Sumatra. Revenues from floating net cages in Maninjau reached 43.3 billion/year. Table 2 showed the development of floating net cages in Maninjau Lake continued to increase due to the economic benefits until the amount greatly exceeded capacity in 2016. In 2016, the number of floating net cages had reached 16,100 units exceeding the optimum 6,000 units.

The farmer of floating net cages faced the problems of the mass fish kills, which always happened every year. Besides, due to the presence of sulfur, the increasing number of leftover deposits and metabolism at the bottom of the lake will cause a slight reversal of the water mass. The weather changes and repeal of the water mass will be toxic to fish, especially fish in the floating net cages.



**Figure 3.** Amount of floating net cages from 1992 to 2016

**Table 2.** Mass fish kills caused by upwelling in Maninjau Lake [13]

Year	Total of floating net cages (unit)	Total of mass fish killed	Financial Loss
1997	2,854	950	IDR 2,700,000,000
2009	9,830	13,413	IDR150,000,000,000
2010	13,129	1,150	IDR18,400,000,000
2012	15,860	250	IDR4,375,000,000,000
2013	16,120	450	IDR8,100,000,000
2014	16,520	680	IDR13,600,000,000
2015	16,620	150	IDR3,000,000,000
2016	20,620	600	IDR12,000,000,000
<b>Total</b>	<b>17,643</b>		<b>IDR212,175,000,000</b>

### 3.4. Fishery Activities

Fishing activities are increasingly scarce or reduced; fishers only take fish in the lake inlets or small streams that flow into the lake. Fish-caught is also decreasing. Many kinds of fish are difficult to find, such as gariang (*Tor soro*) and rinuak (*Psylopsis* sp), the native fish of Maninjau Lake. The price is getting higher. For instance, rinuak, previously it was only IDR 40,000/kg, now it reaches IDR 100,000/kg. Gariang is still found in the river, but the population is decreasing as well as seluang (Rasbora) and barau (Hampala), and captured in only certain areas in Maninjau Lake. Introduced fish either intentionally or not developed in Maninjau, such as marble goby tilapia, catfish, and freshwater lobster. Indonesian Institute of Sciences in Maninjau breeds the native fish such as rinuak and bada, but the stocking activities cannot be done due to unstable lake conditions.

There is an amount of fishing gear using in Maninjau Lake (Figure 4). *Bagan* is a fishing gear used to catch the rinuak (Figure 4a). But now, the rinuak population is currently decreasing and even it needs to be researched extinct rather than prohibited the capture. *Bagan* rinuak is used at night using light from a lamp since rinuak will gather toward the light.



**Figure 4.** a) Bagan; b) Lukah; c) Rago; d) Keramba Tancap

*Lukah* is also a kind of trap, but to catch the small fish such as bada and shrimp (*Figure 4b*). *Lukah* made from blades or bamboo, it is installed in the riverside integrated with the lake. While *Rago* is a shrimp trap (*Figure 4c*). It is installed on the lakeside, submerged, given a ballast, and covered by coconut leaves. *Rago* is usually lifted every day.

There is the traditional cage in Pandan Village, made of bamboo or wood and nets, equipped with fish traps to lead the fish entered into cages (*Figure 4d*). The cages are installed on the lakeside, with a sandy bottom, and the clean waters can flow into the cages. The water inside the cage makes natural aeration to enrich the oxygen reserves in the cages. Fish from the lake will be attracted by good water quality, and enter the net through a hole at the net bottom. Furthermore, after entering the net, the fish needs natural food. Many kinds and sizes of fish stuck in the net, such as tilapia, catfish, snakehead, bonylip barb, fire eel, hampala, silver rasbora, marble goby, amazon sailfin catfish, flowerhorn, and freshwater lobster. The fish which reach the consumption size are caught and separated into permanent storage nets to avoid predators. These cages usually harvested once a week, with an average yield of 25 kg.

The other general fishing equipment is gill nets and cast nets, but now they are rarely used since the fish resources are decreasing.

### 3.5. Fish Diversity

[12] reported that Maninjau Lake (*Table 3*) inhabited by some introduced species and native fish. The singularity of Maninjau Lake has the anguillid eel (*Anguilla bicolor*) since Maninjau Lake is the only one of a natural lake in Sumatra that has access to the Indian Ocean, through the Batang Antokan river.

After stocking up the introduced fish into floating net cages, the seeds which not to be cultivated are thrown into the lake. The introduced fish grow with tilapia seeds or common carp seed.

There are 18 fish species inhabited in Maninjau Lake; most are introduced fish such as tilapia, catfish, marble goby, and lobster shrimp. Currently, some invasive fish have begun, such as Amazon sailfin catfish (*Pteryglichtys pardalis*), while the exotic or aggressive ornamental fish such as flowerhorn (*Amphilophus trimaculatus*) also spread. The economic consumption fish such as tilapia, bada, barau, and asang is the main target to catch. However, flowerhorn is one bycatch using gillnet and it can sell into traditional markets with a price between IDR20,000-30,000 per kilogram. The taste of flowerhorn is not delicious and chewy than tilapia, so it does not desirable as consumption fish. Rinuak is an endemic fish in Maninjau Lake, which classification is Class: Pisces; Order: Osphroneformes; Family: Osphronemidae; Genus: *Psilopsis* and Species: *Psilopsis* sp.

No one knew when the flowerhorn started to inhabit Lake Maninjau. According to local people, there is local wisdom among the flowerhorn breeders. If the breeder reared the flowerhorn for taking part in the fish contest, they must throw some of the flowerhorn seed into rivers, lakes, reservoirs, or other waters for getting lucky. Further explanation, if the breeder hatched 400 seeds, only 100 seeds are selected. The remain of seed was sold to the fish market, others dumped into lakes, rivers, or reservoirs. This activity is done by breeders or farmers who do not understand how dangerous to wild- release the fish. It needs to teach an understanding that the population of native fish species will be disturbed and even extinct due to the expansion of flowerhorn.

Invasive Alien Species (IAS) are species that are introduced into places outside their natural range, negatively impacting native biodiversity, ecosystem services, or human well-being (IUCN). According to [14], [15], Invasive Alien Species are alien species that cause economic or environmental harm or harm to human health, a significant threat to biodiversity and ecosystem functions, and changing the most important ecological in the world.

**Tabel 3.** Fish diversity inhabited in Maninjau Lake

No	Common/Local Name	Species	Family
1	Hampala Barb/Hampal	<i>Hampala macrolepidota</i>	Cyprinidae
2	Gariang	<i>Tor soro</i> **	Cyprinidae
3	Bonylip barb/Nilem	<i>Osteochilus vittatus</i>	Cyprinidae
4	Silver rasbora/Seluang	<i>Rasbora argyrotænia</i>	Cyprinidae
5	Common carp/Mas	<i>Cyprinus carpio</i> *	Cyprinidae
6	Giant gourami/Gurami	<i>Osphronemus gouramy</i>	Osphronemidae
7	Rinuak	<i>Psylopsis</i> sp.	Osphronemidae
8	Mozambique tilapia/Mujair	<i>Oreochromis mossambicus</i> *	Cichlidae
9	Supareh	<i>Puntius</i> sp.	Cyprinidae
10	Nile Tilapia/Nila	<i>Oreochromis niloticus</i> *	Cichlidae
11	Snakehead/Gabus	<i>Channa striata</i>	Opheocephalinidae
12	Anguillid Eel/Sidat	<i>Anguilla</i> sp **	Anguillidae
13	Marble goby/Betutu	<i>Oxyeleotris marmorata</i> *	Elotridae
14	Catfish/Baug	<i>Hemibagrus nemurus</i>	Bagridae
15	Amazon sailfin catfish/Sapu-sapu	<i>Pteryglichtys pardalis</i> ***	Loricariidae
16	Flowerhorn/Lohan	<i>Amphilophus trimaculatus</i> ***	Cichlidae
17	Striped catfish/Patin	<i>Pangasianodon hypophthalmus</i> *	Pangasiidae
18	Freshwater Crayfish	<i>Cherax quadricarinatus</i> ***	Parastacidae

Remarks: \* Introduced fish; \*\* Native fish that cannot find now, \*\*\* Found during the study

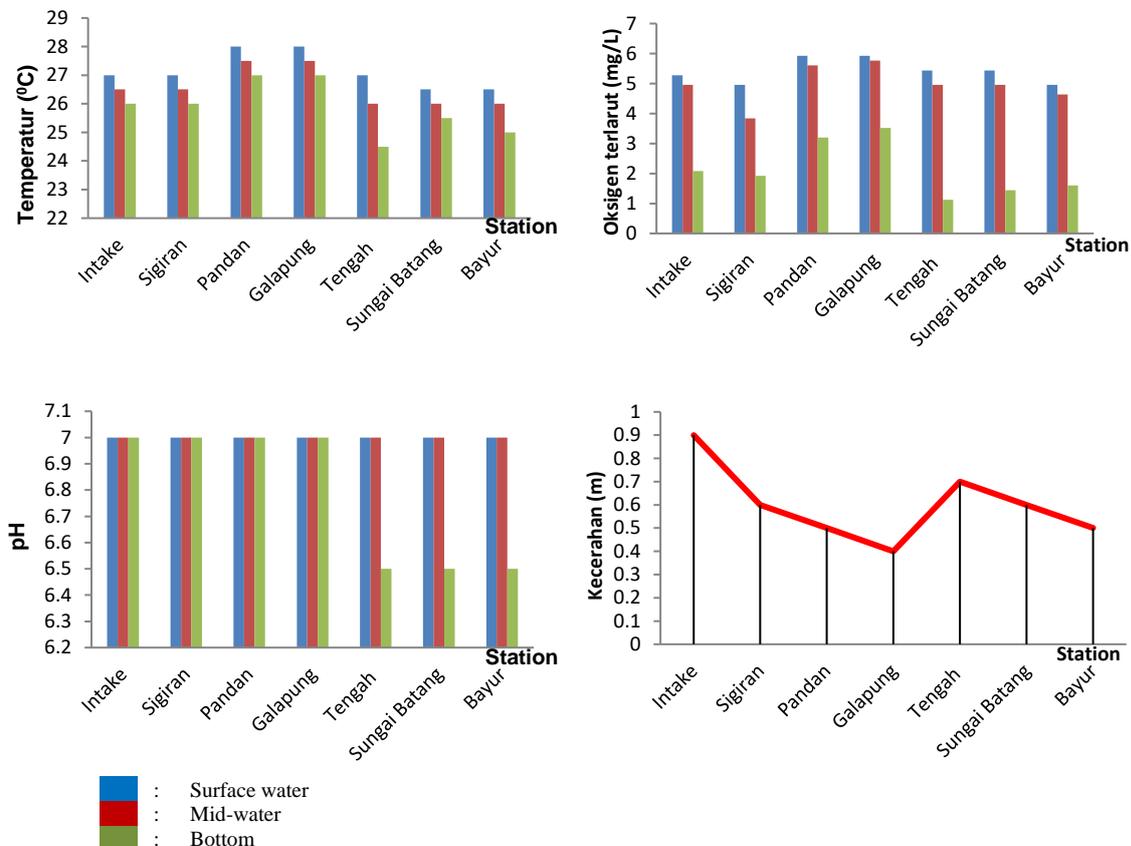
### 3.6. Waters Environmental Condition

Some parameters of the water lake indicated that it was still within the tolerance range for the aquatic organisms' life, including fish (Figure 5). Water temperature was between 24.5 - 28°C, with an average of 26.5°C. Water temperature will decrease based on the depth (surface, mid-water, and bottom). The range of dissolved oxygen content was between 1.12 - 5.92 mg per liter or on average of 4.17 mg/liter, and as well as like temperature, the oxygen will decrease depending on the depth. The dissolved oxygen in Maninjau Lake showed a very drastic decrease, and it related with the average transparency limit area of approximately 1 mg/l with average transparency of 0.6 m. It was impacted the water fertility and showed by the dark green water.

The range of pH was 6.5 - 7 or an average of 6.9. Generally, water lake has an acidity above seven or an average of 8. The pH of Maninjau Lake was relatively the same as some lakes in Indonesia, such as Towuti Lake (7.2 - 8.1) [16], and Ranau Lake (8 - 8.5) [17]. [11] reported that the pH of Maninjau Lake was an average of 7.38. The pH is still ideal for supporting the life and breeding of aquatic organisms in accordance with [18]; the pH range at 6-9 is an ideal for fisheries production. Based on water quality standards for class I, the pH of water is ranged in 6-9.

The transparency of waters lake was in ranges from 0.4 to 0.9 m or an average of 0.6 m, less than 1 m. The condition was due to the presence of floating net cages. Since the leftover food accumulated at the bottom of the water, it affected the waters color change into dark green.

The chlorophyll-a content was between 32.48 - 85.55 mg per liter or an average of 53.99 mg/L. According to [19], [20], waters in the lake with chlorophyll-a concentrations between 3 - 78 mg/L are stated as the eutrophic.



**Figure 5.** Temperature, dissolved oxygen, pH and transparency of Maninjau Lake waters

### 3.7. Maninjau Lake Management Proposed

Maninjau Lake has three functions, namely ecological, social, and economic, that should be managed harmoniously. The ecological function will support environmental health, while the social service supports education, culture, and recreation, and the economic role of the lake is fisheries, electricity, water supply, and tourism industry. Nevertheless, the economic services, especially floating net cages, drives various problems such as algae to bloom occurrence, and mass fish killed.

The management of Maninjau Lake must be done comprehensively by involving various institutions and local wisdom. Local governments with community leaders, traditional and religious leaders played an active role together in a participatory management system (co-management) such as produce the regulations for local fisheries management. Institutional sustainability was also recognized as an important indicator, such as issuing the emergency of local wisdom and the demand for participatory development in management [21]. Local government plays an essential role in determining the management policy for inland fisheries [22]. Co-management is a proposed fisheries management in Maninjau Lake, that it should involve stakeholder groups in different degrees with local interests and roles of management, and related institutions.

## 4. Conclusion

The capture fisheries are still using the traditional fishing gears, while the fish culture is using the floating net cages. There were 18 species inhabited in Maninjau Lake, consists of native and introduced species. Moreover, invasive species have been found, namely *Pteryglichtys pardalis* (Amazon sailfin catfish) and *Amphilophus trimaculatus* (flowerhorn). Nowadays, it is difficult to catch the native fish, *Tor* sp (gariang), and the endemic fish, *Psilopsis* sp (rinuak). Maninjau Lake is in the eutrophic state with quite good waters conditions, but it could become worse since the lake is steadily changing

naturally and also anthropogenic activity. The fisheries management in Maninjau Lake should involve the stakeholder groups that have a different degree in interest and role of management and related institution.

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