Catalogue of

SUMATRAN BIG LAKES

Lukman

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LIPI Press

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Editorial Note

As a scientific publisher, LIPI Press holds on high responsibility to provide high-quality scientific publication. The provision of qualified publication is the epitome of our works to participate in enlightening society intelligence and awareness as stated in The Preambule The 1945 Constitution of the Republic of Indonesia.

Through this popular scientific book, *Catalogue of Sumatran Big Lakes*, LIPI Press contributes to the horizon of readers' thought and insight about the information/condition of the lakes in Sumatra. The information is represented by those of eight large lakes in Sumatra, namely Lake Laut Tawar, Lake Toba, Lake Maninjau, Lake Singkarak, Lake Diatas, Lake Dibawah, Lake Ranau, and Lake Kerinci.

Scattered data and information from various institutions, reports, and journals are thoroughly collected to form a series of lake's ecosystem mosaics in Sumatra that stretch out from Aceh to South Sumatra. Thus, this book is hopefully meaningful to fulfill the need of Indonesian lakes information/references, specifically those of Sumatra.

As a final note, we would like to deliver our heartfelt gratitude to everyone taking part in the process of this book publication.

LIPI Press

Foreword

It should be noted that since early 20th century Indonesian lakes had been studied. The pioneer scientific study was initiated by a German Researcher, Ruttner. He led the historical expedition known as the Sunda Expedition. The expedition covered several lakes in Sumatra, Java, and Bali. Therefore, the scientific expedition had introduced to a new scientific field based on Inland Water Ecology in Indonesia and also some other Tropical Asian Nations. The initiative had resulted in expanding of Indonesian lakes' studies until today.

In this context, Research Center for Limnology was established in 1986. It is part of the Indonesian Institute of Sciences which is directly responsible to the Government of the Republic of Indonesia, particularly in managing and studying of lakes. Although many lakes in Indonesia have been studied and subsequently several scientific reports have been published in scientific journals, there are still limitation and gaps. Therefore, several efforts are encouraged in order to obtain concrete data for most scientific studies.

Due to the limit of references, this catalogue is written and compiled. The catalogue is the first compilation focusing on Sumatran Lakes. Data and information are the result of research activities conducted by Research Center for Limnology and also other agencies including other research institutions and also universities.

It is hoped that this catalogue can be beneficial and useful not only to Indonesian researchers, but also to other lake researchers in Southeast Asian nation.

Mashhor Mansor
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Preface

The study of Indonesian inland waters, especially its fish biota, has been going on since the 17th century, begun Johan or Johannes Nieuhof who in 1653–1662 represented the Nederlandsce Oost-Indiche Compagnie. Some 43 species of Indonesian fishes are named and briefly described, and almost all of them are illustrated (Roberts, 1989). Nevertheless, many of those scientific documents of research activities of Indonesian lakes which have been going through since early 20th century have scattered in various research institutes, both domestically and abroad.

In relation to the needs of data and information which are necessary both for research development and lakes management research document conservation is very important. This is relevant to the Indonesian lake's conditions in which the interest on lake utilization is developed. On the other side, many lake's conditions have been degraded. Therefore, research activities are supposed to be increased to support the lake management and utilization activities.

The author tried to construct a catalogue of the lakes from Sumatra whose data sources are from the results of activities by the Research Center for Limnology, reviewed by other research institutions and universities. The author has received a lot of supports and assistance during the preparation of this book, both from co-workers and colleagues from other institutions especially for the provision of documents and other data.

Therefore, the author would like to thank Mrs. Husnah Samhudi and Mr. Samuel (Research Institute for Inland Fisheries, Ministry of Marine and Fisheries); Mr. Irwan Riadi (Regional Environmental Board, Aceh Tengah Regency, Nangro Aceh Darussalam Province); Mr. Yugo Kumoro (Research Center for Geotechnology, Indonesian Institute of Sciences); Mr. Ridwansyah; Mr. Sulung Nomosatryo, Mr. Tri Suryono, Mrs. Awalina, Mrs. Fachmiyani Sulawesty, Mr. Apip and Mrs. Novi Mayasari (Research Center for Limnology, Indonesian Institute of Sciences) who contribute several manuscripts, also to Prof. Mashhor Mansor (Universiti Sains Malaysia) who is pleased to contribute in providing the foreword of this book, also to Miss Miratul Maghfiroh (Research Center for Limnology, Indonesian Institute of Sciences) for working on the grammatical substances.

The author would also like to thank our library staffs, Mr. Saepul and Mrs. Latifah, who helped provide relevant information, and ultimately to the Research Center for Limnology, Indonesian Institute of Sciences (LIPI) for the support on the publication of this catalogue.

Author

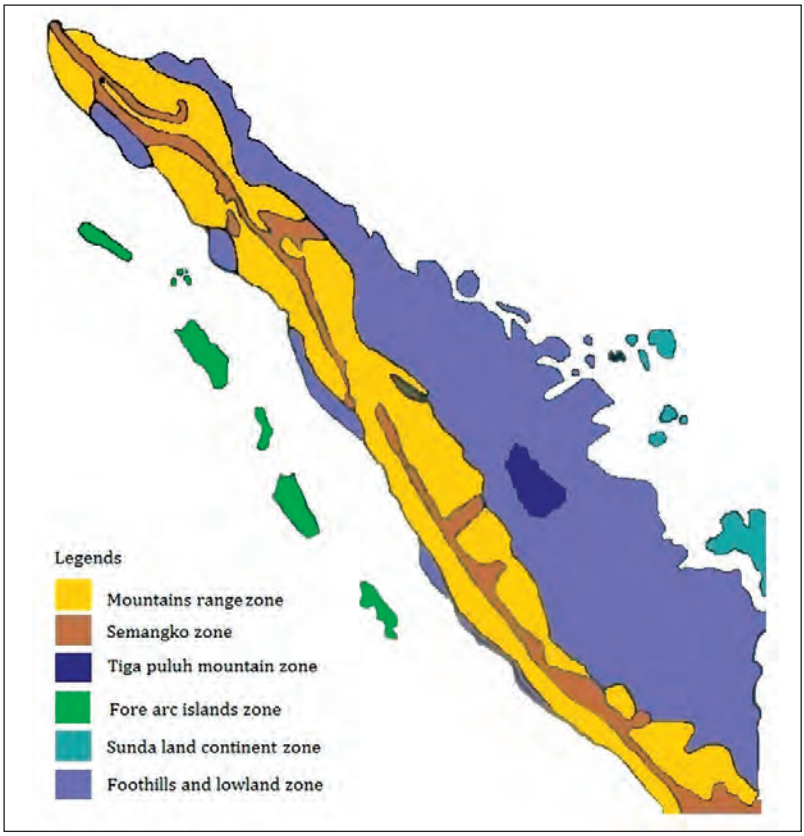
Sumatran Lakes at a Glance

A. Genesis

Most of the large natural lakes in the world were formed by catastrophic events, included tectonic and volcanic activities. Tectonic activities would create formations of depression zone as the impact of the fracture or the lift-up of the Earth's crust.

Sumatra island was influenced by the Indian and Australian plate movement, and the collision between both of which formed a unique geological mosaic. This mosaic of geological feature including a series of fore arch island is a non-volcanic and was formed in the western region of Sumatra island, a series of Bukit Barisan Mountains, and The Great Sumatran Fault (Semangko zone) dividing the island from the Gulf Semangko to Banda Aceh (Figure. 1).

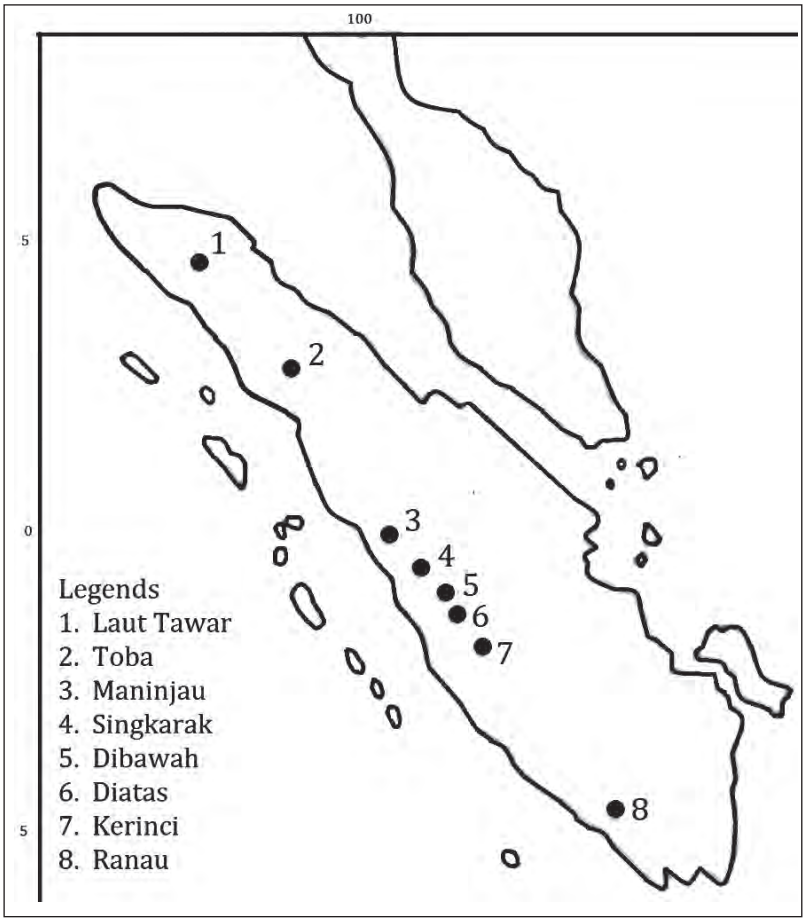
The Great Sumatran Fault played the main role on the formation of the major lakes in Sumatra such as Ranau, Singkarak, and Laut Tawar. For a while, volcanic processes also play a role in the formation of several large lakes, including Lake Toba, a large natural lake occupying the caldera of a supervolcano.



Source: adapted from van Bemmelen (1949); Setiawan (2013)
Figure 1. Physiography Map of Sumatra Island

B. Characteristics and Distribution

The number of lakes in Indonesia was estimated to reach ca. 521 lakes (Nontji, 1994) with diverse shapes, including tectonic type, volcanic type, lakes in flood plain area, and doline type especially the lakes in the karst (limestone) region that relate to the dissolution process of karst. In Sumatra Island, there are at least eight large sized lakes, relatively (Figure 2).



Source: adapted from Nontji (1994)

Figure 2. Distribution of Major Lakes in Sumatra Island

Paternoster lakes were formed as the result of the Sumatra fault, such ad Dibawah and Singkarak lakes. Meanwhile, Toba is the largest lake in Indonesia and also the largest volcanic lake in the world. Lake Toba is the site of a massive super volcanic eruption estimated to occur 69,000 to 77,000 years ago (Chesner, Westgate, Rose, Drake, & Deino, 1991). Beside Lake Toba, Lake Maninjau is lake relics of terrifying

volcanic eruptions from the eruption of Mount Tinjau. The depth of the large Sumatran lakes ranges between 80–508 m (Figure 3).

The small lakes have not been recorded in detail and are mostly scattered in Sumatra island. In Nangro Aceh Darussalam Province, Lake Aneuk Laot is in We Island, and Lake Lau Kawar is in North Sumatra Province. In Jambi Province, located in Kerinci Regions, there are 16 volcanic lakes included in valley type (Table 1). In the downstream area, there are 47 flood plain lake types which have size of > 4.0 ha, eleven lakes of them are listed on Table 2 (Eddy, 2004).

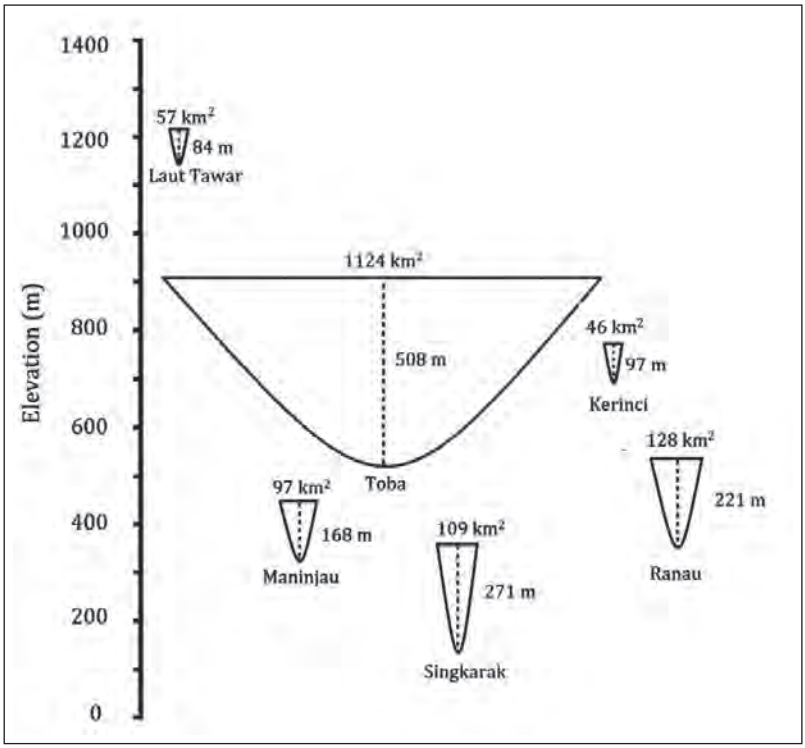


Figure 3. Profile of Six Major Lakes in Sumatra Island

There are also several lakes in Bengkulu Province (Priambudi & Saragih, 2004), they are Lake Dendam Tak Sudah (50 ha), Lake Tes (300 ha), Lake Menghijau (8 ha), Lake Harun Bastari (5 ha), and Lake Lebar (8 ha). While in South Sumatra Province the flood plain lake types are found mainly along the sides of Musi River (Table 3).

C. Research History

The history of the lake study in Indonesia, particularly in Sumatra, had been recorded by tracing the work of German researcher, Ruttner, through the German Sunda Expedition that took place in 1928–1929, covering Lakes Toba, Diatas, Maninjau, Singkarak and Ranau (Ruttner, 1931).

Table 1. List of Small Lakes on Lake Kerinci Watershed in Jambi Province

No.	Name	Altitude (m asl)	Size (ha)	Depth (m)
1.	Cernih*	1,600	5.0	nd
2.	Depati Empat*	1,700	315	nd
3.	Duo*	1,600	10	nd
4.	Gunung Tujuh*	1,950	955	40
5.	Kecil Selatan*	1,300	5	nd
6.	Kecil Utara*	1,600	5	nd
7.	Kumbang Barat*	2,600	5	nd
8.	Kumbang Timur*	2,600	5	nd
9.	Langkat*	900	10	nd
10.	Pauh*	1,300	12.5	nd
11.	Bento**	1,375	<50	3.6
12.	Sati**	2,000	<15	nd
13.	Singkarak**	2,000	1,300	268

*) Volcanic lake; **) Infilled valley lake; nd = no data
Source: Giesen & Sukotjo (1991)

Table 2. List of Small Lakes (≥ 4.0 ha) Included in the Flood Plain Type in Jambi Province

No.	Name	Size (ha)	Depth (m)	Main river
1.	Sipin	30	7	Batanghari
2.	Teluk	20	15	Batanghari
3.	Mudung	15	5	Batanghari
4.	Taligawa	10	5	Batanghari
5.	Kasang	7	nd	Batanghari
6.	Jering	7	nd	Batangtabir
7.	Penghulu Somat	4	nd	Batangtabir
8.	Muara Malembak	4	nd	Batangtabir
9.	Tanjung Tepah	4	nd	Batangtabir
10.	Tanjung Sudin	4	nd	Batangtabir
11.	Pimping	5.6	nd	Batangtabir

nd = no data
Source: Eddy (2004)

Table 3. The Flood Plain Type Lakes in South Sumatra Province

No.	Name	Area (Ha)	Regency
1.	Ulak Lia	115	Musi Banyuasin
2.	Cala	120	Musi Banyuasin
3.	Konger	14	Musi Banyuasin
4.	Gastam	10	Musi Banyuasin
5.	Sidowali	50	Musi Banyuasin
6.	Ujan Mas	14,5	Musi Banyuasin
7.	Teluk Rasau	180	Ogan Komering Ilir
8.	Teluk Punun	25	Ogan Komering Ilir
9.	Teluk Gelam	250	Ogan Komering Ilir
10.	Lebak Nilang	700	Ogan Komering Ilir

Source: Gafar (2012); Kartamihardja et al. (2010)

Subsequent studies of lakes in Indonesia have been done. The studies focuses more on the fishery resources utilization and environmental solving problems which were conducted by government research institutes, especially the Ministry of Marine and Fisheries (Formerly, the Ministry of Agriculture), the Ministry of Public Works, Universities and Research Center for Limnology-Indonesian Institute of Sciences. This book is a brief compilation of data and information of the eight major lakes in Sumatra from diverse sources of publication. Hopefully this book will broaden the knowledge of the readers in understanding the lakes in Indonesia, particularly those in Sumatra.

Lake Laut Tawar

A. Location

Lake Laut Tawar is located in southeastern Nangro Aceh Darussalam, precisely in Aceh Tengah Regency and Takengon City, the Capital of Aceh Tengah Regency, located in the west side of the lake. Lake Laut Tawar is a part of the Gayo Highlands tourist area whose coordinate position is 04º 34'43 N and 96º 55'25" E.

B. Description

Lake Laut Tawar is spread out from east to the west and marked as the big lake in northern part of Sumatra Island. Lake Laut Tawar was formed by tectonic processes (Lehmusluoto & Machbub, 1997), and is a part of Sumatran Fault System.

As a part of Peusangan River catchment, Lake Laut Tawar has the characteristics of a very steep slope, with red-yellow podzolic and complex Rezina soil type predominantly. The depth of solum soil is very shallow and susceptible to erosion (Adhar, 2011).

Source: Iriadi (2015)

Figure 4. A View of Lake Laut Tawar

Figure 5. Map of Lake Laut Tawar

Various economic activities of people in the Lake Laut Tawar and its surounding area are agriculture, plantation, farming, fishing, and tourism (Khasanah et al., 2010). The quite prominent of fishing activity is fishing of *Rasbora tawarensis* known as *depik* fish, also known as endemic species of Lake Laut Tawar.

C. Physical Dimension

Some data on Lake Laut Tawar physical dimensions can be seen in Table 4.

Table 4. Characteristics of Lake Laut Tawar Morphometry

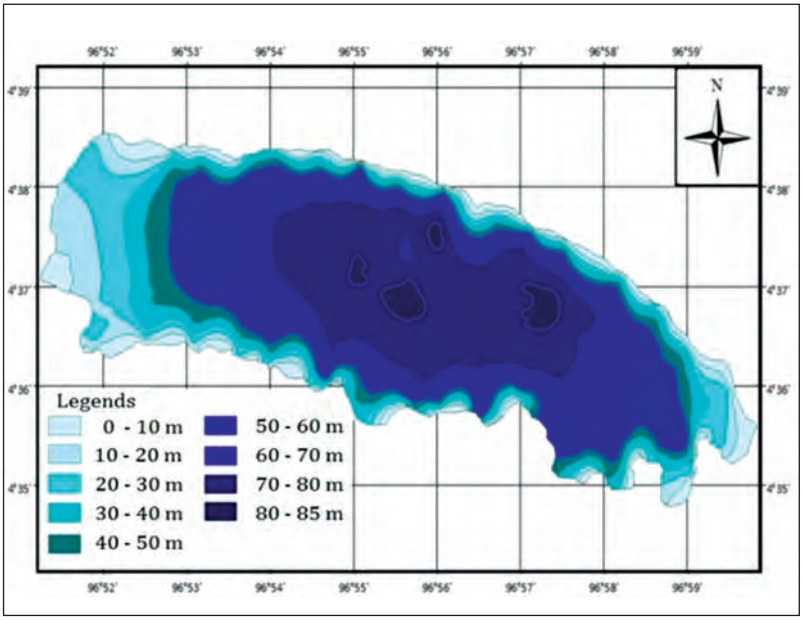
No	Parameter	Values
1	Area of waters (A) (km^2)	57.42
2	Maximum of length (km)	15.7
3	Maximum of width (km)	4.6
4	Shore length (km)	43.9
5	Maximum of depth (m)	84.2
6	Volume (i)(x 10^6 m^3)	538.8
	Volume (ii) (x 10^6 m^3)	2,537.5
	Volume (iii) (x 10^6 m^3)*]	1,446.4
7	Average of depth (m)	25.2
8	Area of cathment (C) (km^2)	194.45
9	Ratio of C/A***]	3.39

Note: *] Self calculation [Area of waters x Average of depth]
***] Self calculation
Source: Husnah & Fahmi (2015); Saleh, Ali, Supriatno et al. (2000); Kholik (2014)

1. Elevation of Lake Laut Tawar: 1,230 m (above msl).
2. Water flow characteristic (Iriadi, 2015; Husnah & Fahmi, 2015)
    a. Inflow rivers: Pademun Toweran, Rawe, Kalang, Bale Nosar, Nosar Bawah, Mengaya, Kalabintang, Kalabintang I–V, Klitu, Ujung Paking, Kebayakan, Kalanampak.
    b. Infow rate: Range 0.04–1.44 m^3/sec.
    c. Total inflow rate: 8.80 m^3/sec.
    d. Outflow river: Krueng Peusangan
    e. Outflow rate: 29.02 m^3/sec.

D. Physiographic Features

The depth of Lake Laut Tawar is put on a map and is shown in Figure 6.

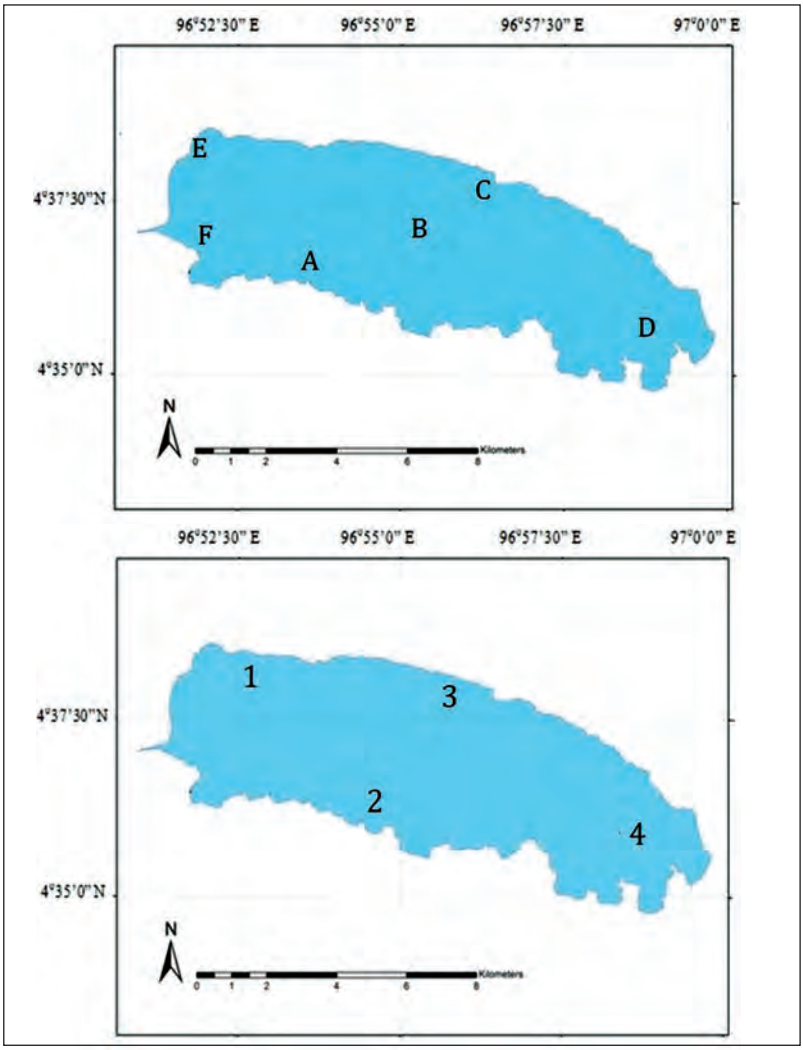


Source: Husnah & Fahmi (2015)

Figure 6. Bathymetry Map of Lake Laut Tawar

E. Water Quality

Lake Laut Tawar had undergone water quality measurement in 2012 and 2015. In 2012, water quality was measured by 4 stations, while in 2015 the number of stations were upped by two stations.



Source: Iriadi (2015) (upper); Husnah (2012) (below)

Figure 7. Water Quality Measured Stations in Lake Laut Tawar in 2014 (upper) and in 2012 (below)

Table 5. Water Quality Condition in Lake Laut Tawar in 2014

Parameters/ Time	Stations					
	A	B	C	D	E	F
Temperature (°C)						
July 2014	24.23	25.07	25.33	24.55	24.0	23.8
October 2014	21.83	22.43	22.57	23.5	23.0	23.4
Transparency (m)						
July 2014	6.2	7.3	6.2	5.6	5.5	5.9
October 2014	4.4	4.5	4.3	3.7	3.8	3.4
Ph						
July 2014	8.24	8.41	8.44	8.32	8.32	8.15
October 2014	8.16	8.37	8.31	8.54	8.2	8.18
Conductivity (mS/cm)						
July 2014	0.121	0.109	0.106	0.105	0.11	0.109
October 2014	0.107	0.110	0.11	0.108	0.104	0.109
Chemical Oxygen Demand (mg/L)						
July 2014	30.33	40.92	23.17	37.19	17.2	22.29
October 2014	9.29	15.35	8.08	11.31	3.23	3.64
Total Phosphorus (mg/L)						
July 2014	0.2	0.09	0.1	0.01	0.03	0.18
October 2014	0.27	0.310	0.23	0.35	0.17	0.26
Dissolved Oxygen (mg/L)						
July 2014	5.93	4.97	6.83	6.50	6.10	5.10
October 2014	6.63	7.52	6.50	8.25	6.37	5.47

Source: Iriadi (2015)

Table 6. Water Quality Condition in Lake Laut Tawar in 2012

Parameters/ Time	Stations			
	1	2	3	4
Chlorophyll (µg/L)				
March 2012	11.11	5.19	4.98	7.93
June 2012	2.78	2.38	2.72	1.98
Total Phosphorus (mg/L)				
March 2012	1.29	1.14	1.38	1.43
June 2012	1.33	1.48	2.11	1.33
Total Nitrogen (mg/L)				
March 2012	0.14	0.14	0.14	0.11
June 2012	0.97	0.72	0.71	0.76

Source: Husnah (2012)

Source: Iriadi (2015)

Figure 8. Takengon City with Lake Laut Tawar as a Background

F. Biological Features

1. Flora

a. Plants (Husnah & Fahmi, 2015; Dewiyanti, 2012)
   1) Floating: *Eichhornia crassipes, Pistia stratiotes, Salvinia natans.*
   2) Emerged: *Brachiaria mutica, Colocasia esculenta, Ipomoea aquatica, Polygonum* sp, *Oryza sativa, Rhynchospora corymbosa.*
   3) Submerged: *Potamogeton* sp., *Ceratophyllum* sp. *Hydrilla verticillata.*

b. Phytoplankton (Husnah & Fahmi, 2015)
   1) Chlorophyceae*: Asterococcus* sp., *Astrodesmus* sp., *Closterium* sp., *Cocconeis scutellum, Coelastrum* sp., *Coscinodiscus* sp., *Cosmarium botrytis, C. lendelli, C. remoforme, Crucigenia quadrata, Cyclotella* sp., *Dictyospherium* sp., *Diploneis* sp., *Gleocystis* sp., *Micrasterias* sp., *Mougeotia* sp., *Oedogonium* sp., *Oocystis* sp., *Pediastrum* sp., *P. biwae, Pleurotaenium* sp., *Phormidium* sp., *Scenedesmus* sp., *Staurastrum gracile, S. sebaldi, S. longiradiatum, Staurastrum* sp., *Tetraedron minimum, Tetraedron* sp., *Zygnema* sp.
   2) Bacillariophyceae: *Aulacoseira granulate, Cyclotella* sp., *Cymbella* sp., *Diatoma elongatum, D. vulgare, Diploneis* sp., *Eunotia veneris, Fragilaria* sp., *F. elongatum, F. intermedia, F. virescan, Gomphonema* sp., *Gyrosigma, Navicula* sp., *N. cuspidata, N. falaisiensis, N. lacustris, N. placentula, N. pupula, Nitzchia* sp., *Pinnularia* sp., *P. gibba, Peridinium* sp., *Phormidium tenue, Pleurosigma* sp., *Stauroneis* sp., *Surirella* sp., *S. elegans, Synedra* sp.

2. Fauna

a. Zooplanktons (Husnah & Fahmi, 2015)
   1) *Anuraeopsis* sp., *Actinophyrius* sp., *Asplanchna* sp., *Brachionus* sp., *Cyclops* sp., *Diaptomus* sp., *Difflugia* sp., *Euglypha*

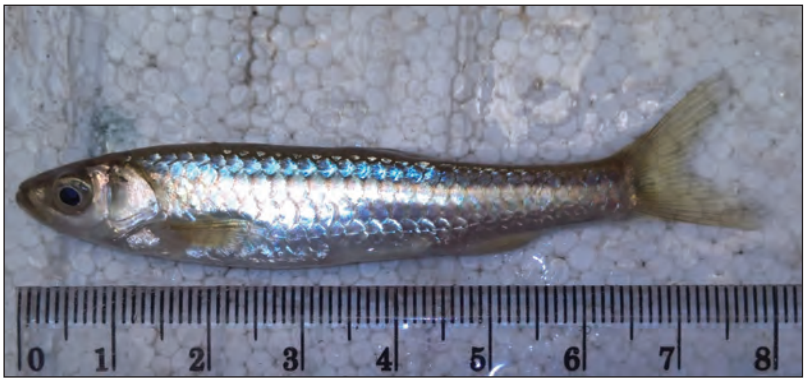
sp., *Keratella* sp.., *Monostyla* sp., *Nauplius* sp., *Notholca* sp., *Oxytrycha* sp., *Pleosoma* sp., *Polyarthra* sp., *Trachelomonas* sp., *Trichocerca* sp.

b. Benthic (Kartamihardja, Satria, & Sarnita, 1995; Rudi, Fadli, & Muchlisin, 2009)

Bithynia sp., *Tarebia* sp., *Pleuracera* sp., *Thiara* sp., *Melanoides tuberculata, Bellamya sumatraensis, Pomacea canaliculata, Corbicula javanica, Anodonta woodiana.*

c. Fish (Marini & Fahmi, 2015; Muchlisin & Siti-Azizah, 2009; Muchlisin, Siti-Azizah, Rudi & Fadli, 2009):

Anabas testudineus, Aplocheilus panchax, Betta sp., *Chanos chanos*, Cyprinus carpio*, Carassius auratus, Channa gachua, C. striata, Clarias batrachus, C. gariepinus*, Ctenopharyngodon idella*, Homaloptera gymnogaster, Liposarcus pardalis*, Monopterus albus, Neolissochilus* sp., *Oreochromis mossambicus*, O. niloticus, Osteochilus hasselti, O. kahayensis, O. kappeni, O. waadersi, Poropuntius tawarensis, Poecilia reticulata, Puntius brevis, Rasbora sumatrana, R. tawarensis, Tetraodon* sp., *Tor douronensis, T. soro, Trichogaster trichopterus, Trichogaster* sp., *Trichopis vittata, Xiphophorus hellerii*, X. maculatus.**) Introduction



Source: Iriadi (2015)

Figure 9. *Rasbora tawarensis,* Endemic Species of Lake Laut Tawar

3. **Primary Productivity (Husnah & Fahmi, 2015):**

   0.33–63 mg C/m^2/day

4. **Biomass and Potency of Fish Production (Marini & Fahmi, 2015):**

   a. Fish biomass: 0.34–180.9 kg/Ha; Average: 46.2 kg/Ha
   b. Fish potency production (MEI Method): 10.86 kg/Ha/yr

5. **Fishery products:**

   O. niloticus, *C. carpio*, *R. tawarensis*

G. Sosio Economic Condition

Table 7 shows land use in Lake Laut Tawar catchment area.

Table 7. Land Use in Lake Laut Tawar Catchment Area

No.	Land Use	Ha	%
1	Secondary dry land forest	7,518	38.7
2	Mixture dry land agriculture	9,169	47.2
3	Dry land agriculture	656	3.4
4	Paddy field	1,204	6.2
5	Settlement	658	3.4
6	Open land	240	1.2
Total		**19,445**	**100**

Source: Kholik (2014)

H. Lake Utilization

Lake Laut Tawar is utilized for:

1. Fisheries (Kartamihardja et al., 1995; Muchlisin et al., 2009; Dinas Kelautan dan Perikanan Kabupaten Aceh Tengah, 2009):

   455 tons (1988), 223 tons (1995), 525 tons (2012)

2. Cage Aquaculture (Marini & Hufiadi, 2015):

280 units (2013)

I. Deterioration of Lake Environment

Lake Laut Tawar is deteriorating due to (Muchlisin & Siti-Azizah, 2009):

1. Fish introduction;
2. Decreasing of fish production;
3. Pollution from domestic, agriculture, and cage aquaculture;
4. Decreasing of water level: ~2 m

J. Legistation and Institutional Measures for Upgrading Lake Environments:

Unfortunately, no data could be gathered.

Lake Toba

A. Location

Lake Toba is located in North Sumatra Province and part of seven regencies, namely Karo, Simalungun, Toba Samosir, North Tapanuli, Humbang Hasundutan, Dairi and Samosir (Figure 12). Lake Toba is one of 76 areas within Indonesian National Strategy Region (NSR) declared through the Government Regulation number 26/2008 on the National Spatial Plan.

B. Description

Lake Toba is the largest lake in Indonesia. The lake is a depression of Toba volcano eruption center, characterized by the steep slope between lake and the plateau (1,000 m above sea level) in the southwest.

Toba, as the largest lake in Indonesia has various functions and intensive use. The area is particularly used for tourism and fishing, source water for Hydroelectric Power Plant (HEPP), and raw water material. Its centres of tourism have been growing while making use its panoramic view as the main object of the sites.

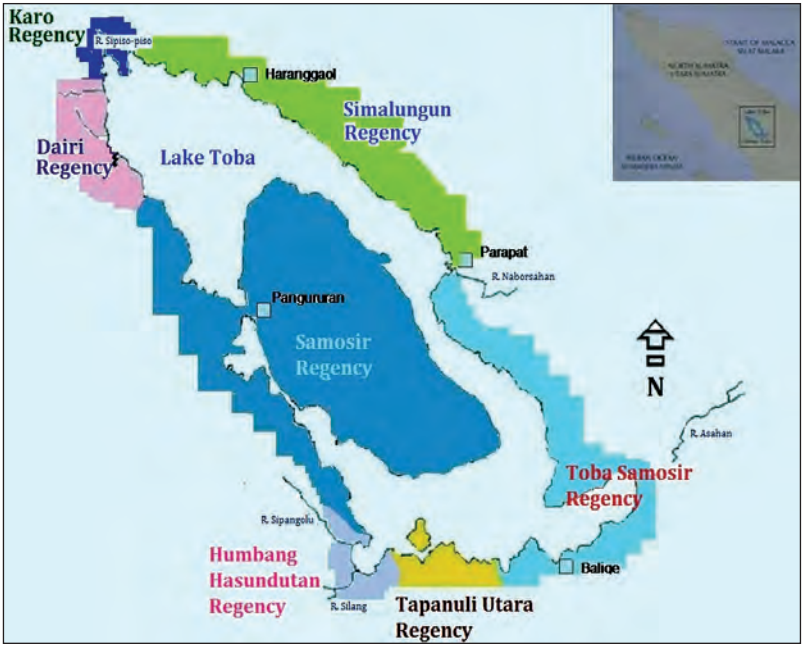
Source: Lukman (2010)

Figure 10. A View of Lake Toba

Figure 11. Map of Lake Toba in North Sumatra Province

According to the national policy, Lake Toba and several other lakes such as Lake Maninjau and Lake Batur become the basis of the National Tourism Development Master Plan (Ardika, 1999). Moreover, the fishery activities in Lake Toba have been continuing since 1950s (Soerjani Wargasasmita, Djalil, & Tjitrosoedirjo, 1979).

In order to support the policies of Lake Toba and surrounding area as an NSR, the utilization of this area is authorized by The Presidential Regulation number 81 of 2014 as The Lake Toba Spatial Plan.



Source: Lukman (2013)

Figure 12. The Map of Regency Distribution in Lake Toba Area

C. Physical Dimension

1. Monthly of lake surface elevation (Year 1986–1999) (Anonymous, 2008a): 902.28–905.23 m msl
2. Main island: Samosir, Sibandang, Tulus.
3. Hydrological characteristic (Departemen PU, 2008; Sudarsono, 1989)
   a. Outflow river: Asahan (Flow rate average is 100 m^3/sec.)
   b. Inflow river: Silang (dominant; inflow rate + 10 m^3/sec.), Naborsahan, Bonandolok, Sipultakhuda.
   c. Small river (289) is the dominant inflow, only 71 are the permanent.
   d. Yearly inflow rate:
      1) Normal season = 41.6 m^3/sec (July)–124.9 m^3/sec (November)
      2) Dry season = 8.6 m^3/sec (January)–62.5 m^3/sec (April)
      3) Wet season (1999) = 83.5 m^3/sec (August)–493.8 m^3/sec (May).
   e. Yearly outflow rate:
      1) Normal season = 85.5 m^3/sec (November)–94.6 m^3/sec (April)

Table 8. Characteristics of Lake Toba Morphometry

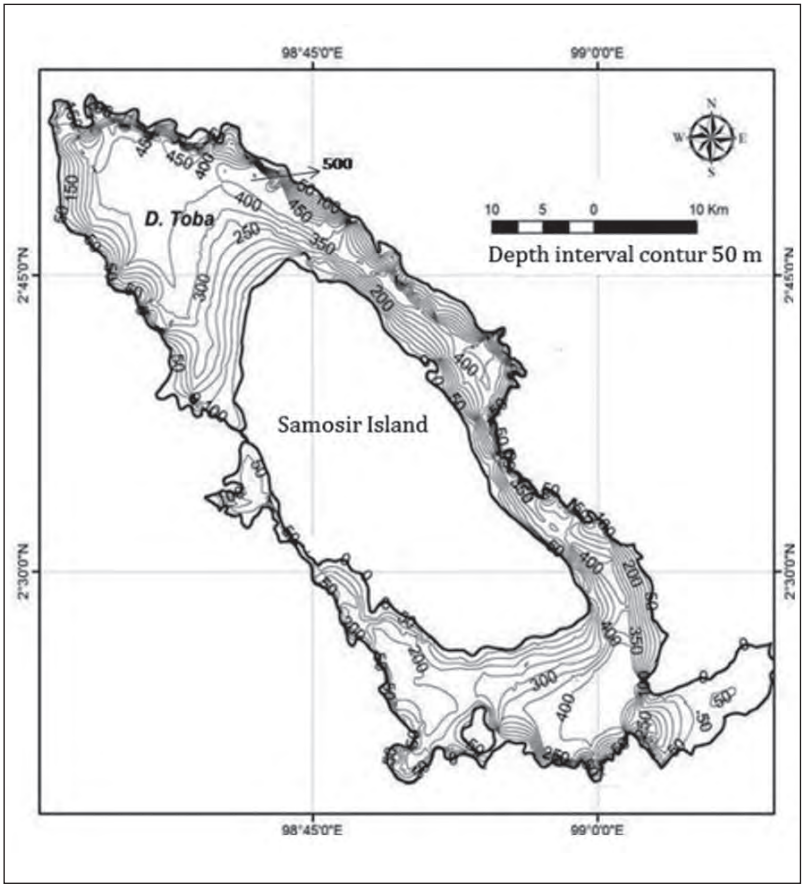
No.	Parameter	Values
1	Area of waters (A) (km^2)	1,124
2	Shore line length (km)	428.7
3	Maximum of length (km)	50.2
4	Maximum of width (km)	26.8
5	Maximum of depth (m)	508
6	Volume (x 10^9 m^3)	256.2
7	Average of depth (m)	228
8	Water residence time (years)	81
9	Area of cathment (C) (km^2)	2,486
10	Ratio of C/A	2.21

Source: Lukman & Ridwansyah (2010)

2) Dry season = 21.1 m^3/sec (August)–41.7 m^3/sec (September)
3) Wet season = 107.6 m^3/sec (November)–183.1 m^3/sec (April)

D. Physiographic Feature

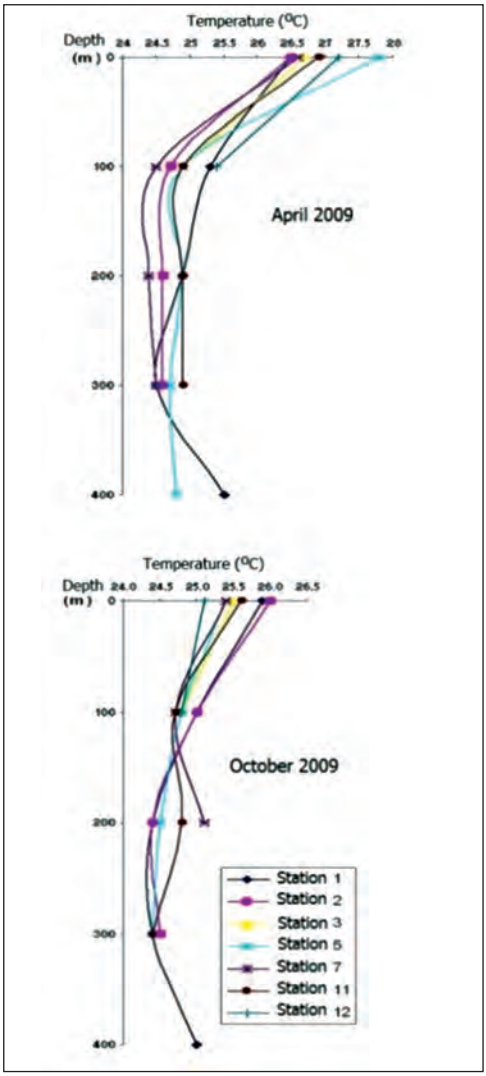
The depth of Lake Toba is illustrated on a map in Figure 13.



Source: Lukman & Ridwansyah (2010)

Figure 13. Bathymetric Map of Lake Toba

Lake Toba can be categorized as oligomictic lake. Its water stratiphication data can be seen in Figure 14.

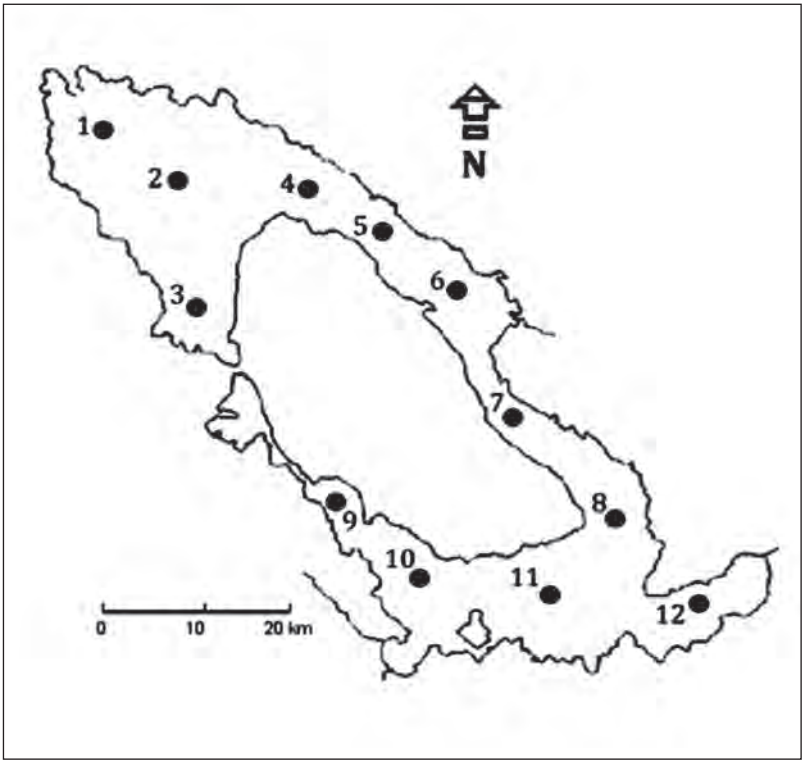


Source: Lukman & Ridwansyah (2010)

Figure 14. Temperature Vertical Stratification Pattern of Lake Toba

E. Water Quality

There were 12 stations scattered around Lake Toba to observe its water quality.



Source: Lukman (2011)

Figure 15. Water Quality Measured Stations in Lake Toba

Table 9. Water Quality Condition of Lake Toba

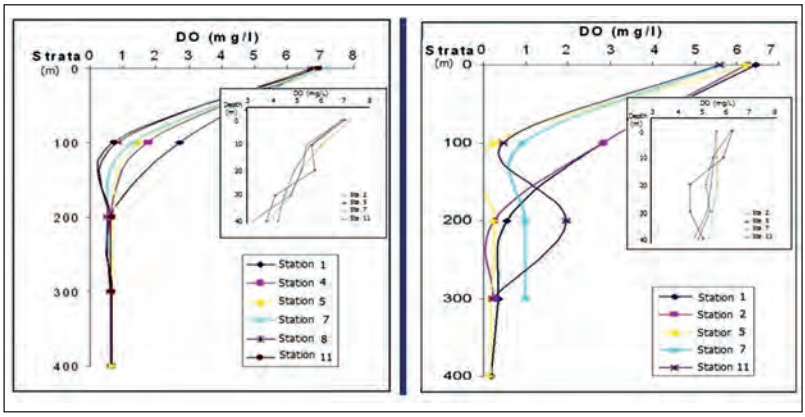
Parameters/ Time	Stations											
	1	2	3	4	5	6	7	8	9	10	11	12
Transparency*) (m)												
Apr 2009	15	nd	nd	13	14	11	9	9	nd	nd	13	9
Oct 2009	11	11	9	7	9	9	9	11	9	9	9	8
Conductivity *) (mS/cm)												
Apr 2009	0.159	0.158	0.154	0.157	0.158	0.157	0.156	0.156	nd	nd	0.157	0.155
Oct 2009	0.160	0.160	0.162	0.161	0.161	0.161	0.160	0.159	0.162	0.161	0.160	0.160
pH*)												
Apr 2009	8.4	8.5	8.2	7.8	9.0	8.7	8.9	9.0	nd	nd	8.9	8.6
Oct 2009	7.7	7.7	7.7	7.6	7.7	8.1	7.7	7.7	7.3	7.4	7.1	7.4
Total Phosphorus **) (µg/L)												
Apr 2009	8	5	16	45	34	16	26	18	18	21	18	8
Oct 2009	16	21	18	20	18	18	18	8	13	nd	21	21
Total Nitrogen)(in µg/L)**												
Apr 2009	51	13	19	102	57	102	83	108	19	32	57	19
Oct 2009	93	93	148	nd	93	302	253	74	272	nd	179	93

Source: Lukman (2011) *); Nomosatryo & Lukman (2011) **); nd = no data

Table 10. Content of Chlorophyll (mg/m^3) on April 2009 and October 2009 in Lake Toba

Time/ Depth (m)	Stations (mg/m^3)					
	2	3	5	7	11	12
April 2009						
0	0.540	0.344	0.421	1,710	0.540	0.813
10	0.651	0.355	0.382	1,163	1,337	0.862
20	1.091	0.380	0.553	1,333	0.935	1,132
30	1.092	0.866	0.541	0.899	1,254	0.687
Oktober 2009						
0	1,701	1,404	0.593	0.850	0.850	1,106
10	1,441	1,699	0.335	1,145	0.850	0.554
20	1,402	1,402	0.850	0.595	1,441	0.258
30	1,147	1,481	0.337	1,104	1,106	0.552

Source: Lukman (2011)



Source: Lukman & Ridwansyah (2010)

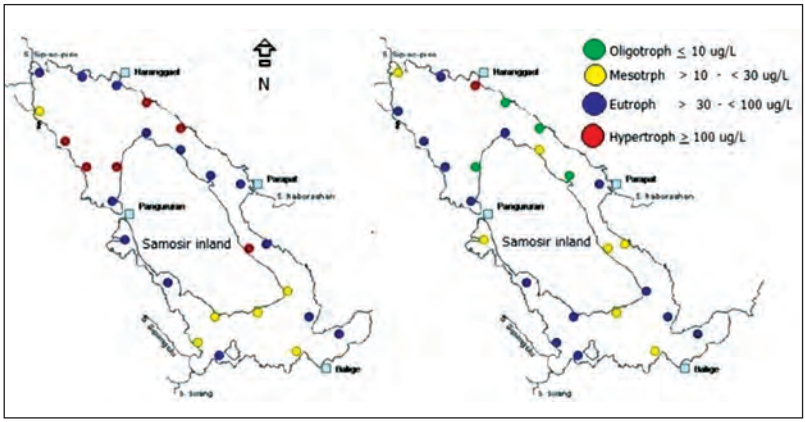
Figure 16. Oxygen Vertical Distribution Profile of Lake Toba (April 2009 [left]; October 2009 [right])

F. Biological Features

1. Flora

a. Plant (from Soerjani et al., 1979)
   1) Floatings: *Eichornia crassipes, Azolla pinnata, Spirodela polyrhiza, Lemna minor.*
   2) Emerged: *Nymphaea* sp., *Nelumbo nucifera.*
   3) Submerged: *Potamogeton malaianus, P. polygonifolius, Myriophyllum spicatum, Najas* sp., *Ceratophyllum demersum, Utricularia* sp., *Chara* sp., *Hydrilla verticillata.*

b. Phytoplanktons (Sulawesty, 2011):
   Coelastrum microporum, Dictyosphaerium sp., *Pediastrum duplex, Scenedesmus quadricauda, Cosmarium contractum, Staurastrum prionotum, S. acanthastrum, S. brachiatum, S. multispiniceps, Ulothrix variabilis, U. zonata, Gloeocapsa* sp., *Anabaena viguieri, Oscillatoria borneti, Microcystis aeruginosa, Cymbella tumida, Melosira granulate, Peridinium* sp., *Navicula radiosa, N. falaisiensis, N. lacustris, Nitzschia linearis, Pinnularia nobila, Synedra acus, S. ulna.*



Source: Lukman (2013)

Figure 17. Lake Toba Total Phosphorus Condition (March 2010 [left]; Aug 2010 [right])

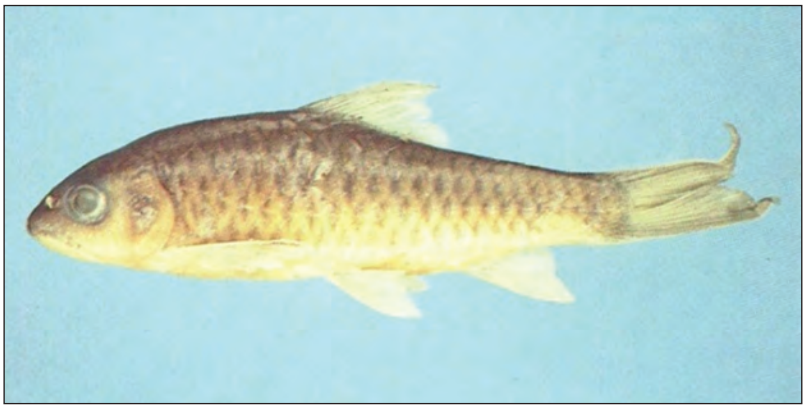
2. Fauna

a. Zooplanktons (Tjahyo, Nastiti, Purnomo et al., 1998): Keratella, Cyclops, Bosmina

b. Benthic (Soerjani et al., 1979):
Brotia costula, *Thiara scabra*, *Melanoides tuberculata*, *M. granifera*, *Anentome helena*, *Lymnaea bervispira*, *L. rubiginosa*, *Physsastra sumatrana*, *Corbicula tobae*.

c. Fish (Soerjani et al., 1979; Kartamihardja, 1987):
Oreochromis mossambicus, O. niloticus, Cyprinus carpio, Clarias batrachus, C. nieuhofi, Lissochilus sp., *Osteochillus hasselti, Puntius binotatus, P. gonionotus, P. javanicus, Ophiocephalus striatus, O. micropeltes, Tors soro, Neolissochilus thienemanni, Channa gachua, Osphronemus goramy, Trichogaster trichopterus, Nemachilus fasciatus, Rasbora jacobsoni*[a], *Lebistes reticulatus, Aplocheilus panchax, Mystacoleucus padangensis*[a)], *Oxyeleotris marmorata.*

- [a)] Introduced species from Lake Singkarak, Sumatra in 2003 (Kartamihardja & Sarnita, 2008).



Source: Kottelat et al. (1993)

Figure 18. *Neolissochilus thienemanni*, Eendemic Species of Lake Toba

3. **Primary Productivity** (Kartamihardja, 1987):
   2.060–2.704 g C/m^2/day

4. **Biomass (Soerjani et al., 1979):**
   Potamogeton (9,200gr/m^2); *M. spicatum* (2387 gr/m^2)

5. **Fish production potential** (Krismono & Sarnita, 2003):
   2,519–7,309 tons/year

6. **Fishery products** (Anonymous, 2011; Purnomo, Kartamihardja, Wijopriono et al., 2005):
   O. mossambicus, O. niloticus, M. padangensis

7. **Cage aquaculture production potential (On oligotrophic condition)** (Lukman & Hamdani, 2011):
   35,282 tons/year

G. Sosio Economic Condition

Table 11 shows the land use in Lake Toba catchment area.

Table 11. Land Use in Lake Toba Catchment Area

Land use	Area (Ha)	%
Low land forest	171.8	0.1
High land forest	2,532.6	10.4
Industrial plant forest	31,452.2	12.9
Housing	876.3	0.4
Dry land agriculture	67,496.4	27.6
Dry land agriculture and shrub	43,018.2	17.6
Swamp	1,940.2	0.8
Paddy field	11,247.9	4.6
Schrub	12,474.8	5.1
Open area	50,374.0	206
Total	**244,373.5**	**100.0**

Source: Departemen Kehutanan (2008)

H. Lake Utilization

Lake Toba is utilized for:

1. Fisheries (Fish production) (Dinas Kelautan dan Perikanan Provinsi Sumatra Utara, 2011; Purnomo et al., 2005): 4,462 tons (2005), 12,169 tons (2010; dominated [11507 tons] by *M. padangensis*) (Production declined after 2010 because over-fishing) of *M. padangensis* (Koeshendrajana, Sari, Reswati et al., 2010)
2. Cage culture fish production (Dinas Kelautan dan Perikanan Provinsi Sumatra Utara, 2011): 47,478 tons (2010)
3. Hydroelectric Power Plant (in outlet): 600 MW
4. Raw water: 5,004 customers (in Balige)

I. Deterioration of Lake Environment

Lake Toba's condition is deteriorating due to (Lukman, 2013):

1. Euthrophication based on the total phosphorus (TP) concentration

Source: Lukman (2010)

Figure 19. Renun Hydro Electric Power Plant. The HEPP uses water supply from other catchment in Lake Toba area.

2. Overfishing
3. Over capacity of cage culture fisheries

J. Legistation and Institusional Measures for Upgrading Lake Environments:

There are regulations that helps the preservation Lake Toba:

1. Indonesian President Regulation number 81/2014 in terms of Zone Planning of Lake Toba and Surounding Area
2. North Sumatra Governor Regulation number 1/2009 in terms of Water Quality Standard Lake Toba

Lake Maninjau

A. Location

Lake Maninjau is located in West Sumatra Province, precisely in Agam Regency. It is located in a district, Tanjung Raya. Lake Maninjau is one of tourist destinations which is located in route between Padang (Provincial capital) and Bukittinggi, the centre of tourist destination in West Sumatra.

B. Description

Lake Maninjau is a volcanic lake. The volcanic activity is still active and characterized by the frequent occurrence of sulfur gases, which are known as *tubo belerang* (*tubo*: poison) (*belerang*: sulfur).

Maninjau is one of the centers of national lake tourism development in Indonesia (Ardika, 1999), but in recent years the tourism conditions is decreased due to the deterioration of lake waters condition as an impact of the cage aquaculture development.

Source: Lukman (2014)

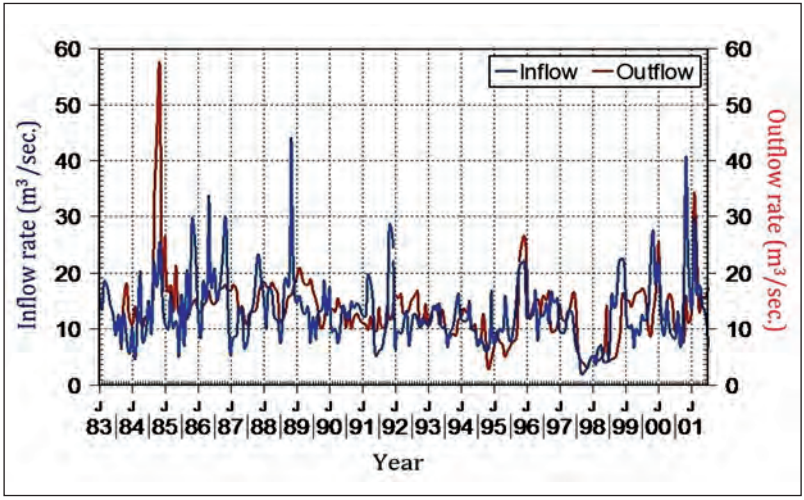
Figure 20. A View of Lake Maninjau

Figure 21. Map of Lake Maninjau

The rapid development of cage aquaculture leads to the dead lake condition. Fish kills often occur, either due to algae blooming or low oxygen conditions. In this case, *tubo belerang* phenomenon and pollution from cage aquaculture activity, threatens the fish reproduction which led the deterioration of fish natural population in this lake.

C. Physical Dimension

1. Monthly of lake surface elevation (msl) (1984–2001) (Fakhrudin Wibowo, Subehi, & Ridwansyah, 2002): 461.22 m (December 2007)– 464.74 m (Last 1984)
2. Total inflow rate: 13.37 m^3/sec.
3. Total outflow: 13.39 m^3/sec
4. Outflow river: Antokan river



Source: Fakhrudin et al. (2002)

Figure 22. Inflow and Outflow Rate Fluctuation of Lake Maninjau

Table 12. Charecteristics of Lake Maninjau Morphometry

No	Parameter	Values
1	Area of waters (A) (km^2)	97.37
2	Shore line length (km)	52.68
3	Maximum of length (km)	16.46
4	Maximum of width (km)	7.50
5	Maximum of depth (m)	168
6	Volume (x 10^9 m^3)	10.226
7	Average of depth (m)	105.02
8	Water residence time (years)	132.6
9	Area of cathment (C) (km^2)	1.36
10	Ratio of C/A	1.51

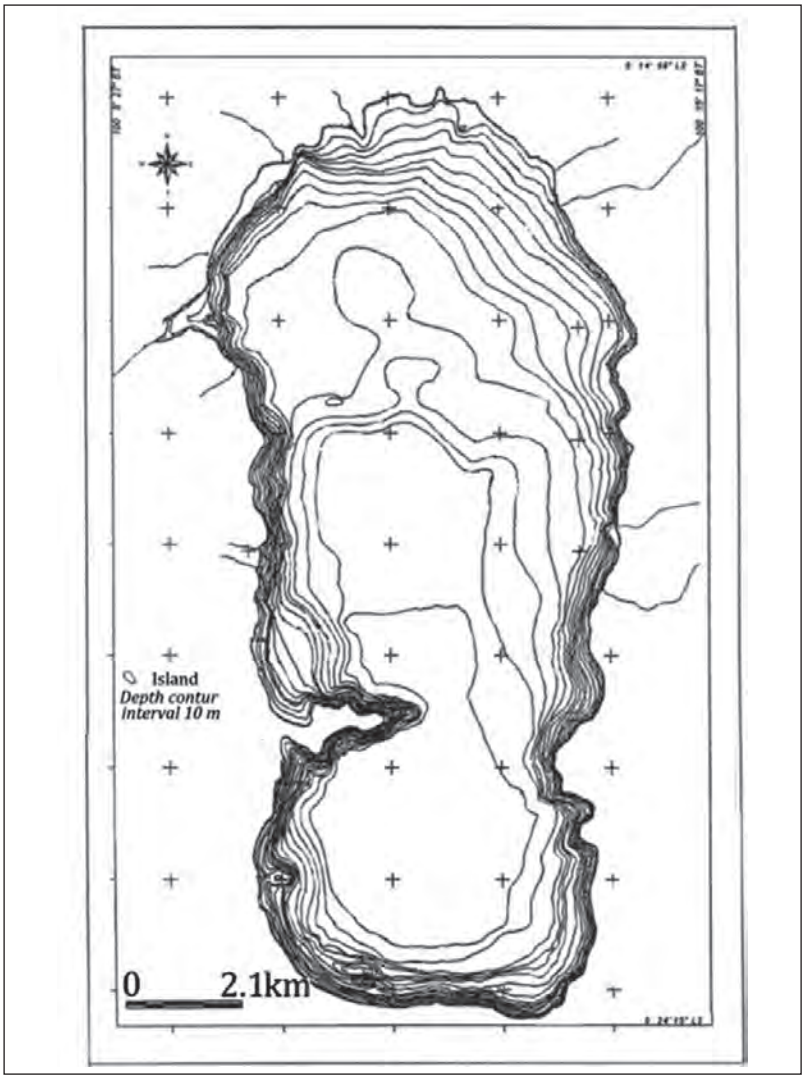
Source: Fakhrudin et al. (2002)

Source: Lukman (2014)

Figure 23. Southern Catchment Condition of Lake Maninjau

D. Physiographic Features

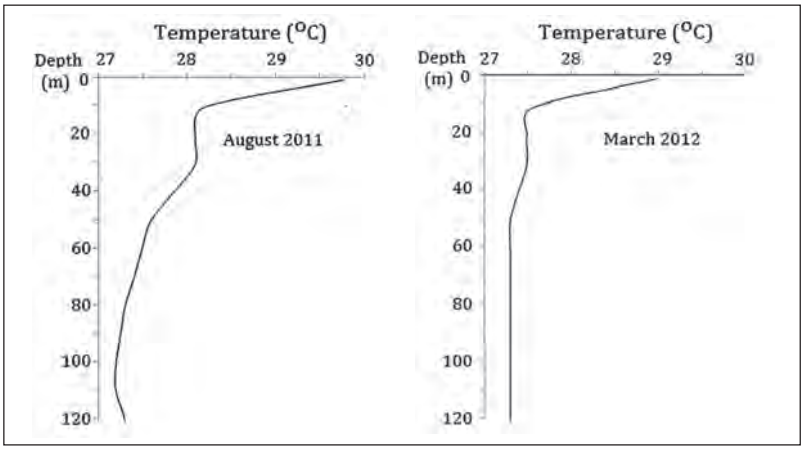
Figure 24 shows the depth of Lake Maninjau in a map.



Source: Fakhrudin et al. (2002)

Figure 24. Bathymetry Map of Lake Maninjau

Lake Maninjau can be categorized as polymictic lake. Data on its water stratiphication can be seen in Figure 25.

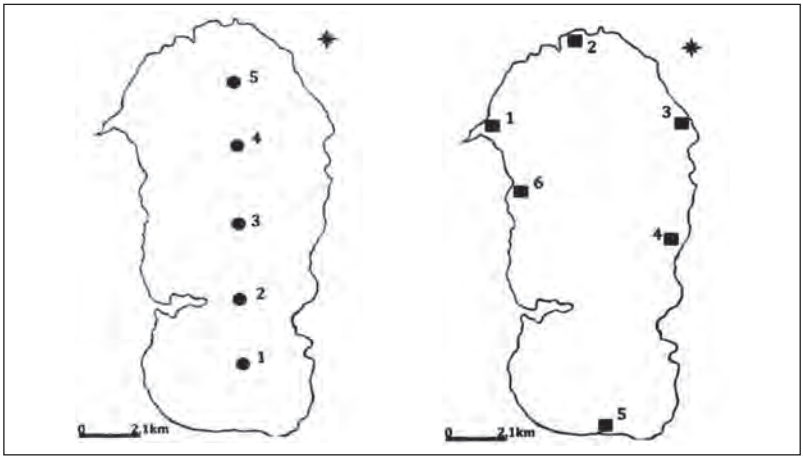


Source: Lukman (2012)

Figure 25. Temperature Vertical Stratification Pattern of Lake Maninjau

E. Water Quality

Analysis of Lake Maninjau's water quality is divided into analysis on its open zone and aquaculture zone.



Source: Lukman (2012) (kiri); Lukman, et al. (2015) (kanan)

Figure 26. Water Quality Measured Stations at Open Zone (left) and Cage Aquaculture Zone (right) in Lake Maninjau

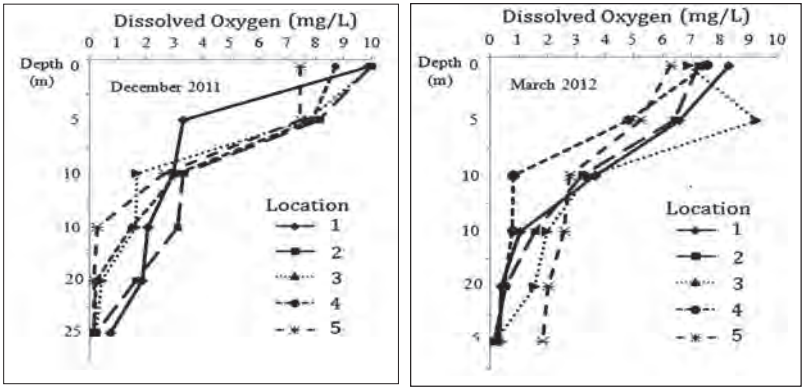
1. Open Zone

Table 13. Water Quality Condition in Open Zone of Lake Maninjau

Parameters/ Time	Station				
	1	2	3	4	5
Transparency (m)					
August 2011	0.8	0.9	0.85	1.1	1.2
March 2012	1.2	1.1	1.2	1.2	1.2
pH[2]					
October 11	9.40	8.60	8.73	8.81	8.36
March 2012	6.86	6.83	6.87	8.53	7.98
Conductivity (mS/cm)					
August 2011	0.628	0.368	0.305	0.321	0.107
March 2012	0.874	0.920	0.930	0.895	0.910
Total Nitrogen (mg/L)					
August 2011	0.5816	1.4542	0.9048	0.6410	0.8025
March 2012	6.4151	7.4292	5.9748	6.6824	5.0786
Total Phosphorus (mg/L)					
August 2011	0.0729	0.0462	0.0352	0.0271	0.0481
March 2012	0.0208	0.0219	0.0208	0.0198	0.0208
Chlorophyll (mg/m^3)*					
August 2011	34.31	43.88	23.88	27.76	20.68
March 2012	46.58	39.06	32.19	33.55	39.06

*) Average value from depth water coloum 0.0 m; 1.5 m; 3.0 m and 4.5 m
Source: Lukman (2012)

Dissolved Oxygen



Source: Lukman (2012)

Figure 27. Oxygen Vertical Distribution Profile in Open Zone of Lake Maninjau

2. Water Quality in Cage Aquaculture Zone

Table 14. Water Quality Condition in Cage Aquaculture Zone of Lake Maninjau

Parameters/ Time	Stations					
	1	2	3	4	5	6
Transparency (m)						
June 2013	3.2	1.8	5.6	3.5	2.2	nd
September 2013	1.9	2.1	2.1	2.1	1.9	3.2
December 2013	2.3	1.8	2.1	2.1	2.1	2.60
March 2013	2.0	1.8	2.1	2.0	2.3	3.00
pH						
June 2013	7.2	7.9	7.4	7.7	7.9	nd
September 2013	9.0	8.7	9.2	9.0	9.6	9.5
December 2013	8.6	7.9	8.3	8.1	8.8	8.8
March 2013	8.1	8.0	8.0	8.1	9.3	9.2

Parameters/ Time	Stations					
	1	2	3	4	5	6
Conductivity (mS/cm)						
June 2013	117.0	113.7	114.7	115.3	115.0	nd
September 2013	124.7	137.8	127.8	140.8	129.2	127.3
December 2013	125.0	125.7	125.3	126.0	126.3	125.0
March 2013	126.7	124.7	129.0	131.3	126.0	126.2
Chemical Oxygen Demand (mg/L)						
June 2013	50.6	62.7	77.9	40.0	103.6	nd
September 2013	97.6	106.7	83.9	97.6	111.2	93.0
December 2013	20.3	29.4	18.8	0.6	12.7	65.8
March 2013	5.1	80.9	6.8	2.1	6.1	3.6
Total Nitrogen (mg/L)						
June 2013	0.222	0.511	0.423	0.387	0.406	nd
September 2013	1.290	1.710	1.667	1.562	1.974	1.052
December 2013	0.768	1.427	1.402	1.979	0.287	1.652
March 2013	0.344	1.485	0.295	0.317	0.529	0.390
Total Phosphorus (mg/L)						
June 2013	0.060	0.035	0.015	0.054	0.010	nd
September 2013	0.004	0.004	0.007	0.054	0.006	0.000
December 2013	0.040	0.063	0.065	0.050	0.029	0.032
March 2013	0.042	0.042	0.033	0.093	0.032	0.044

Parameters/ Time	Stations					
	1	2	3	4	5	6
Chlorophyll (mg/L)						
June 2013	12.18	20.24	12.09	21.52	10.82	nd
September 2013	17.85	16.37	19.62	11.40	12.29	18.00
December 2013	9.49	19.19	12.73	23.77	14.43	14.35
March 2013	19.35	24.18	24.50	22.01	20.18	38.77

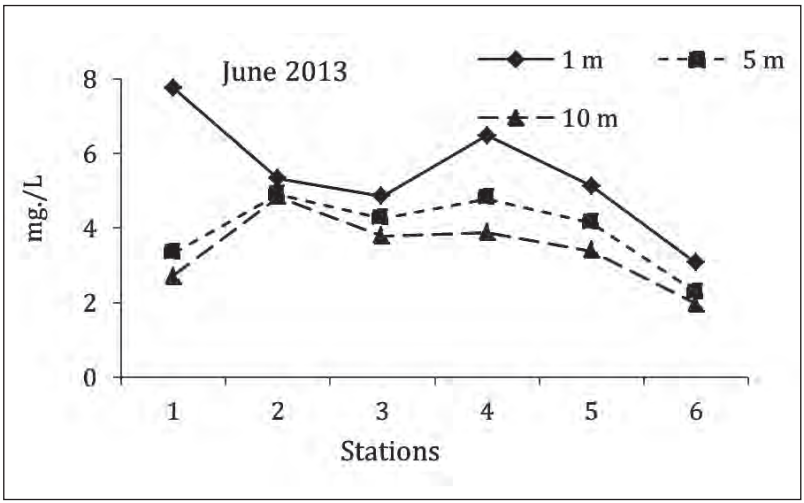
Note: nd = *no data*

Source: Lukman, Isdradjat, Muchsin et al. (2015)

Source: Lukman (2011)

Figure 28. Blooming of Phytoplankton in Lake Maninjau

Dissolved Oxygen



Source: Lukman et al. (2015)

Figure 29. Dissolved Oxygen Distribution Profile in Cage Aquaculture Zone of Lake Maninjau

F. Biological Features

1. Flora

a. Plants (UI&PU, 1978; Pusat Studi Lingkungan Hidup, 1984; Giesen & Sukotjo, 1991):
   1) Floating: *Azolla pinnata, Eichhornia crassipes, Lemna perpussilla, Najas marina.*
   2) Emerged: *Alternantera philoxeroides, Colocasia esculenta, Cyperus compressus, C. distans, C. flabelliformis, C. haspan, C. kyllingia, Eriocaulon longifolium, Ipomoea aquatica, Monochoria hastata, Ludwigia adscendens, Nelumbo nucifera, Panicum repens, Polygonum barbatum, Potamogeton malaianus, P. polygonifolius.*
   3) Submerged: *Hydrilla verticillata*

b. Phytoplanktons (from Sulastri, 2002):
   1) Chlorophyceae: *Actrinastrum* sp., *Ankistrodesmus* sp., *Asterococcus* sp., *Cladophora* sp. *Coelastrum* sp., *Coelosphaerium* sp., *Cosmarium* sp., *Chrysocapsa* sp., *Crucigenia* sp., *Dictyosphaerium* sp., *Franceia* sp., *Neprocytium* sp., *Oocystis crass, Oocystis pusilla, Oocystis lacustris, Oocystis* sp., *Quadrigulla* sp., *Scenedesmus* sp., *Spirulina* sp., *Sphaerocystis* sp., *Spondylosium* sp., *Staurastrum* sp., *Tetraedron minimum, Tetraedron muticum, Tetraedron* sp., *Treubaria* sp.
   2) Chrysophyceae: *Asteronella* sp., *Cyclotella* sp., *Cymbella* sp., *Denticula* sp., *Diatoma* sp., *Eunotia* sp., *Fragilaria* sp., *Frustulia* sp., *Melosira* sp., *Navicula* sp., *Nitzschia* sp., *Surirella* sp., *Synedra* sp., *Synedra ulna.*
   3) Cyanophyceae: *Anabaena* sp., *Aphanocapsa* sp., *Aphanothece* sp., *Chroococcus turgidus, Chroococcuss varius, Chroococcus* sp., *Coelosphaerium* sp., *Gomposhaeria* sp., *Microcystis* sp., *Oscillatoria* sp., *Sphaerocystis* sp.
   4) Phyrophyceae: *Glenodineum* sp., *Peridinium* sp.
   5) Euglenophyceae: *Euglena* sp., *Trachelomonas* sp., *Phacus* sp.

2. Fauna

a. Zooplanktons (Touran & Sulawesty, 2007):
   Microcyclops sp., *Cyclopoida*, *Thermocyclops* spp., *Tropocyclops* sp., *Nauplius stage, Chydorus* sp., *Diaphanosoma brachyurum*, *Conochilus unicornis*, *Gastropus stylifer*, *Lecane leontina*, *Lecane* sp., *Keratella cochlearis*., *K. scarsa*., *K. irregularis, Fillinia longiseta.*
b. Benthic:
   1) Mollusca (UI/PU, 1978; Bahri, 2006):
      Bellamya javanica, *Brotia costula varicose*, *B. testudinaria*, *Corbicula javanica*, *C. moltkiana*, *C. Sumatrana*, *Emmeri-*

ciopsis lacustris, *Indoplanorbis exustus*, *Lymnaea brevispira*, *Melanoides granifera*, *M. tuberculata*, *Physastra stagnalis*, *Pomacea canaliculata*, *Pseudodon vondembuschianus*, *Thiara scabra*, *Vivipara javanica*.

2) Anelida & Insecta (Sudarso, 2002):
3) Oligochaeta: *Branchiura sowerbyi, Branchiodrilus hortensis, Haemonais waldvogeli, Nais variabilis, Strephensoniana trivandrana, Limnodrilus hoffmeisteri.*
4) Polychaeta: *Lysostoides alticola*.
5) Ephemeroptera: *Baetis* sp., *Acentrella* sp., *Brachycercus* sp., *Caenis* sp.
6) Tricoptera: *Cheumatopsyche* sp., *Anagapetus* sp.
7) Coleoptera: *Stenelmis* sp., *Helophorus* sp., *Macronychus* sp., *Hexacylloepus* sp.
8) Turbellaria: *Cura* sp.
9) Diptera: *Cardiocladius* sp. *Reomyia* sp., *Ablabesmyia janta*, *Tanytarsus* sp., *Rheotanytarsus* sp., *Monopelopia* sp., *Pseudorthocladius* sp., *Fitttkaumyia* sp., *Rheocricotopus* sp., *Polypedilum* sp., *Procladius* sp., *Simulium* sp., *Hexatoma* sp., *Antocha* sp.
10) Collembola: Hypogastruridae
11) Hirudinea: Erpobdellidae

c. Fish: (UI/PU, 1978; Pusat Studi Lingkungan Hidup, 1984; Weber & de Beaufort 1913, 1916):

Anabas testudineus, *Anguilla mauritania*, *Botia macranthus*, *Channa striata*, *Clarias batrachus*, *Crossochilus gnatopogon*, *Cyclocheilichthys apogon*, *C. siaja*, *Cyprinus carpio*, *Dermogenys pusillus*, *D. sumatranus*, *Fluta alba*, *Hampala macrolepidota*, *Homaloptera gymnogaster*, *Labeobarbus soro*, *L. tambroides*, *Mastacembelus unicolor*, *Mystacoleucus padangensis*, *Mystus*

nemurus, *Nemacheilus fasciatus*, *Oreochromis mossambicus*, *O. niloticus*, *Osphronemus goramy*, *Osteochillus hasselti*, *O. schlegeli*, *O. vittatus*, *Puntius belinka*, *P. fasciatus, P. gonionotus*, *P. oligolepis*, *P. schwanefeldi*, *Rasbora argyrotaenia*, *R. lateristriata*, *R. lat. var. Sumatrana*, *Trichogaster trichopterus*, *Tylognathus falcifer*.

3. **Primary Productivity:**
   nd

4. **Biomass:**
   nd

5. **Fishery products:**
   Rasbora spp., *O. niloticus*

6. **Cage Aquaculture product:**
   C. carpio, *O. niloticus*

Source: Lukman (2014)

Figure 30. Molusc (*C. moltkiana*) Catching Activity in Lake Maninjau, Substrate Disturbation by Feet (above) and by Hand While Diving (below)

G. Sosio Economic Condition

Table 15 shows land use in Lake Maninjau catchment area

Table 15. Land Use in Lake Maninjau Catchment Area (in 2010)

Land use	Area (Ha)	%
Forest	5,507.1	39.5
Open land	81.1	0.6
Settlement	286.7	2.1
Mixture plant	301.4	2.2
Paddy field	2998	21.5
Dry land agriculture	1,435.7	10.3
Schrub	3,336.6	23.9
Total	13,946.6	100.0

Source: Ridwansyah (2010)

H. Lake Utilization

Lake Maninjau is utilized for:

1. Fisheries: 112 tons/year (2003)
2. Freshwater Clam fisheries (*C. moltkiana*) = 751 tons/year (Lukman, Isdrajat, Muchsin et al., 2017)
3. Cage Aquaculture: 18,600 units (Lukman et al., 2015)
4. Tourism
5. Hydroelectric Power Plant: 450 MW

I. Deterioration of Lake Environment

Lake Maninjau's condition is deteriorating due to:

1. Eutrophication condition based on the total phosphorus (TP) concentration
2. Over capacity of cage culture fisheries

Source: Lukman (2011)

Figure 31. Selling of Clam (*C. moltkiana*) in Traditional Market

Source: Lukman (2011)

Figure 32. Cage Aquaculture Activity in Lake Maninjau

J. Legistation and Institusional Measures for Upgrading Lake Environment:

There is a regulation that helps the preservation Lake Maninjau, that is Regional Regulation of Agam Regency for cage aquaculture control in Lake Maninjau.

Lake Singkarak

A. Location

Lake Singkarak is located in Solok and Tanah Datar Regencies, West Sumatra Province. Nearly 40% of lake area relies in Solok Regency and approximately 60% of it is in Tanah Datar Regency.

B. Description

Singkarak is a tectonic lake included in the Sumatran fault zone and lined in the lake center, frequently uplift the geothermal fluid. This contains sulfide causing fish death mass (Natawidjaja & Kumoro, 1995). The inlet lake is from outlet Lake Dibawah and outlet through to Umbilin river, and it acts as a sediment sink (Lehmusluoto & Machbub, 1997).

Lake Singkarak is the upstream of Ombilin River. However, most of the lake water is channeled through a tunnel cut through the Mount Merapi to Batang Anai in order to support Singkarak Hydroelectric Power Plant (HEPP) in Pulau Asam, Lubuk Alung, Padang Pariaman district. The tunnel was built in 1992 along the 19 kms, and was recorded as the longest tunnel in this country.

Source: Sulawesty (2004)

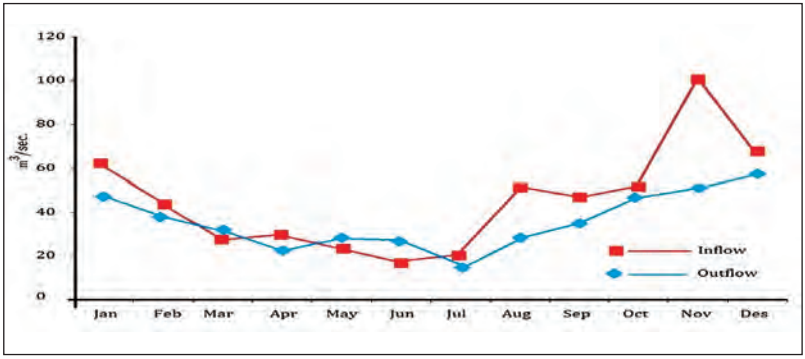
Figure 33. A View of Lake Singkarak

Figure 34. Map of Lake Singkarak

Firstly, water from Lake Singkarak flows through Ombilin Rivers, then pass to Indragiri River and empties into the Strait of Malacca. Right now most of water flows to Indian Ocean through Batang Anai River.

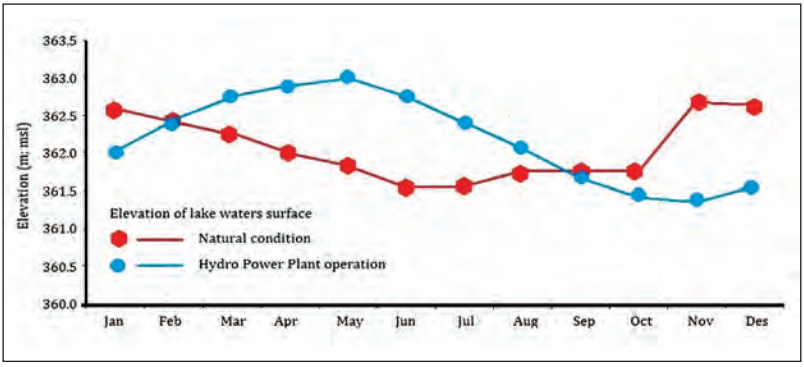
C. Physical Dimension

1. Lake surface elevation: 362 m msl
2. Outflow river: Ombilin (Qtotal =1.1325 x 10^6 m^3/yr)*]
   *] *Self calculation from outflow data below*
3. Inflow rivers: Baing, Paninggahan, Pingai, Sumani, Pingai, Saningbakar, Suman, Sumpur.



Source: Wibowo, Subehi, & Ridwansyah (2002)

Figure 35. Inflow and Outflow Rate Fluctuation of Lake Singkarak (Average Value of 1998, 1999, 2000, 2001)



Source: Wibowo et al. (2002)

Figure 36. Water Surface Elevation Fluctuation of Lake Singkarak (Average Value of Natural Condition in 1998, 1999, 2000, 2001)

Table 16. Characteristics of Lake Singkarak Morphometry

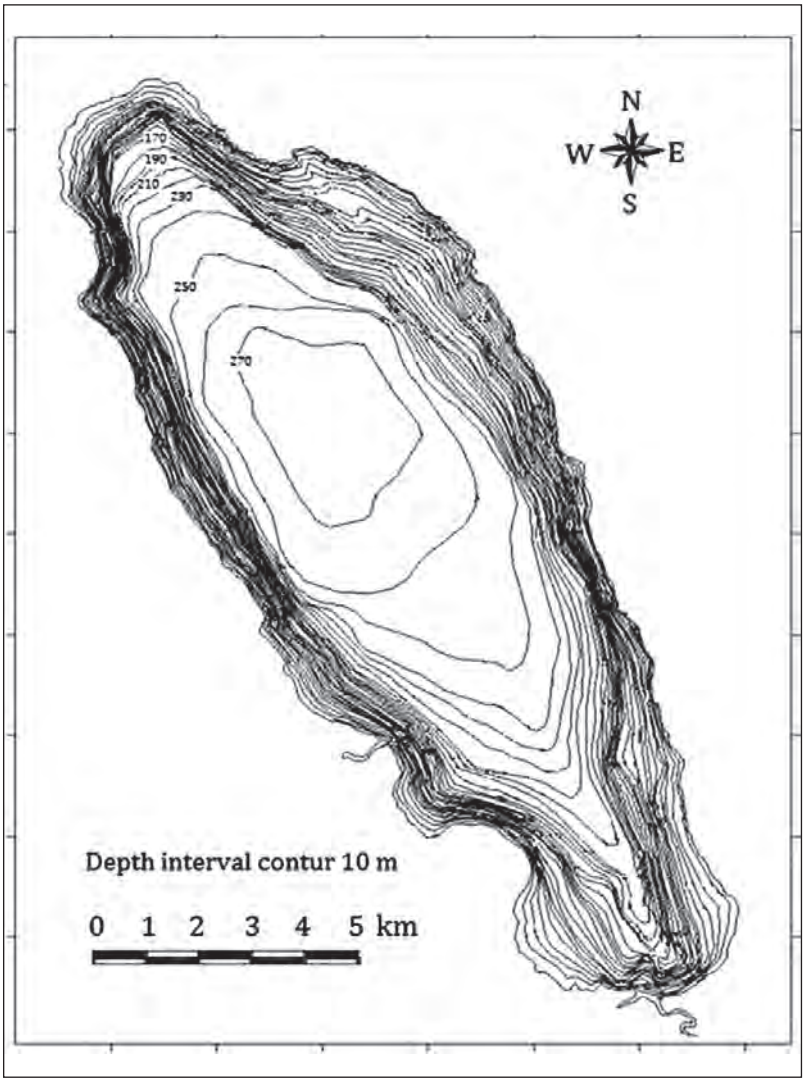
Parameters	Values
Surface area (A) (km^2)	109.08
Maximum length (km)	20.81
Maximum width (km)	7.17
Length of shore line (km)	55.81
Maximum depth (m)	271.5
Volume (km^3)	19.49
Mean depth (m)	178.68
Water residence time (years)*	17.2
Catcment Area (CA) (km^2)*	1290
Rasio CA/A	11.98

**] Self calculation*
Source: Wibowo et al. (2002)

Source: F. Sulawesty (2004)
Figure 37. Reservat Area of Bilih Fish (*Mystacoleucus padangensis*) in Lake Singkarak

D. Physiographic Features

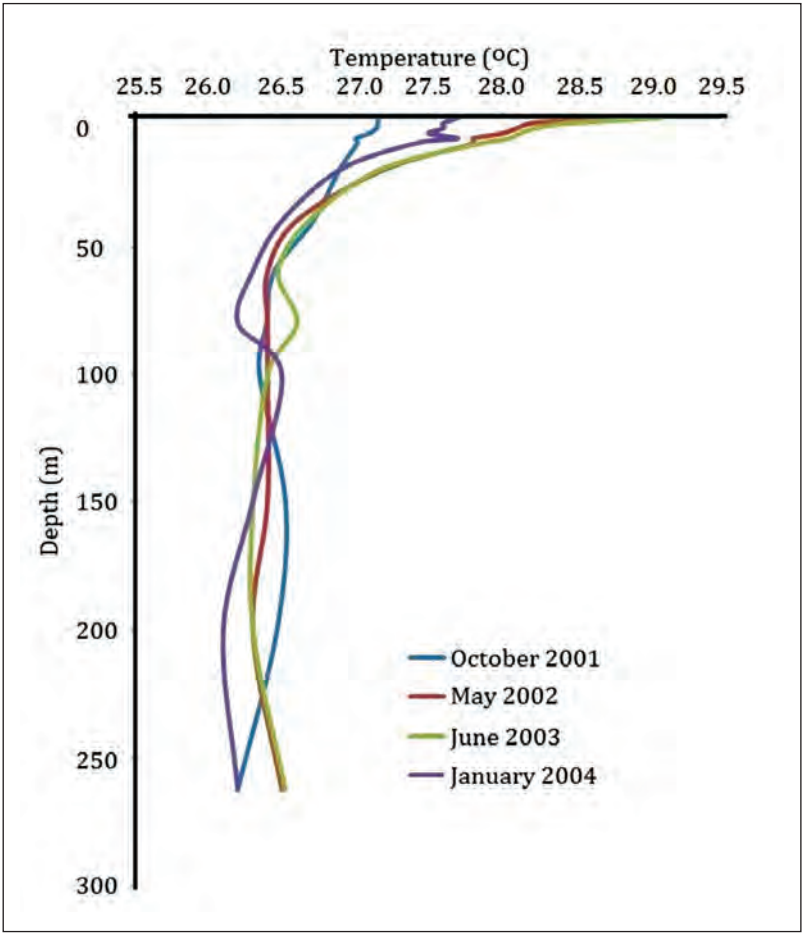
Figure 38 shows the map of depth of Lake Singkarak.



Source: Wibowo et al. (2002)

Figure 38. Bathymetry Map of Lake Singkarak

Figure 39 shows the data on Lake Singkarak's water stratification.

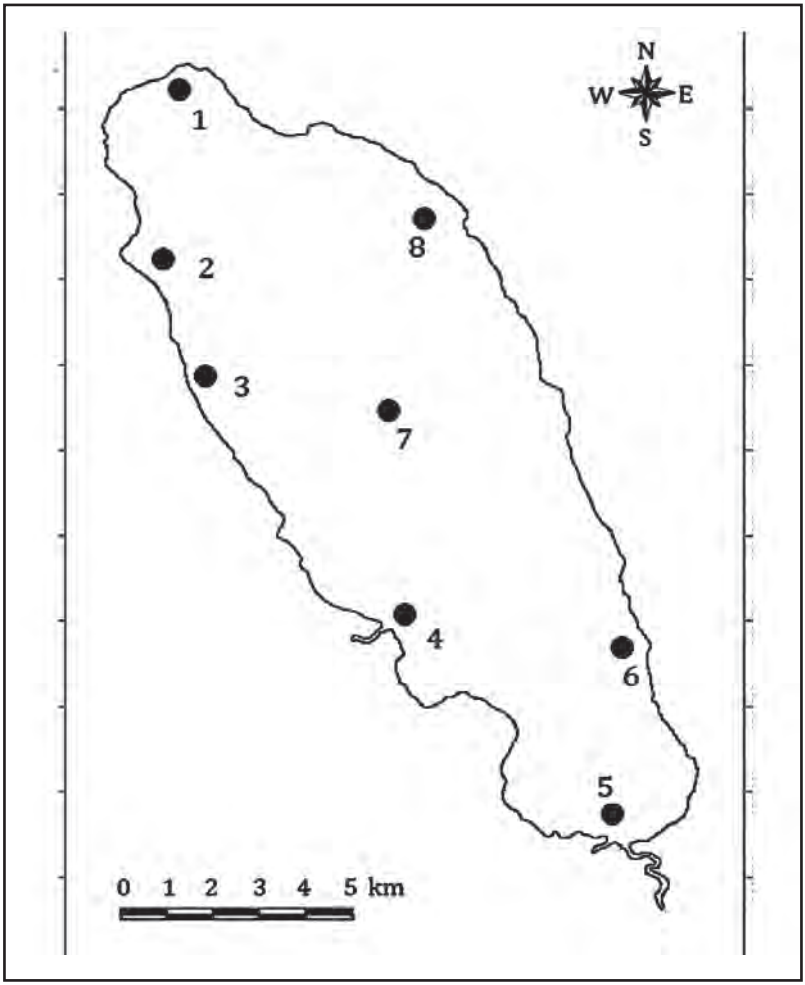


Source: Sulawesty, Sunanisari, Mulyana et al. (2002); Suryono, Nomosatryo, Mulyana et al. (2006)

Figure 39. Temperature Vertical Stratification Pattern of Lake Singkarak

E. Water Quality

Water quality in Lake Singkarak was measured in 8 stations across the lake. Figure 40 shows the location of the stations. Meanwhile, Table 17 and Figure 41 to 42 shows the results of the measurements.



Source: Suryono, et al. (2006)

Figure 40. Water Quality Measured Stations in Lake Singkarak

Table 17. Water Quality Condition in Lake Singkarak

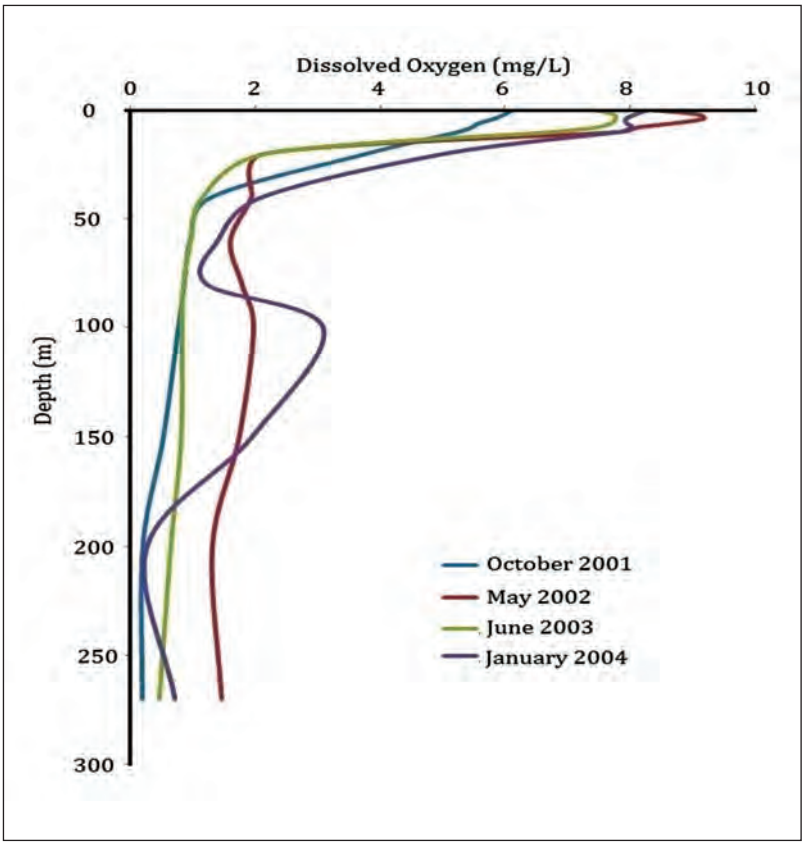
Parameters/ Time	Stations							
	1	2	3	4	5	6	7	8
Transparency (m)								
June 2003	1.8	2.6	2.6	2.1	1.7	2.2	2.1	2.5
January 2004	4.2	4.9	5.4	3.2	5.4	4.7	7.2	4.5
pH								
June 2003	8.4	8.5	8.6	8.5	8.7	8.6	8.8	8.4
January 2004	8.7	8.6	8.5	8.6	8.5	8.6	8.8	8.4
Conductivity								
June 2003	nd	nd	nd	nd	nd	nd	nd	nd
January 2004	0.189	0.190	0.189	0.190	0.190	0.189	0.191	0.191
Total Nitrogen (mg/L)								
June 2003	0.218	0.189	0.214	0.364	0.372	0.125	0.152	0.308
January 2004	0.268	0.123	0.984	0.456	0.416	0.306	0.367	0.316
Total Phosphorus (mg/L)								
June 2003	0.010	0.008	0.015	0.008	0.008	0.009	0.011	0.010
January 2004	0.002	0.037	0.008	0.083	0.006	0.006	0.002	0.002
Chemical Oxygen Demand*] (mg/L)								
Dec. 2012	3.72	nd	nd	nd	3.89	nd	5.26	4.07

Note: nd= no data

Source: Suryono et al. (2006); *] Lubis, Kasry, Fajari (2013)

F. Biological Features

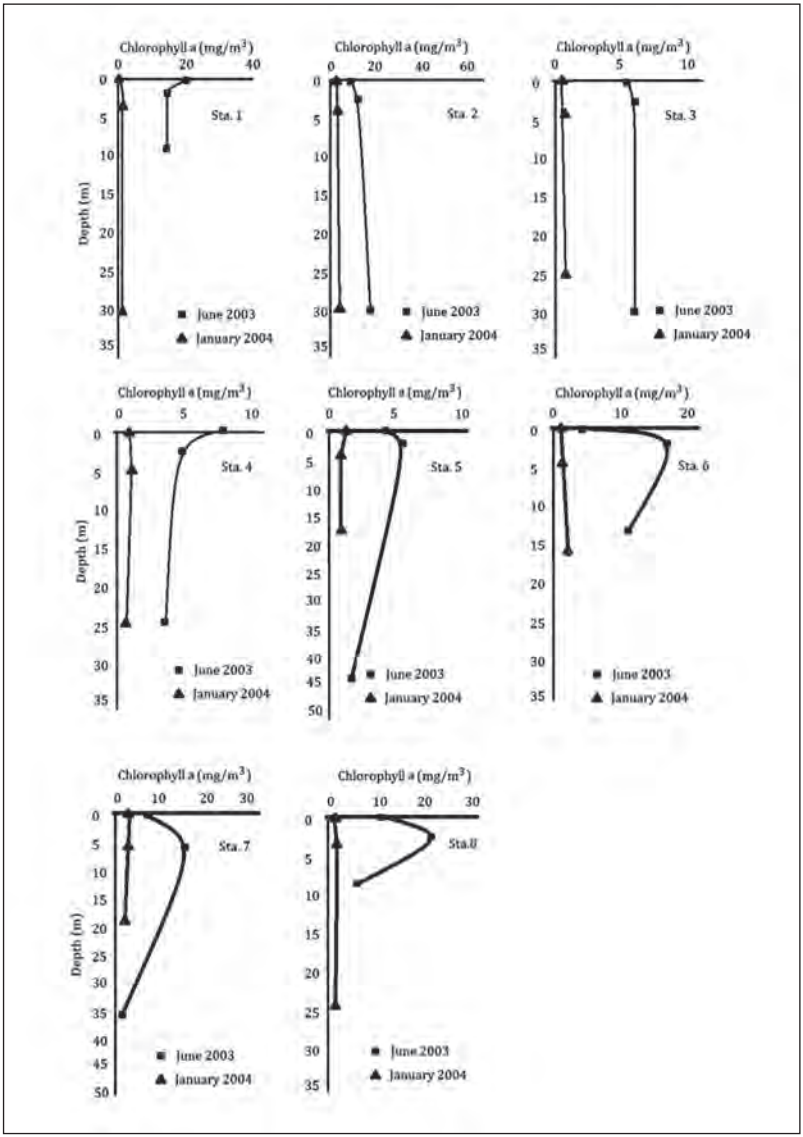
Dissolved Oxygen:



Source: Sulawesty et al. (2002); Suryono et al. (2006)

Figure 41. Oxygen Vertical Distribution Profile of Lake Singkarak

Chlorophyll a:



Source: Suryono et al. (2006)

Figure 42. Vertical Distribution Profile of Lake Singkarak Chlorophyll a

1. Flora

a. Plants (Pusat Studi Lingkungan Hidup, 1984; Giesen & Sukotjo, 1991):
   1) Floating: *Azolla pinnata, Eichhornia crassipes, Lemna perpussilla, Najas indica, Pistia stratiotes, Spirodela polyrhiza.*
   2) Emerged: *Altenantera philoxeroides, Colocasia esculenta, C. flabelliformis, Cyperus* sp., *Ipomoea aquatica, Limnocharis plava, Ludwigia adscendens, Nelumbo nucifera, Nymphoides indica, Panicum repens, Polygonum barbatum, P. pulchrum, Potamogeton malaianus, Scirpus mucronatus.*
   3) Submerged: *Hydrilla verticillata*

b. Phytoplankton (Sulawesty et al., 2002):
   1) Chlorophyceae: *Actinastrum* sp., *Chlorella* sp., *Cosmarium* sp., *Dictyosphaerium* sp., *Kirchneriella* sp., *Oocystis* sp., *Scenedesmus* sp., *Staurastrum* sp., *Tetraedron* sp.
   2) Cyanophyceae: *Anabaena* sp., *Chroococcus* sp., *Merismopedia* sp., *Microcystis* sp., *Spirulina* sp.
   3) Chrysophyceae: *Navicula* sp., *Surirella* sp., *Synedra* sp.
   4) Pyrrophyta: *Peridinium* sp.
   5) Euglenophyceae: *Euglena* sp.

2. Fauna

a. Zooplanktons (Wulandari, Afrizal, Nurdin et al., 2014):
   Arcella sp., *Bosmina* sp., *Branchianus* sp., *Centrophyxis* sp., *Ceriodaphnia* sp., *Chydosrus ovalis, Colpoda* sp., *Cyclops fuscus, Diaphanosoma brachium, Diaphanosoma* sp., *Diaptomus* sp., *Keratella valga tropica, Microsetella* sp., *Moina* sp., *Trichocerca capucina, Trichocerca* sp.

b. Benthic:
   1) Mollusca (Pusat Studi Lingkungan Hidup, 1984; UI&PU, 1978):
      Bellamya grassi costa, *B. javanica*, *B. sumatrensis*, *Brotia costula*, *Costradens ascia dimotus*, *Corbicula moltkiana*, *C. sumatrana*, *Digoniostoma truncatum*, *Emmericiopsis lacustris*, *Gryaulus convexiusculus*, *Lymnaea rubiginosa*, *Melanoides granifera*, *M. tuberculata*, *Pila ampullacea*, *Thiara scabra, Vivipara javanica*.

c. Fish (Pusat Studi Lingkungan Hidup, 1984; UI&PU, 1978; Weber & de Beaufort 1913, 1916):
   Anabas testudineus, *Channa lucius*, *Clarias batrachus*, *Cyclocheilichthys apogon*, *C. dezwaani*, *C. siaja*, *Cyprinus carpio*, *Glyptothorax platypogonoides*, *Gobiopterus brachypterus*, *Hampala bimaculata*, *H. macrolepidota*, *Hampala* sp., *Homaloptera gymnogaster*, *Labeobarbus douronensis*, *L. tambroides*, *Mastacembelus erythrotaenia*, *M. unicolor*, *Mystacoleucus padangensis*, *Mystus planiceps*, *Nemachilus olivaceus*, *Oreochromis mossambicus*, *O. niloticus*, *Osphronemus goramy*, *Osteochilus hasselti*, *O. kappeni*, *O. vittatus*, *Puntius belinka*, *P. schwanefeldi*, *Rasbora argyrotaenia*, *R. jacobsoni*, *R. spilotaenia*, *Tetraodon mappa*, *T. palembangensis*, *Trichogaster trichopterus*.

3. Primary Productivity:

nd

4. Biomass:

nd

5. Fish production potential (Syandri, 1998)**:**

542.46 ton/year

6. **Fishery products** (Azhar, 1993)**:**

   Cyclocheilichthys dezwaani, *H. macrolepidota*, *M. padangensis*, *O. vittatus*.

7. **Cage aquaculture production potential:**

   nd

8. **Cage Aquaculture product:**

   Oreochromis niloticus

Source: F. Sulawesty (2004)

Figure 43. *Mystacoleucus padangensis,* Known as Bilih Fish, the Potential Fish in Lake Singkarak

G. Sosio Economic Condition

Table 18 shows land use in Lake Singkarak catchment area.

Table 18. Land Use in Lake Singkarak Catchment Area

Landuse	Area (Ha)	%
Primary dry land forest	23,235.4	23.19
Secondary dry land forest	5,595.9	5.58
Plant forest	29.4	0.03
Housing	3,665.2	3.66
Plantation	167.4	0.17
Dry land agriculture	28,062.1	28.01
Dry land agriculture and schrub	21,749.6	21.71
Paddy field	14,559	14.53
Schrub	2,815.7	2.81
Open land	316.5	0.32
Total	100,196.2	100

Source: BPDAS (2011)

H. Lake Utilization

Lake Singkarak is utilized for:

1. Fisheries (Fish production) (Dinas Perikanan Kabupaten Tanah Datar & Kabupaten Solok, 2000):
   a. 941.4 tons (1996); 990.6 tons (1997); 368.8 tons (1998); 585.2 tons (1999); 499.9 tons (2000)
2. Cage culture fish production: (Pemerintah Kabupaten Solok, 2012):
   a. 97.08 tons (2011)
3. Hydroelectric Power Plant (in outlet):
   a. 175 MW

Source: Sulawety (2004)

Figure 44. "Alahan"; Catching System of *M. padangensis*, Trapping Riverine Migration Fish to Lake Singkarak Inlets

4. Tourism: (Dinas Pariwisata, Seni, dan Budaya Kabupaten Tanah Datar, 2007; Dinas Pariwisata, Seni, dan Budaya Kabupaten Solok, 2008)):
   a. 10,204 tourists to Tanah Datar Regency (2006)
   b. 55,284 tourists to Solok Regency (2008)

I. Deterioration of Lake Environment

Lake Singkarak is deteriorating due to (KLH, 2014):

1. Critical land in catchment area (43,000 ha);
2. The threat of domestic and agricultural pollution;
3. Overfishing especially species *M. padangensis*.

J. Legistation and Institusional Measures for Upgrading Lake Environment:

Unfortunately, no data can be gathered.

Lake Diatas

A. Location

Lake Diatas is located in Solok Regency, West Sumatra Province, particularly in the foothills of Talang Mount which is classified as an active volcano. This lake is also a part of Batanghari river watershed. Lake Diatas was first known as a tourist destination located on the edge of the main road of Kerinci-Muaralabuh-Kerinci-Padang. It is used as a temporary rest area to travel from Solok-Sungai Penuh, Padang-Jambi or Padang-Palembang.

B. Description

Lake Diatas is the graben lake and was formed by the tecto-volcanic activity. Erosion of the Gumati chanel, the outlet of the lake, had caused the decrease of lake surface ~9 metres (Giesen & Sukotjo, 1991).

The land use of Lake Diatas watersheed nowadays is intensively enough for both agriculture and settlement. Therefore, conservation of Lake Diatas should be considered to keep the sustainability of the lake. Giesen & Sukotjo (1991) stated that lake has endemic fish as well, *Cyclocheilichthhys dezwaani*. Therefore, conservation to this species is important to concern.

Source: Apip (2016)

Figure 45. A View of Lake Diatas

Figure 46. Map of Lake Diatas

C. Physical Dimension

1. Monthly of lake surface elevation (msl) (Ridwansyah, 2009): 1.531 m
2. Outflow river: Gumanti river
3. Outflow rate (at moment): 1.25 m^3/sec.

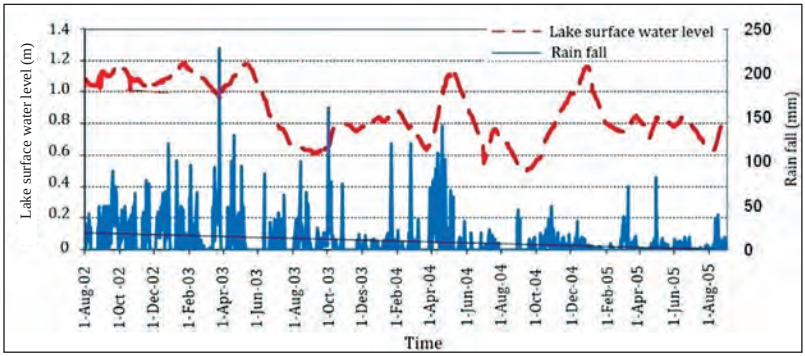
Table 19. Characteristics of Lake Diatas Morphometry

No.	Parameter	Values
1	Area of waters (A) (km^2)	12.45
2	Shore line length (km)	19.97
3	Maximum of length (km)	6.42
4	Maximum of width (km)	2.88
5	Maximum of depth (m)	47
6	Volume (x 10^6 m^3)	302.06
7	Average of depth (m)	24.3
8	Water residence time (years)	7.7
9	Area of cathment (C) (km^2)	40.86
10	Ratio of C/A*	3.28

Source: Ridwansyah (2009)

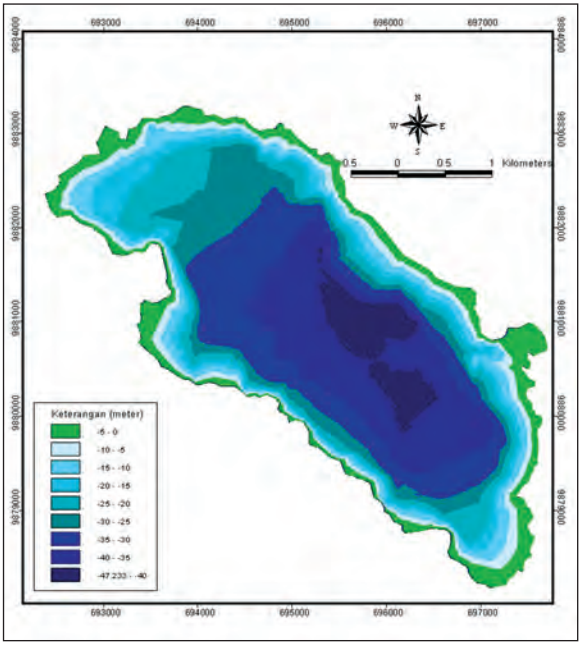
D. Physiographic Features:

Figure 47 shows rainfall and water surface level of Lake Diatas, while Figure 48 shows its depth.



Source: Ridwansyah (2009)

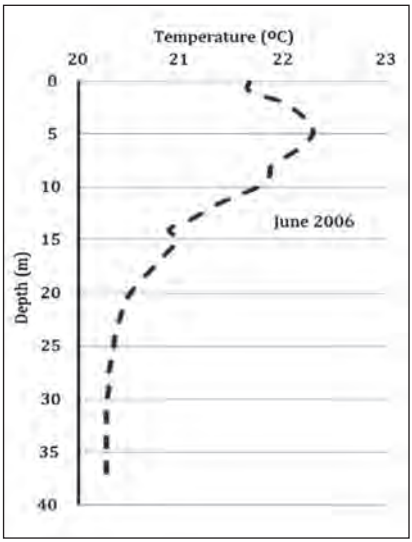
Figure 47. Rainfall in Lake Diatas Area and Lake Surface Water Level



Source: Ridwansyah (2009)

Figure 48. Bathymetry Map of Lake Diatas

Lake Diatas can be categorized as polimictic lake. Figure 49 shows its stratification pattern as of June 2007.



Source: Ridwansyah (2009)

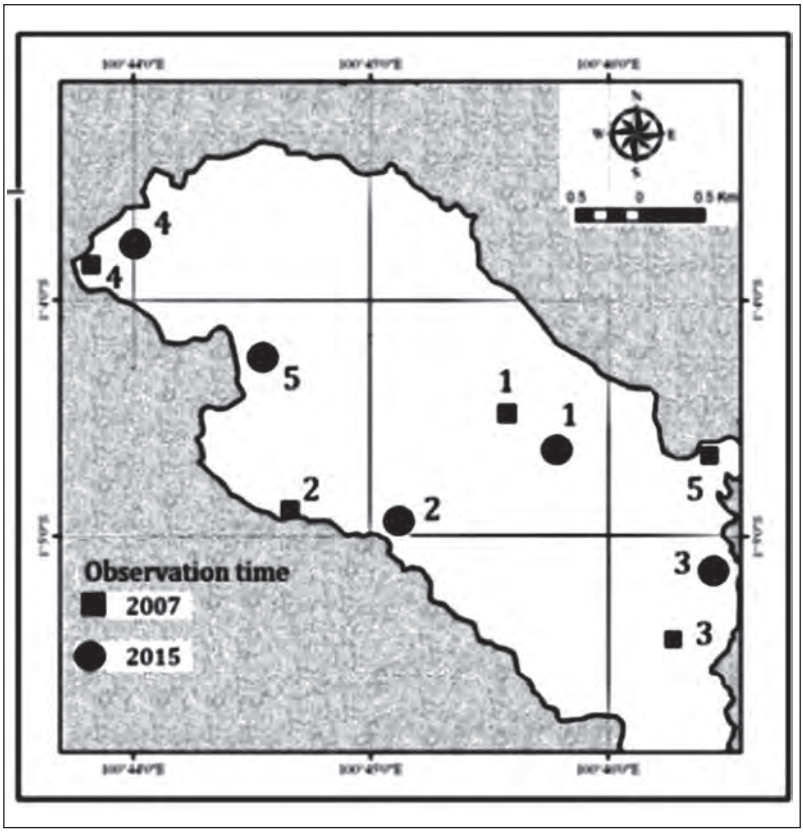
Figure 49. Temperature Vertical Stratification Pattern of Lake Diatas

Source: Apip (2016)

Figure 50. Outlet Area of Lake Diatas

E. Water Quality

Water quality in Lake Diatas was observed in 2007 and 2015 (Figure 51). Table 20 shows the results of the observations.



Source: Ridwansyah (2009); Samuel & Adiansyah (2016)

Figure 51. Water Quality Measured Stations in Lake Diatas

Table 20. Water Quality Condition in Lake Diatas

Parameters/ Time/	Stations				
	1	2	3	4	5
Transparency (m)					
February 2015	7.6	8.4	Nd	7.2	7.1
May 2015	6.0	5.0	Nd	5.0	5.0
September 2015	7.0	6.5	6.5	6.5	7.0
November 2015	4.2	3.9	4.2	5.0	4.2
Temperature (°C)					
February 2015	21.9	23.2	24.2	21.9	22.1
May 2015	23.9	24.3	24.6	24.2	24.2
September 2015	23.4	23.6	23.2	24.1	23.4
November 2015	22.7	22.7	22.5	23.1	23.0
pH					
February 2015	7.5	7.5	7.5	7.5	7.5
May 2015	7.5	7.5	7.5	7.5	7.5
September 2015	7.5	7.5	7.5	7.5	7.5
November 2015	7.7	7.8	7.8	7.8	7.8
Conductivity (µmS/cm)					
February 2015	106	103	103	106	106
May 2015	96	94	100	107	114
September 2015	92	97	97	90	96
November 2015	112	113	114	116	113
Dissolved Oxygen (mg/L)					
February 2015	7.08	7.05	7.59	7.08	6.93
May 2015	7.05	6.85	7.05	7.05	7.05
September 2015	6.85	6.85	6.85	6.85	6.85
November 2015	6.4	6.4	6.4	6.6	6.3

Parameters/ Time	1	2	3	4	5
Nitrate (mg/L)					
February 2015	0.77	0.356	0.404	0.029	0.022
May 2015	0.019	0.006	0.039	0.090	0.006
September 2015	nd	nd	Nd	nd	nd
November 2015	0.016	0.368	0.400	0.479	0.335
Total Phosphorus (mg/L)					
February 2015	0.01	0.005	0.011	0.007	0.017
May 2015	0.021	0.021	0.034	0.032	0.026
September 2015	0.039	0.06	0.051	0.08	0.048
November 2015	0.007	0.005	0.005	0.008	0.045
Chlorophyll a (µg/L)					
February 2015	1.44	1.97	0.93	0.13	1.08
May 2015	1.154	0.951	1.332	1.363	0.974
September 2015	1.492	1.54	1.222	0.936	0.85
November 2015	2.505	2.465	2.768	2.587	2.96

Source: Samuel & Adiansyah (2016)

F. Biological Features

1. Flora

a. Plants (Giesen & Sukotjo, 1991; UI/PU, 1978):
   1) Wetland area: *Cladium mariscus, Leersia hexandra; Pandanus helicopus, Panicum repens, Rhyncospora corymbosa, R. rugosa.*
   2) Floating: *Spirodela polyrhiza*

3) Emerged: *Colocasia esculenta, Eleocharis dulcis, E. Tetraquetra, Machaerina rubiginosa, Polygonum barbatum, Potamogeton malaianus, P. polygonifolius, Scirpus mucronatus.*
4) Submerged: *Ceratophyllum demersum, Hydrilla verticillata.*

b. Phytoplankton: nd

2. Fauna

a. Zooplankton: nd
b. Benthic:
Mollusca (UI&PU, 1978; Pusat Studi Lingkungan Hidup, 1984): *Brotia costula, Corbicula moltkiana, C. sumatrana, Melanoides granifera, M. tuberculata, Thiara scabra.*
c. Fish (Pusat Studi Lingkungan Hidup, 1984; Weber & de Beaufort, 1913, 1916):
Cyclocheilichthys dezwaani, *Cyprinus carpio*, *Hampala macrolepidota*, *Labeobarbus tambroides*, *Nemacheilus* sp., *Osteochillus hasselti*, *Puntius gonionotus*, *P. maculatus*, *P. schwanefeldi*, *Rasbora elegans*, *Rasbora* sp.

3. Primary Productivity:

nd

4. Biomass (Samuel & Adiansyah, 2016):

Fish production potential: 44 kg/ha/year

5. Fishery product:

nd

6. Cage Aquaculture product:

nd

G. Sosio Economic Condition

Table 21 shows land use in Lake Diatas catchment area.

Table 21. Land Use in Lake Diatas Catchment Area

Land use	Area (Ha)	%
Natural forest	1,200	30.8
Open land	-	-
Settlements	-	-
Mixture plant	-	-
Paddy field	325	8.3
Fields	-	-
Shrub	-	-
Others: Grassland, shrub, lake edge bogs, setelement, garden	2,375	60.9
Total	**3,900**	**100.0**

Source: Giesen & Sukotjo (1991)

H. Deterioration of Lake Environment

According to Pusat Studi Lingkungan Hidup (1984), Lake Diatas' condition is deteriorating due to:

Present influx of nutrients from horticulture, rice field, and township area

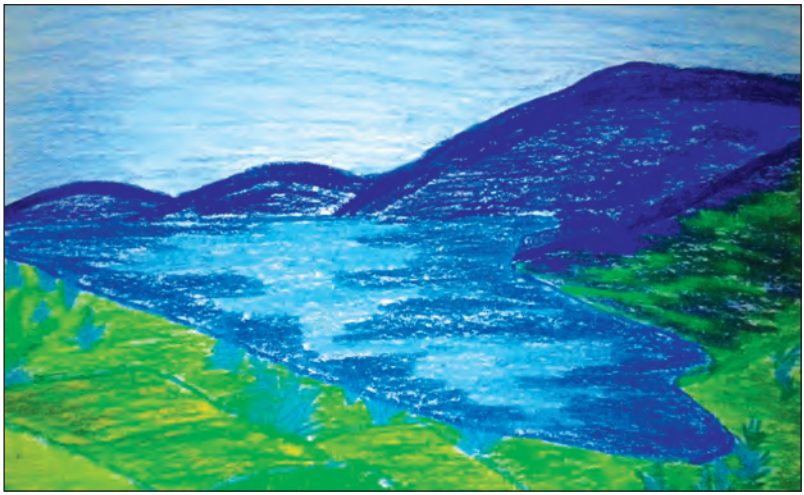
I. Legistation and Institusional Measures for Upgrading Lake Environment:

Unfortunately, no data can be gathered.

Lake Dibawah

A. Location

Lake Dibawah is located in Solok Regency, West Sumatra Province. The lake is situated nearly to Lake Diatas, but both lake's catchment areas are different.



Source: Drawn by Nomay (2016)

Figure 52. A View of Lake Dibawah

B. Description

Lake Dibawah is tectonic and considered a very depth graben lake (Vestapen, 1973). The surrounding slops of lake are steep risen and up to 600 m above the surface water. The outlet of Lake Dibawah flows the water out towards Lake Singkarak. The surrounding slopes are very steep, commonly deforested, and most of them are used for agriculture.

Figure 53. Map of Lake Dibawah

C. Physical Dimension

Monthly of lake surface elevation (msl): 1,462 m.

Table 22. Characteristics of Lake Dibawah Morphometry

No	Parameter	Values
1	Area of waters (A) (km^2)	11.20
2	Shore line length (km)	nd
3	Maximum of length (km)	6.3
4	Maximum of width (km)	2.9
5	Maximum of depth (m)	309
6	Volume (x 10^6 m^3)	2.54
7	Average of depth (m)	227
8	Water residence time (years)	72
9	Area of catchment (C) (km^2)	nd

nd: No data

Source: Ruttner (1931)

D. Physiographic Feature:

Unfortunately, no data can be gathered on Lake Dibawah's physiographic features, such as bathymetry and water stratification.

E. Water Quality

Table 23 shows some aspects of water quality measured in Lake Dibawah.

Table 23. Water Quality Condition in Lake Dibawah

Parameters	Values
Transparency (m)	11.1
Temperature (°C)	22.6
pH	7.3
Dissolved oxygen (mg/L)	5.8

Source: Ruttner (1931)

F. Biological Features

1. Flora

a. Plants (Pusat Studi Lingkungan Hidup, 1984):
   1) Wetland area: *Azolla pinnata, Panicum repens*
   2) Floating: *Spirodela polyrhiza*
   3) Emergent: *Eleocharis dulcis, Polygonum barbatum, Potamogeton polygonifolius*

b. Phytoplankton: nd

2. Fauna

a. Zooplankton:
   nd

b. Benthic: (from UI&PU, 1978)
   1) Molluscs: *Brotia costula*, *Corbicula sumatrana*, *Melanoides granifera*, *M. tuberculata.*

c. Fish (Weber & de Beaufort, 1913, 1916): *Cyclocheilichthys dezwaani*, *Cyprinus carpio*, *Hampala macrolepidota*, *Mystacoleucus padangensis*, *Osteochillus hasselti*, *Puntius gonionotus*, *P. schwanefeldi*, *Rasbora* sp.

3. Primary Productivity:

nd

4. Biomass:

nd

5. Fishery product:

nd

G. Sosio Economic Condition

Land use in Lake Dibawah catchment area (Giesen & Sukotjo, 1991) is mostly used as Protection and utilization forest, and non-forestry land.

I. Deterioration of Lake Environment

Lake Dibawah's condition is deteriorating due to (Giesen & Sukotjo, 1991):

1. Severe deforestation on steep catchment
2. The lake is in eutrophic condition probably due to deforestation and fertilizers used in agriculture.

J. Legistation and Institusional Measures for Upgrading Lake Environment:

Unfortunately, no data can be gathered.

Lake Kerinci

A. Location

Lake Kerinci lies on Bukit Barisan Mountain Range and is in the haven of Kerinci-Seblat National Park, Kerinci Regency, Jambi Province.

Its geographic position ranges between 2º 07'S–2 11' S and 101º 26'E–101º 31'E. Meanwhile, it has approximately 1.5 million ha total area which is within enclave of Kerinci Seblat National Park. It spread in four provinces, Jambi, West Sumatra, Bengkulu and South Sumatra (Nontji, 1992).

B. Description

Lake Kerinci is the volcano-tectonic lake. The lake is segment of Great Fault of Sumatra formed by formation of tectonic graben between two active faults, Sungai Penuh and Sungai Abu Fault. Activities of volcanic complex south of the graben produced tuffs deposited in northeastern (Pardede, 1982).

Source: Apip (2016)

Figure 54. A View of Lake Kerinci

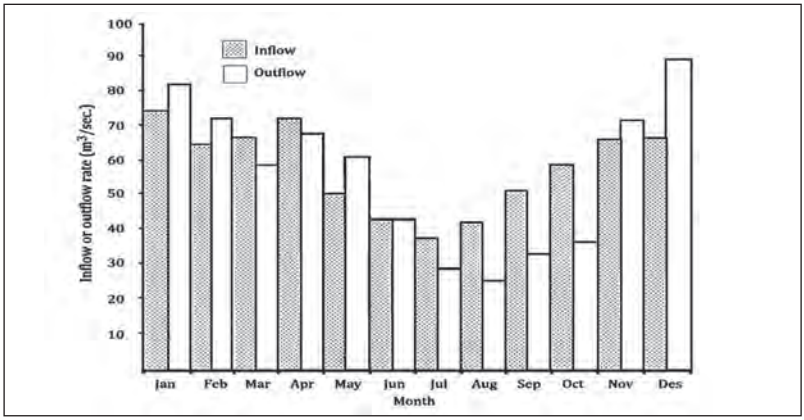
Figure 55. Map of Lake Kerinci

In early 1990, the existence of Lake Kerinci was seriously threatened by water hyacinth (*Eichhornia crassipes*) bloom, in which 80% of lake surface was barely covered with the pest plant. Finally, a successful control program of water hyacinth eradication in 1995–1998 was implemented using grass carp (*C. idella*) (Hartoto, Sumantadinata, Awalina, & Yustiawati, 2000).

C. Physical Dimension

Maximum of lake surface elevation: 787 m (1978) (msl) (DPU & Yaramaya, 1983)

1. Outflow river: Merangin
2. Inflow river: Siulak Deras, Selaman, Kerinci Pulau Tengah, Jujun
3. Inflow and outflow rate (DPU & Yaramaya, 1983):
    a. The bigest inflow river: Siulak (26.9–52.6 m^3/sec.)
    b. Monthly mean inflow: 37.9 m^3/sec (July)–74.3 m^3/sec (January)
    c. Monthly mean outflow: 29.7 m^3/sec (July)–94.6 m^3/sec (December)
    d. Annual mean out flow = 57.31 m^3/sec.



Source: DPU & Yaramaya (1983)

Figure 56. Inflow and Outflow Rate Fluctuation of Lake Kerinci

Table 24. Characteristics of Lake Kerinci Morphometry

No.	Parameter	Values
1	Area of waters (A) (km^2)	46
2	The length of shore line (km)	31.47
3	Maximum of length (km)	9.80
4	Maximum of width (km)	4.59
5	Maximum of depth (m)	97
6	Maximum volume (x 10^9 m^3)	1.6
7	Average of depth (m)	35.60
8	Water residence time (months)	10.8
9	Area of cathment (C) (km^2)*	1,004.9
10	Ratio of C/A*	21.8

*) Self calculation

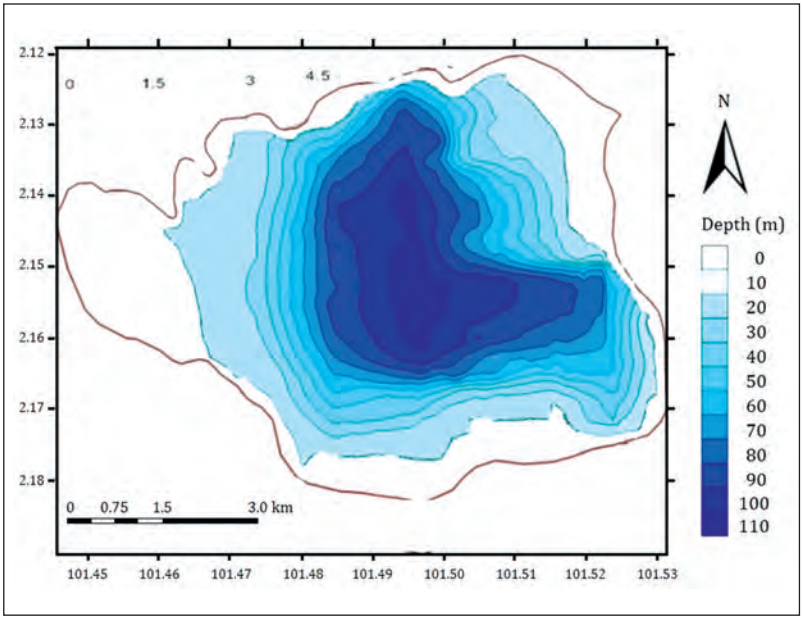
Source: DPU & Yaramaya (1983)

Source: Apip (2016)

Figure 57. Merangin River, The Outlet of Lake Kerinci

D. Physiographic Feature

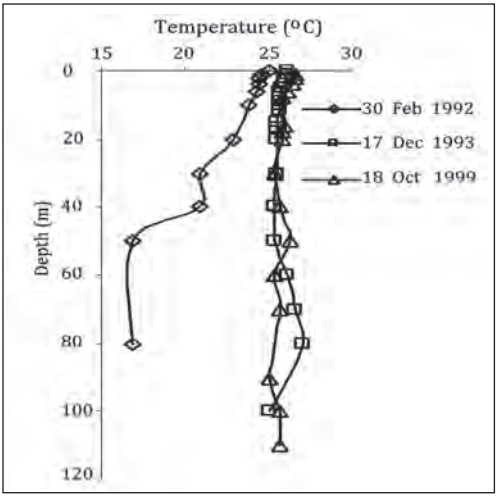
Figure 58 shows the map of depth of Lake Kerinci.



Source: Samuel (2014)

Figure 58. Bathymetry Map of Lake Kerinci

Lake Kerinci can be categorized as polymictic lake. Figure 59 shows its water stratification pattern.

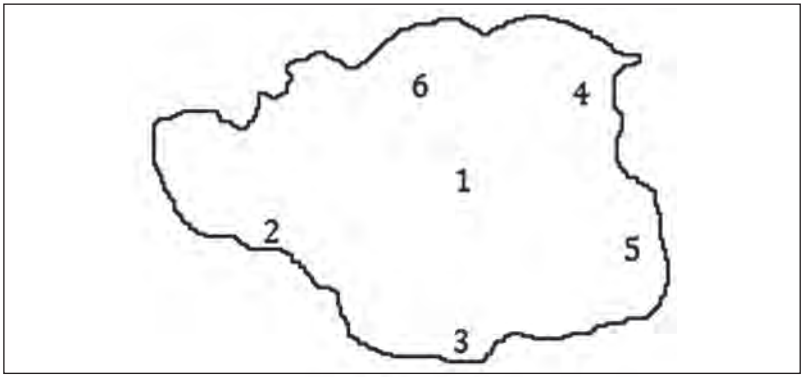


Source: Awalina (2000)

Figure 59. Temperature Vertical Stratification Pattern of Lake Kerinci

E. Water Quality

Water quality in Lake Kerinci was observed from 6 stations across the lake. Table 25 to 26 and Figure 61 shows the results of the observation.



Source: Samuel, Suryadi, & Ardiansyah (2015)

Figure 60. Water Quality Measured Stations in Lake Kerinci

Table 25. Water Quality Condition in Lake Kerinci in 2013

Paramaters/ Time	Stations					
	1	2	3	4	5	6
Transparency (m)						
April 2013	1.20	1.00	1.05	1.10	1.20	1.00
June 2013	1.25	1.25	1.50	1.15	1.25	1.30
August 2013	1.20	1.15	1.20	1.20	1.30	1.20
October 2013	1.2	1.1	1.2	1.2	1.4	1.2
Ph						
Average*	7.6	7.6	7.6	7.6	7.7	7.6
Conductivity(µS/cm)						
Average*	87	90	88	88	89	88
Chlorophyll a (ug/m^3)						
April 2013	45	48	28	36	25	26
June 2013	41	31	34	23	40	18
August 2013	23.5	22.5	19.5	21.5	23.0	22.0
October 2013	19.5	17.5	17.5	17.5	17.5	19.5
Total Phosphorus (TP)(ug/L)						
April 2013	80	85	61	71	54	55
June 2013	76	81	59	73	51	57
August 2013	79.7	82.7	77.0	82.0	72.7	75.3
October 2013	73.3	75.7	72.0	74.3	76.3	74.3

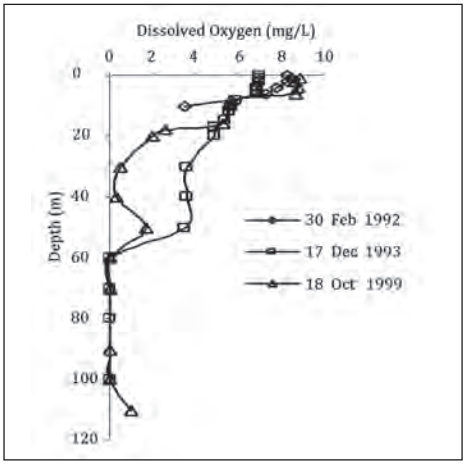
*) Data April 2013; June 2013; August 2013 & October 2013
Source: Samuel et al. (2015)

Table 26. Water Quality Condition in Center of Lake Kerinci in 1992

Parameters/Time	Climate	Mean value	Number sampling*)	Conf.limit (95%)
Total Phosphorus (TP) (mg/L)				
February 1992	Wet	0.066	11	0.02
July 1992	Dry	1.935	18	1.38
December 1993	Wet	0.249	17	0.04
Total Nitrogen (TN) (mg/L)				
February 1992	Wet	0.766	11	0.12
July 1992	Dry	0.888	18	0.31
December 1993	Wet	1.741	17	0.47
Chemical Oxygen Demand (mg/L)				
February 1992	Wet	37.65	11	4.62
December 1993	Wet	12.22	17	1.13
October 1999	Wet	31.57	12	6.99

*) Water sample from the depth (m): 0, 2,4,6, 10, 20, 30, 50, 60, 70, 80.
Source: Awalina & Aisyah (2002)

Dissolved Oxygen (*in center of the lake*)



Source: Awalina (2000)

Figure 61. Oxygen Vertical Distribution Profile of Lake Kerinci

F. Biological Features

1. Flora

a. Plant (Soeryani, 1981; Looij & Wijgergangs, 1992):
   1) Floating: *Azolla pinnata, Eichhornia crassipes, Lemna perpusilla, Pistia stratiotes, Spirodela polyrhiza.*
   2) Emerged: *Colocasia esculenta, Cyclosorus interruptus, Cyperus digitatus, C. haspan, C. platysstylis, Echinocloa stagnina, Hanguana malayana, Ipomoea aquatica, Limnocharis plava, Mimosa pigra, Pandanus* sp.*, Polygonum pulchrum, Polygonum sp., Scirpus grossus, Saccharum spontaneum, Fimbristylis dichotoma, Fuirena umbellata, Eleocharis ochrostachys, Lipocharpa chinensis, Rhynchospora corymbosa, Scleria scrobiculata.*
   3) Submerged: *Blixa* sp.*, Hydrilla verticillata, Ceratophyllum demersum, Najas indica, Potamogeton crispus, P. malaianus.*
   4) Creeping: *Alternantera philoxeroides, A. sessilis, Hymeneachne acutigluma, Leersia hexandra, Ludwigia adscendens, L. hyssopifolia.*

b. Phytoplankton (Sulawesty & Yustiawati, 1999)
   1) Chlorophyceae: *Chlorella* sp., *Cosmarium* sp., *Staurastrum* sp.
   2) Chrysophyceae: *Melosira* sp., *Synedra* sp.
   3) Pyrrophyta: *Glenodinium* sp.
   4) Euglenophyceae: *Euglena* sp.

2. Fauna

a. Zooplankton: nd

b. Benthic:
   1) Molluscs (Giesen & Sukotjo, 1991): *Bellamya javanica, B. sumatrensis, Brotia costula, Corbicula rivalis, Indoplanorbis exotus, Lymnaea rubiginosa, Melanoides granifera, M. tuberculata, Pila ampullacea, Pomacea* sp.*, Thiara scabra.*

c. Fish (Giesen & Sukotjo, 1991; UI & DPU, 1979):
Anabas testudineus, Aplocheilus panchax, Channa gachua, C. striata, Clarias teysmanni, Ctenopharingodon idella, Fluta alba, Hampala macrolepidota, Hampala sp., *Helostoma temmincki, Tor soro, T. tambra, T. douronensis, Mastacembelus maculatus, Mastacembelus* sp., *Mystus planiceps, Oreochromis mossambicus, Oreochromis niloticus, Osteochillus vittatus, Puntius huguenini, P. gonionotus, Puntius* sp., *Rasbora* sp., *Trichogaster trichopterus, Trichogaster pectoralis.*

3. **Primary Productivity:**
nd

4. **Biomass:**
nd

5. **Fish production potential:** (Samuel, Suryati, Adiansyah, 2015)
920–1647 tons/yr

6. **Fishery products** (Dinas Peternakan dan Perikanan Kabupaten Kerinci, 2012):
Hampala macrolepidota, Cyprinus carpio, Oreochromis niloticus, Tor spp., *Osteochilus vittatus.*

7. **Cage aquaculture production potential:**
nd

G. Sosio Economic Condition

Figure 27 shows land use in Lake Kerinci catchment area.

Table 27. Land Use in Lake Kerinci Catchment Area

Land use	Area (Ha)	%
Forest	21,746.79	24.49
Mixed farms	3,272.86	3.69
Dry field	20,975.70	23.62
Open land	179.16	0.20
Plantation	907.21	1.02
Settlement	2,325.18	2.62
Padi field	13,827.95	15.57
Shrub	25,538.94	28.76
No data	23.21	0.03
	88,797.00	100

Source: Mukhoriyah & Trisakti (2014)

H. Lake Utilization

Lake Kerinci is utilized for (Dinas Peternakan dan Perikanan Kabupaten Kerinci, 2012):

1. Fisheries: Fish production 1,092.1 tons (2011)
2. Cage aquaculture: 688 tons (2011)

I. Deterioration of Lake Environment

Lake Kerinci's condition is deteriorating due to:

1. Threatened by sedimentation problems as consequences of watershed damage in the upper part of Lake Kerinci due to illegal deforestration and subsequently induces erosion and siltation problems (DPU & Yaramaya, 1983);
2. Disappearance of local fish species and introduction of exotic fish (Nontji, 1992);
3. Dropped of fish production (Hartoto et al., 2000)

J. Legistation and Institusional Measures for Upgrading Lake Environment:

Unfortunately, no data can be gathered.

Lake Ranau

A. Location

Lake Ranau is located in southwest Sumatra Island. The lake is the second largest in Sumatra after Lake Toba. Most part of the lake lies in South Sumatra, precisely in Ogan Komering Ulu (OKU) Selatan Regency and another part is in Lampung Province particularly in Lampung Barat Regency.

Source: RC for Limnology (2001)
Figure 62. A View of Lake Ranau

B. Description

Lake Ranau is tecto-vulcanic lake (van Bemmelen, 1949). The lake is caldera of Mount Ranau and was formed as a part of Sumatra tectonic fault history. Mount Seminung in the southeastern Lake Ranau formed as post of caldera.

The lake is located in convergence zone between Kepahiang-Makakau and Ranau-Suoh segment (Michaela, 1994). Some disruption

Figure 63. Map of Lake Ranau

of ecosystems that occurred in the lake is the release of sulfur to the water which caused fish death.

There are several attractions in the area that became the destination of the tourists, including Mariza Island, hot spring, and waterfalls Subik Tuha.

C. Physical Dimension

1. Lake surface elevation (msl) (Harsono, Wibowo, Ridwansyah, 2002): 538.7 m
2. Main island: Meriza
3. Inflow river and flow rate (on August 2001) (Harsono et al., 2002):
   a. Warkuk (20.125 m^3/sec.), Pilla (1.168 m^3/sec.), Meijin (0.915 m^3/sec.), Sepuyuh (0.171 m^3/sec.), Kedok (0.222 m^3/sec.), Senangkal (0.875 m^3/sec.), Sebarak (0.196 m^3/sec.)
   b. Total inflow rate: 23.67 m^3/sec.
4. Outflow river: Silabung

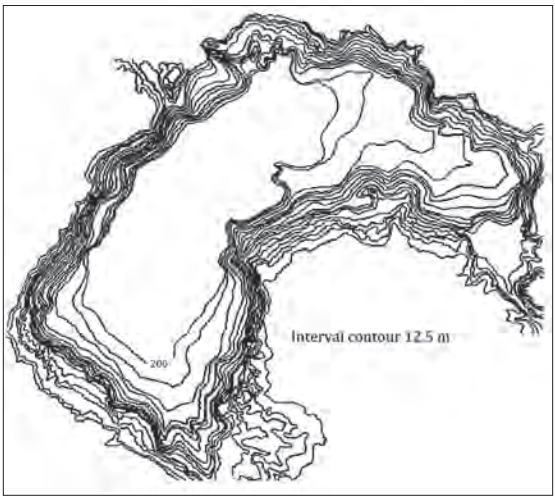
Table 28. Characteristics of Lake Ranau Morphometry

No.	Parameter	Values
1	Area of waters (A) (km^2)[3]	128.13
2	The length of shore line (km)[4]	63.78
3	Maximum of length (km)[4]	15.4
4	Maximum of width (km)[4]	12.9
5	Maximum of depth (m)[3]	221
6	Volume (x 10^9 m^3)[3]	19.92
7	Average of depth (m)[*]	155.5
8	Water retention time (years)[*]	26.7
9	Area of catchment (C) (km^2)[5]	362.8
10	Ratio of C/A[*]	2.83

*] self calculation
Source: Harsono et al. (2002)

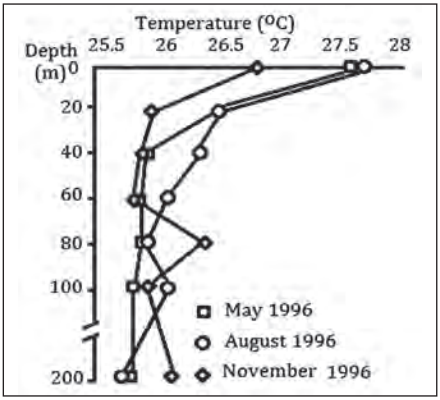
D. Physiographic Feature

Figure 64 shows the depth of Lake Ranau, while Figure 65 shows its water stratification. Lake Ranau can be categorized as meromictic lake (Lehmusluoto & Machbub, 1997).



Source: Harsono et al. (2002).

Figure 64. Bathymetry Map of Lake Ranau



Source: Sulastri, Sunanisari, & Nomosatryo (1999)

Figure 65. Temperature Vertical Stratification Pattern of Lake Ranau

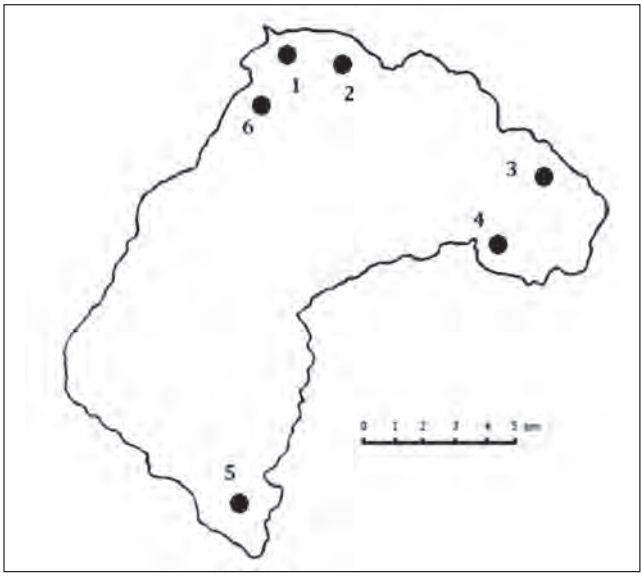
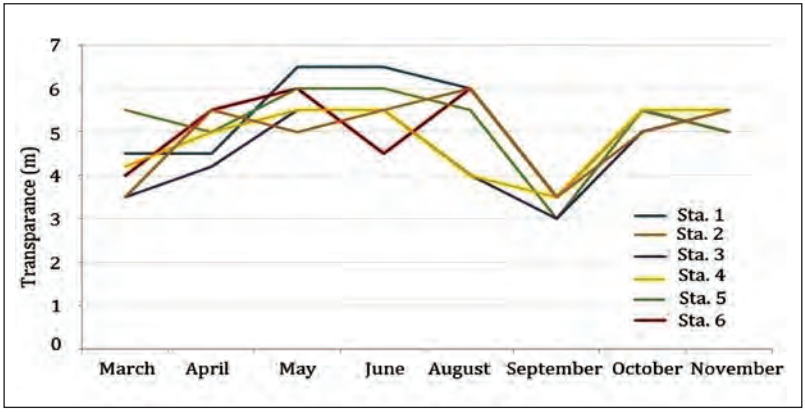


Figure 66. Water Quality Measured Stations in Lake Ranau

E. Water Quality

Six stations were scattered around Lake Ranau to observe its water quality. Table 29 and Figure 68 shows the results.



Source: Subagdja et al. (2013)

Figure 67. Transparensy Pattern in Lake Ranau

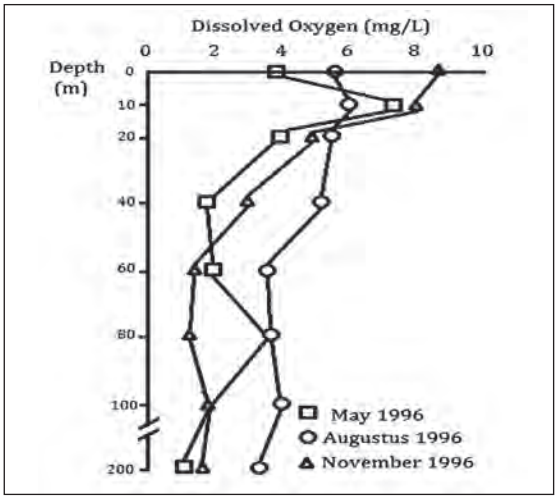
Transparency

Table 29. Water Quality Condition of Lake Ranau

Parameters/ Time	Stations					
	1	2	3	4	5	6
pH						
April 2013	8.5	8.5	8.5	8.5	8.5	8.5
June 2013	8.5	8.0	8.0	8.5	8.0	8.5
August 2013	8.5	8.5	8.5	8.0	8.0	8.5
October 2013	8.5	8.5	8.5	8.5	8.5	8.5
Conductivity (µS/cm)						
April 2013	290	310	310	310	320	320
June 2013	310	320	310	310	290	300
August 2013	370	360	360	380	350	360
October 2013	360	380	400	370	370	370
Chlorophyll a (mg/L)						
April 2013	0.035	0.040	0.045	0.044	0.045	0.044
June 2013	0.035	0.040	0.045	0.050	0.051	0.045
August 2013	0.060	0.054	0.038	0.039	0.048	0.046
October 2013	0.039	0.030	0.042	0.043	0.031	0.040
Phosphorus (mg/L)						
April 2013	0.078	0.120	0.097	0.092	0.085	0.090
June 2013	0.112	0.116	0.112	0.127	0.113	0.122
August 2013	0.092	0.092	0.096	0.072	0.112	0.072
October 2013	0.087	0.070	0.113	0.099	0.125	0.097

Source: Subagdja et al. (2013)

Dissolved Oxygen



Source: Sulastri et al. (1999)

Figure 68. Oxygen Vertical Distribution Profile of Lake Ranau

F. Biological Features

1. Flora

a. Plants (Sunanisari, Nomosatryo, Mulyana, 2002; Kartamihardja & Utomo, 2000):
   1) Floating: *Eichhornia crassipes, Pistia stratiotes.*
   2) Emerged: *Monochoria hastata, Ottelia alismoides, Limnophila* sp.
   3) Submerged: *Potamogeton pectinatus, Ceratophyllum demersum, Hydrilla verticillata, Myriophylum* sp., *Najas* sp., *Utricularia* sp.

b. Phytoplanktons (Sulastri & Sulawesty, 2002):
   1) Chlorophyceae: *Actinastrum* sp., *Asterococcus* sp., *Botryococcus* sp., *Cladophora* sp., *Chlorella* sp., *Chrysocapsa* sp., *Coelastrum* sp., *Cosmarium* sp., *Crugenia* sp., *Dyctyosphaerium*

sp., *Franceia* sp., *Gloeocystis* sp., *Lagerheimia* sp., *Mallomonas* sp., *Nephrocytium* sp., *Oocystis* sp., *Rhizoclonium* sp., *Scenedesmus* sp., *Sphaerocystis* sp., *Spirogyra* sp., *Spirulina* sp., *Staurastrum* sp., *Tetraedon* sp., *Tetrapedia* sp., *Ulothrix* sp.

2) Chrysophyceae: *Achnantes* sp.,*Cocconeis* sp., *Cyclotella* sp., *Cymbella* sp., *Diatoma* sp., *Denticula* sp., *Ephitemia* sp., *Fragillaria* sp., *Gomphonema* sp., *Melosira granulate, Melosira* sp., *Navicula* sp., *Nitzschia* sp., *Pleurosigma* sp., *Surirella* sp., *Synedra* sp., *S. ulna.*
3) Cyanophyceae: *Anabaena* sp., *Aphanocapsa* sp., *Aphanothece* sp., *Chroococcus* sp., *Gloeothece* sp., *Microcystis* sp., Nostoc sp.
4) Pyrrophyta: *Glenodineum* sp., *Peridinium* sp.
5) Euglenophyceae: *Phacus* sp., *Trachelomonas* sp.

2. Fauna

a. Zooplankton (Subagdja et al., 2013):
   1) Sarcodina: *Actinosphaerium* sp., *Actinophrys* sp., *Acanthocystis* sp., *Difflugia* sp., *Euglypha* sp.
   2) Monogononta: *Lecane* sp., *Notholca* sp., *Trichocerca* sp., *Polyartha* sp.
   3) Crustacea; *Mesocyclops* sp., *Nauplius* sp.

b. Benthic (Subagdja et al., 2013; Sulawesty, Sudarso & Badjoeri, 2002):
   1) Crustacea: *Palaemonetes* sp.,
   2) Mollusc: *Bellamya* sp., *Brotia* sp., *Corbicula* sp., *Melanoides tuberculata, M. granifera, M. maculata, Thiara lineata, T. scabra, Pomacea* sp.
   3) Annelida: *Aulodrilus* sp., *Branchiura sowerbyi, Chaetogaster* sp., *Dero* sp., *Hirudinea* sp., *Limnodrilus* sp., *Ophidonais* sp., *Pristina* sp.

4) Insecta: *Chironomus., Clinotanypus* sp., *Diamesinae* sp., *Ictinogamphus* sp., *Tanypus* sp., *Baetis* sp., *Lepidoptera* sp., *Tinoides* sp.

c. Fish (Subagdja et al., 2013; Kartamihardja & Utomo, 2000; Sulastri, 2002):
Anabas testudineus, Channa striata, Clarias sp., *Colossoma macropomum, Cyclocheilichthys apogon, Cyprinus carpio, Hampala ampalong, H. macrolepidota, Mastacembelus unicolor, M. maculatus, Mystacoleucus marginatus, Mystus nemurus, Notopterus notopterus, Oreochromis mossambicus, O. niloticus, Osteochilus hasselti, O. vittatus,Pristolepis grooti*, *Puntius javanicus, P. lineatus, P. tetrazona, Rasbora argyrotaenia*, *Tor douronensis, Trichogaster trichopterus.*

d. Primary Productivity (Sulastri et al., 2002): 20.99–89.28 mg C/m^3

e. Biomass of fish (Fahmi & Umar, 2013): 14.05–115.9 kg/Ha

f. Fishery product (Subagdja et al., 2013): *H. macrolepidota, O. mossambica, P. grooti, O. vittatus,* and *O. niloticus.*

3. Primary Productivity:

nd

4. Biomass:

nd

5. Fish production potential (from Subagdja et al., 2013**):**

16.72–18.52 kg/Ha/year

6. Fishery product:

nd

G. Sosio Economic Condition

Table 30 shows land use in Lake Ranau catchment area.

Table 30. Land Use in Lake Ranau Catchment Area

Land Use	Area (Ha)	%
Forest	8,237.823	22.7
Dry land	2,439.847	6.7
Resetlement	279.407	0.8
Paddy field	1,978.892	5.5
Bush	18,012.36	49.6
Plantation	5,333.723	14.7
Total	**36,282.05**	

Source: Natsir (2010)

H. Lake Utilization:

Unfortunately, no data can be gathered in the lake's utilization.

I. Deterioration of Lake Environment:

Domestic wastes becomes the main factor of Lake Ranau deterioration.

J. Legistation and Institutional Maesures for Upgrading Lake Environment:

Unfortunately, no data can be gathered.

Sumatran Lakes: Final Thoughts

The catalogue of lakes is simply a collection of data and it is far from complete aptness. Due to various limitations, not all data can be compiled and displayed. However, from these data, the development and progress of the research in Indonesian lakes are portrayed representatively.

The previously-old research reports and results are sometimes hard to find. However, it is a challenge for researchers and research institutions to track down and complete the history of the research. The former data are obviously important references of the lake's conditions and the basis of subsequent research. The data can help to explain the past condition of the lake when the human activities surrounding the lake were presumably lessened.

The lake's condition is constantly changing in line with the development of the community. It requires a frequent monitoring in order to provide decisions of the policy that should be applied to conserve the sustainability of the lake. The monitoring results should be compiled accordingly to review the lake's development.

Studies of Sumatran lakes are still continued with various approaches recently. Therefore, efforts to compile data and refinement of the catalogue should be continued for the next period of research. On the other hand, studies of lakes in Indonesia have been and are still being carried out in different areas and islands such as in Kalimantan, Sulawesi, Papua, and even on small lakes in Java. The compilation of data in the form of catalogue is the simplest way on how the data can be preserved and used for the future, both for researchers or stakeholders.

Finally, the author expects that the catalogue would be one of the references for researchers, observers, and policy makers in Indonesia despite of its limitations. Hopefully, this catalogue will also encourage the publication of other catalogues from the remaining islands in Indonesia, and help the readers understand the lake ecosystem as an essential entity for human beings.

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Glossary

Cage aquaculture : A farming method of aquatic organisme (fish, especially) in lentik system with a particular type of rearing facility, can either use net or bamboo, be land-based or water based. Other terms are cage culture, floating net aquaculture, or pen culture.

Catchment area : A unit area of land which collect rain water that falls on it and drain the water into waters body such as rivers or lakes, which is usually limited by mountain ridge. Other terms of the watershed.

Chemical Oxygen Demand (COD) : A measurement of organic pollutan on natural water and waste water.

Chlorophyll : The main pigment and part of green plants (eg in phytoplankton or algae), which absorbs light energy for photosynthesis activity.

Conductivity : A measure of the ability of an aqueaous solutan to carry an electric current.

Emerged plant : Type of aquatic plant which sticking or erecting above the water surface, which grows in saturated soil water or waterlogged soil, from the ground 0.5 m above water surface (supra littoral) until the sediments in 1.5 m water depth (upper littoral).

Endemic species : Animal or plant whose their existence or distribution is limited to a particular region as a result of geographic or geological isolation from other areas.

Epilimnion : The turbulent superficial layer of a lake lying above the metalimnion which does not have permanent thermal stratification (Gr. *epi* on, *limne* lake).

Eutrophic : Waters with a good supply of nutriens and hence a rich organic production (Gr. *eu* well, *trophein* to nourish).

High trophic criteria of lake waters, characterized by tran levels of nutrient and chlorophyll and low transparency depth.

Eutrophication : Lakes condition are undergoing nutrient enrichment and the ensuing progressive deterioration of their quality, due to the luxuriant growth of plants with its repercussion on the overall metabolism of the water effected.

Fault : Earth's plates fracture or discuntinuity in a volume of rock, across which there has been significant displacement as a result of rock-mass movement. Large faults within the Earth's crust result from the action of plate tectonic forces, with the largest forming the boundaries between the plates, such as subduction zones or transform faults.

Floating plant : Type of aquatic plant of leaf-type float *(floating-leaved)* are rooted in the sediments submerged in mid littoral zone (depth of

about 0.5–3.0 m), and has leaves floating. Type of aquatic plant of free-type float *(freely floating*) does not have roots to the substrate, and floating freely on or in the water, usually limited to the protected area and no turbulence.

Hypolimnion : The deep layer of a lake lying below the metalimnion and removed from the surface influences. (Gr. *hypo* under, *limne* lake).

Introduction species: The non-native species of animal or plant and living outside its native distributional range. The species has arrived in some area by human activity, either deliberate or accidental.

Meromictic : Those lakes that at undergo only a partial circulation down to a depth determined by a density stratification (Gr. *Meros* part, *miktos* mixed).

Mesotrophic : Waters with a medium supply of nutriens and hence a midlle organic production (Gr.*eu* well, *trophein* to nourish).

Middle trophic criteria of lake waters, characterized by transp levels of nutrient and chlorophyll and transp transparency depth.

Metalimnion : The layer of water in a lake between the epilimnion and hypolimnion in which the temperature exhibits the greatest difference in a vertical direction (Gr. *meta* between, *limne* lake).

Morphometry : Landscape characteristic of lake water bodies such as the physical dimensions size, which is required in determining the water residence time, biological production potential, and determine the lake sensitivity lake to materials allochtonous loading.

Oligomictic : The lakes with little seasonal change in term to their water vertical movement. The lakes usually stable and stratified, generally equatorial lakes and shallow low-altitude with a very slow or rare mixing.

Oligotroph : Waters with a small supply of nutriens and hence a small organic production (Gr. *oligos* small, *trophein* to nourish) Low trophic criteria of lake waters, characterized by low levels of nutrient and chlorophyll and high transparecy depth.

Overfishing : Fishing effort condition exceeds the level of natural fish production. The natural reproduction can not replace the catch. It is a form of over exploitation where fish stocks are reduced to below acceptable levels.

Phytoplankton : Floating microscopic plants (algae) role as primary producers and generally have chlorophyll.

Polymictic : The lakes with many mixing periods or continuous circulation throughout the year. Polymictic lakes are influenced by diel fluctuations in temperature, such as superficial warming and nocturnal cooling. Downwelling convection currents of cool upper layers destroy the stratification, and nocturnal circulation takes place until terminated by the following day's warming.

Primary productivity: Complex biochemical reactions in the formation of organic materials through the process of photosynthesis, or biomass formation by binding energy through photo/chemosynthesis.

Stratification : Varied conditions pattern of the lake water vertically, which is formed releted to heat binding of the water. The condition is controlled by a number of factors: the physical force of wind energy, flow and movement of water, basin morphometry, and

the loss of water. Patterns of density variations that affect to lake chemical and physical properties and cycles, as well as productivity and degradation processes. The lake stratification is generally formed of three layers vertically namely: epilimnion, metalimnion and hipolimnion.

Submerged plant : Type of submerged are at all depths in the photic zone (sunlight penetrable zone). Vascular angiosperms are only to 10 meters depth (hydrostatic pressure of 1 atm) in the lower part of littoral zone (*infralittoral*), and plants non-vasaular (such as macroalgae) there until the lower limit of the photic zone (*littoriprofundal*).

Transparency : The water clarity level, usually to determine the photic depth or to determine the water quality level. Tranparency is measured with the Sechi disk, a disc with $\pm$ 20 cm diameter in black and white color. The disk is dramend into the water and measured a maximum depth of disk appearance. Theoritically, Sechi (Transparency) depth about 5% of PAR (*Photosynthetically active radiation*).

Eutrophic : High trophic criteria of lake waters, characterized by high levels of nutrient and chlorophyll and low transparency depth.

Water retention time : Other term is water residence time. The length of the water at one of hydrological system (atmosphere; soil; river, lake). The lake water retention time is determined by the volume of the lake and water inflow or outflow.

Zooplankton : Floating microscopic animals, in freshwater is dominated by four major groups of animals: protozoa, rotifers, and two sub-classes crustace; cladocera and copepod.

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Author Information

The author was born in a small city, Maja, located at the foot of Ciremay Mount, Majalengka, West Java on May 14, 1962. Author's primary and high school education were in Majalengka. The author continued his higher education at Bogor Agricultural Institute, taking the Department of Water Resources Management at the Faculty of Marine and Fisheries, as well as, taking S2 education (master) in Waters Sciences Program and Doctoral Education in the Water Resources Management Program, in the same university. Some of the non-formal education (training & course) have been followed by author, e.g. Wetland Course Management (Netherlands), Aquatic Resources Management (Japan), and Research Business Management (Australia).

Since the beginning of his career in 1988 until now, the author has been a researcher at the Center for Research Limnology-Indonesian Institute of Sciences (LIPI). The author has done many researches in limnological areas on several lakes in Indonesia which have been written in various journals. The author is also involved in the preparation of several academic manuscripts of government water management policy.

Some of the books the author has written are: i) *Danau Lindu; Keteduhan yang Merindu* [*Lake Lindu; Hoping in Silences*] (LIPI Press; 2007; In Indonesian); ii) *Danau Toba; Karakteristik Limnologi dan Mitigasi Ancaman Lingkungan dari Pengembangan Karamba Jaring Apung* [*Lake Toba, Characteristics of Limnology and Mitigation of Environmental Threat from Cage Aquaculture Development*] (LIPI Press, 2013); and iii) *Konsep Pengelolaan Perikanan Sidat di Perairan Poso Sulawesi Tengah; Timbangan Ilmiah* [*Concept of Sidat Fishery Management on Poso Waters, Central Sulawesi*; *Scientific Reviews*] (Pusat Penelitian Limnologi-LIPI; 2015; In Indonesian).

Catalogue of

SUMATRAN BIG LAKES

Catalogue of Sumatran Big Lakes is a compilation of data and information of eight large lakes in Sumatra Island, namely Lake Laut Tawar, Lake Toba, Lake Maninjau, Lake Singkarak, Lake Diatas, Lake Dibawah, Lake Ranau, and Lake Kerinci. The information of the lakes is presented briefly and covers various aspects, such as its water quality, geographical position, physical dimension, and biological feature.

There is no perfection in a human effort to build something, but a process of continuous improvement will further refine the existing one. Hopefully this book can enlighten Indonesian people about various specific ecosystems and provides benefits for human lives to more able to care and maintain those for the sake of human sustainability.

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