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The Trophic Status and Fish Potential Yield of Ayamaru Lake in West Papua, Indonesia

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Abstract: Ayamaru lake is a shallow lake located in the Maybrat district, West Papua which has a significant role in supporting the water supply, transportation, tourism, fisheries, and transit area for the migratory bird. The data and information of the trophic status and the fish potential yield in this lake should be understood before making any decisions for effective resource management to enhance fish production. The study was conducted in March and July 2019 in five sampling sites of Ayamaru lake, West Papua. Three water quality parameters were sampled for this study namely transparency, chlorophyll-a, and total phosphate. Moreover, these three parameters were used to calculate the Trophic State Index (TSI) and Fish Potential Yield. The result showed that based on the TSI value, the Ayamaru lake was categorized as a mesotrophic lake supported by its clear water. This waterbody has a fish potential yield of 56.33 kg/ha/year or 55.2 ton/year.
Keyword: Trophic status, Fish Potential Yield, Ayamaru, West Papua

Abstrak: Danau Ayamaru termasuk danau dangkal yang terletak di Kabupaten Maybrat, Papua Barat. Danau ini memiliki peranan penting diantaranya sebagai sumber air, transportasi, pariwisata, perikanan dan daerah transit bagi burung migran. Data dan informasi mengenai status tropic (TSI) dan potensi produksi perikanan di danau ini perlu diketahui agar keputusan dalam mengelola sumberdaya ikan dan peningkatan produksi perikanan di danau tersebut. Penelitian dilakukan bulan Maret dan Juli 2019 pada lima stasiun penelitian di Danau Ayamaru, Papua Barat. Parameter kualitas air yang diukur meliputi kecerahan, chlorofil a dan total posphat. Ketiga parameter tersebut selanjutnya dianalisis menggunakan Morphoedaphic Index untuk mengetahui nilai dari status tropic dan potensi produksi perikanannya. Hasil penelitian menunjukkan bahwa berdasarkan nilai TSI, Danau Ayamaru tergolong ke dalam perairan mesotropik yang terlihat dari airnya yang jernih. Nilai potensi produksi perikannya sebesar 56.33 kg/ha/tahun atau 55.2 ton/tahun.
Keyword: Status tropic, Potensi Produksi Perikanan, Ayamaru, Papua Barat

1. Introduction

The 6th SDGs aim to ensure the availability and sustainability management of water and sanitation for all. It requires a comprehensive monitoring and knowledge base of social and economic water needs at a national scale. It needs the effort supporting by the Government that should not cause adverse environmental manifestations from regional to global scale [1]. To reach the issue, one way to keep the water source is lake management. The Government of Indonesia has decided the fifteen lakes to become prioritized of management, i.e. Rawapening Lake (Central Java), Rawa Danau Lake (Banten), Batur Lake (Bali), Toba Lake (North Sumatera) Kerinci Lake (Jambi), Maninjau Lake (West Sumatera), Singkarak Lake (West Sumatera), Poso Lake (Central Sulawesi), Mahakam-Semayang Cascade Lake (East Kalimantan), Melintang Lake (East Kalimantan), Tondano Lake (North Sulawesi), Tempe Lake (South Sulawesi), Matano Lake (South Sulawesi), Limboto Lake (Gorontalo), Sentarum Lake (West Kalimantan), Jempang Lake (East Kalimantan), and Sentani Lake (Papua) [2]. Currently, the Ayamaru lake is not one of the prioritized lakes in Indonesia. But this lake has many functions, beside serves for water supply, transportation, tourism, and fisheries, Ayamaru Lake is a transit area for the migratory bird. As an ecological view, it is a major point to an action should be taken to manage it carefully.

Ayamaru Lake is a karst lake that is located in Maybrat District, West Papua Province, Indonesia. This is a shallow lake that has an important role in supporting the livelihood of the district people. The lake shrank about 50 meters since 2005, became a swamp, and was overgrown by grass. Besides, competition in the utilization of freshwater resources among several sectors also damages the aquatic ecosystem. The Ayamaru lake is a form of widening of Ayamaru river, which consists of three water bodies, namely Jow Lake (7 km in length, 2 km in width), Semitu Lake 2 km in length, 1.5 km in width) and Yate Lake (3 km in length, less than 1.5 km in width) [3].

The state of the ecosystem is commonly provided by the synoptic information of ecological indicators. Their main attribute is the combination of a range of environmental factors in a single value, which is thought useful for management and makes ecological quality concepts easily understandable for the decision-maker and the general public [4]. There are several methods to determine the productivity classification of water bodies, namely the TRIX index ([5]; [6]), nitrogen-phosphorus ratio model [7], and Secchi depth [8]. However, the Trophic State Index (TSI) proposed by Carlson is the method most commonly used for calculating the state ([9]; [10] .

The total yield of a water body could predict fishery management by some tools, namely Morpho Edaphic Index, chlorophyll a, and shoreline development [11]. Therefore, the data of chlorophyll in TSI could be used for analyses of the potential fish production [12].

This paper analyzed the trophic status and fish potential yield in Ayamaru Lake, West Papua. It could give the information before determining the effective resource management to enhance fish production.

2. Material and method

2.1. Time and Location

Ayamaru Lake is located in Maybrat district, Papua, and distributed in eight villages, namely Segior, Woman, Mefkajem, Kartapura, Mapura, Yukase, and Jitmau. The water source of this lake comes from six rivers as follows Ela, Ismayi, Framu, Mosway, Tetsayoh, and Bawi.

The study was conducted in March and July 2019, for the representative of wet season and dry season. Five stations for sampling and water quality measurement were determined by the representative of the inlet, outlet, village, and fish farm area, namely Semitu, Mosway, Mapura, the middle of the Ayamaru lake, and Johavah area (Fig 1 & Table 1). The survey collected the primary data.

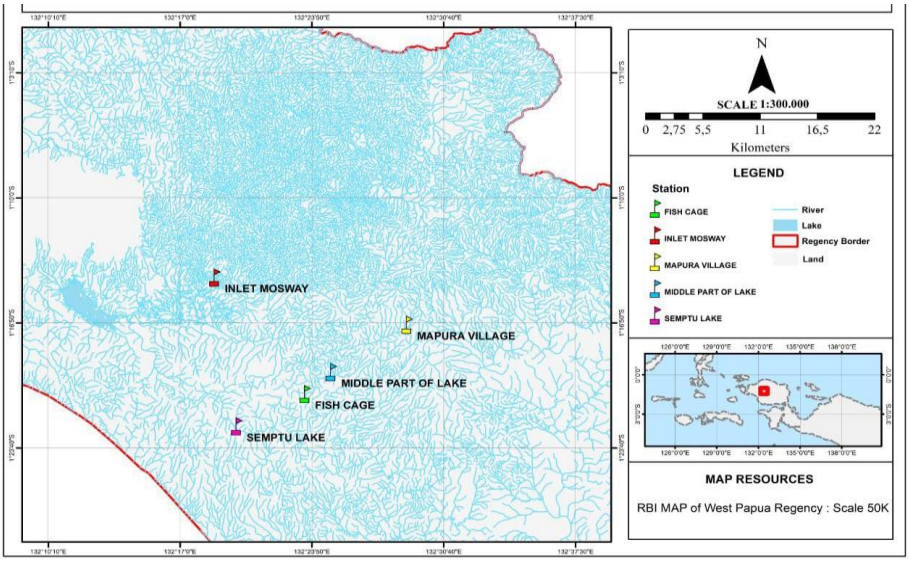


Figure 1. Map of sampling site in Ayamaru Lake, West Papua.

2.2 Method

Water sample for measurement chlorophyll and total phosphate were taken by a water sampler (volume 2 liters) at surface water. Water samples slowly lifted and opened the water faucets expenditure, and then the water was poured into the sample bottles of water and closed. Transparency parameter was measured directly in the field. Measurement and analysis of chlorophyll and total phosphate were carried out in the Research Institute for Inland Fisheries and Extension Laboratory, referred to [13] [14].

2.3 Data analysis

The water body's trophic status can be assessed using phosphorus, chlorophyll, transparency, and sediment resuspension. Phosphorus is representation of the limiting nutrients in the water's body. The chlorophyll is an indicator of phytoplankton biomass. The transparency is dependent on both algal biomass and sediment resuspension, expressed by Secchi depth [15]. Methods for classifying trophic states are based on the foundational work of Carlson from 1977. The trophic state index (TSI) of Ayamaru lake was calculated by using Carlson's formula:

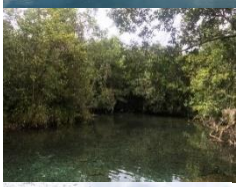
$$TSI(SD) = 60 - 14{,}41\ Ln\ (SD)$$
$$TSI(CA) = 30{,}6 + 9{,}81\ Ln\ (CA)$$
$$TSI(TP) = 4{,}15 + 14{,}42\ Ln\ (TP)$$

$$Average\ TSI\ = \frac{TSI\ (SD + CA + TP)}{3}$$

where:

SD =Secchi depth (m)
CA =Chlorophyll-a (µg/l)
TP =Total phosphor (µg/l)

Table 1. The location of sampling in Ayamaru Lake

Stations	Coordinate	Remark	
Semitu	S. 010 16' 389" E. 1320 14' 357"	Water body	
Mosway	S. 010 14' 21" E. 1320 11' 469"	Inlet	
Mapura	S. 010 15' 116" E. 1320 18' 647"	Village	
Middle of lake	S. 010 16' 211" E. 1320 11' 831"	Water body	
Johafah	S. 010 16' 283" E. 1320 14' 570"	Floating cage area	

Pictures source: Research Institute for Inland Fisheries and Extension, 2019.

Table 2. The parameter of water quality observed in Ayamaru Lake

No.	Parameter	Unit	Material and Tools	Methods
1	Transparency	m	Secchi disc	In situ
2	Chlorophyll	mg/m^3	Spectrophotometer	[13]
3	Total Phospat (TP)	mg/L	Spectrophotometer	SNI 06-6989.31-2005 [14]

CTSI is Carlson Trophic State Index, and Ln is the natural logarithm. CTSI consists of the concentration of three items of water quality parameters: Transparency, Chlorophyll-a (Chl-a), Total Phosphate (TP), which are calculated to form an index value, and determine the eutrophication level of reservoir water quality. Based on the values of CTSI, the lakes are classified as oligotrophic (low productive), mesotrophic (moderately productive), and eutrophic (highly productive). The range of Carlson's trophic state index values and the lake classification are presented in Table 3.

Fishery managers have widely used estimates of fish potential yield to determine harvest limits. Estimation of fish potential yield is the capability of the water body to produce the fish in one year (Kg/ha/year). This model is calculated based on the chlorophyll-a data by using the formula [15]:

$$Y = 28.2 + 10.5 \times \text{chl-a}$$

where:
- Y = fish potential yield (kg/ha/year)
- Chl-a = Chlorophyll- a (µg/L)

Table 3. Carlson's trophic state index values and classification of lakes [16]

TSI values	Trophic status	Attributes
<30	Oligotrophic	Clearwater, oxygen throughout the year in the hypolimnion
30-40	Oligotrophic	A lake will still exhibit oligotrophy, but some shallower lakes may become anoxic during the summer
40-50	Mesotrophic	Water moderately clear; increasing probability of hypolimnetic anoxia during summer
50-60	Low Eutrophic	Lower boundary of classical eutrophic: decreased transparency, warm-water fisheries only
60-70	Medium Eutrophic	Blue-green algae dominate, alga scums and macrophyte problems
70-80	Heavy Eutrophic	Heavy alga blooms possible throughout the summer, often hypereutrophic
>80	Hypereutrophic	Alga scums, few macrophytes, summer fish kills

3. Result and discussion

The water quality was collected based on Transparency, chlorophyll-a, and total phosphate in March and July 2019. These three parameters are used to analyze the TSI and fish potential yield in Ayamaru Lake which is a karst lake and has clear water. It is supported by the transparency parameter value and showed that the waters were clear to the bottom in all stations. This value depends on the weather condition, measurement time, watercolor, cloudiness, and suspended solids in the waters. The more transparent the water is, the more intense light penetrates.

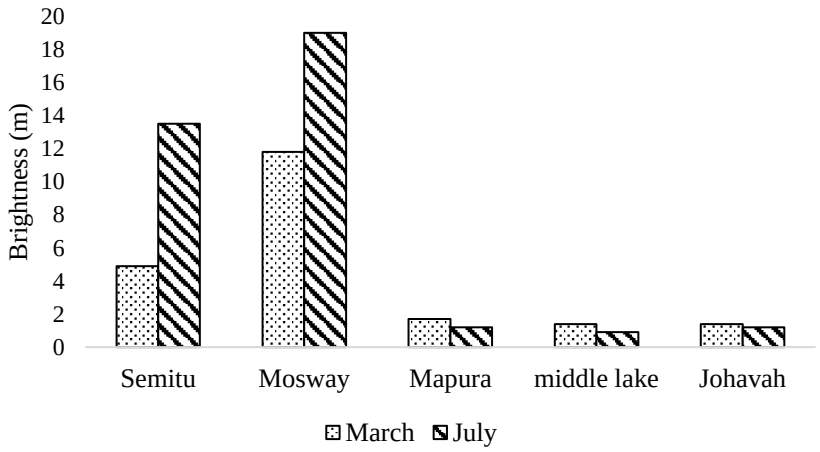


Fig. 2. Transparency measurement in Ayamaru Lake

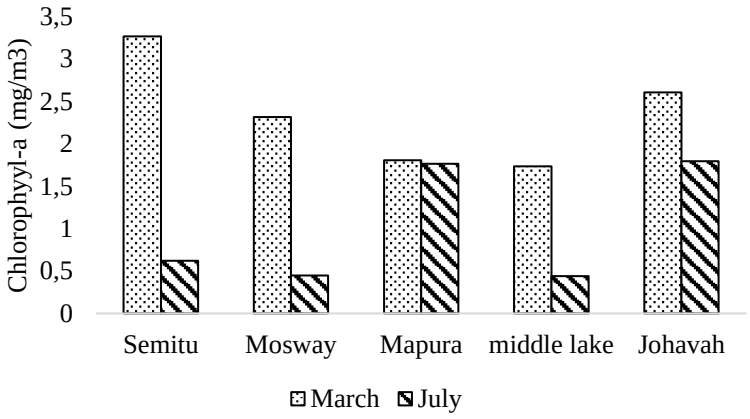


Fig 3. Chlorophyll-a measurement in Ayamaru lake 2019.

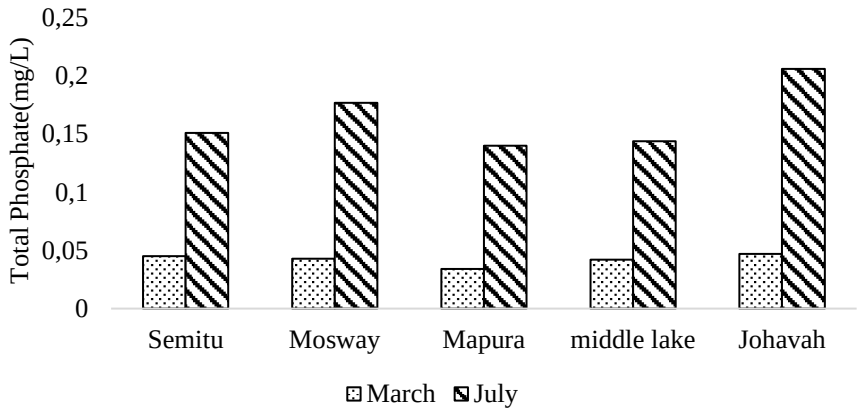


Fig 4. Total phosphate measurement in Ayamaru lake 2019.

The result of transparency measurement in Figure 2 showed that the water is clear to the bottom in all stations (0.9-19 meters). In general, the measurement in July was higher than in March. The highest result is 19 m presented in Mosway station in July because this is the deepest area in Ayamaru Lake. Moreover, the lowest transparency was 0.9 m in the middle lake station in July.

The other important parameter is chlorophyll-a (Fig. 3). This study presented that this parameter fluctuated. The highest chlorophyll-a was 3.26 mg/m^3 in Semitu station in March 2019. The lowest value was 0.44 mg/m^3 in the middle of the lake in July.

The limiting factor in a water body is nutrients. This study is represented by the total phosphate. The result showed that total phosphate in July was higher than in March 2019 (Fig. 4). The highest total phosphate measurement was 0.20 mg/L in the Johavah station while the lowest was 0.03 mg/L in the Mapura station.

The limiting resources in the water bodies are the nutrients such as nitrogen and phosphorus. Increasing this limiting factor tends to result in increased plant growth followed by subsequent trophic levels. Consequently, the trophic index may sometimes be used to make a rough estimate of its biological condition.

The spatial distribution of TSI in March and July 2019 was fluctuated and presented in Table 5. In general, based on the TSI analysis the trophic state of Ayamaru lake was 47.18 and 48.95 in March and July, respectively. It was categorized as Mesotrophic. Some stations showed an increasing and decreasing state of TSI. The Semitu and middle lake stations were in stable states from March to July 2019. Besides, Johafah and inlet Mosway station showed decreasing state from low eutrophic to mesotrophic and mesotrophic to oligotrophic respectively. Meanwhile, Mapura station resulted increasing state from mesotrophic to low eutrophic due to influenced from the activities of villager.

Table 5. Spatial distribution of TSI in 2019

Station	TSI (SD)	TSI (CA)	TSI (TP)	TSI	State
			March		
Semitu	37.09912	42.21379	59.04207	46.11833	Mesotrophic
Inlet Mosway	24.43469	38.84308	58.38651	40.55476	Mesotrophic
Mapura Village	52.35365	36.39883	55.00012	47.91753	Mesotrophic
In the middle of lake	55.15144	35.99407	58.0472	49.7309	Mesotrophic
Johafah	55.15144	39.99618	59.66913	51.60558	Low Eutrophic
			July		
Semitu	22.49524	25.91047	76.49918	41.63496	Mesotrophic
Inlet Mosway	17.57063	22.74482	78.79008	39.70184	Oligotrophic
Mapura Village	57.37275	54.78208	75.40848	62.5211	Low Eutrophic
In the middle of lake	61.51825	22.54618	75.81471	53.29304	Mesotrophic
Johafah	57.37275	36.34436	80.97797	58.23169	Mesotrophic

Moreover, the chlorophyll-a data were analyzed for getting the fish potential yield in Ayamaru lake. The result of the study is presented in Table 6. In 2019, The average fish potential yield in this area was 56.33 kg/ha/year. Some stations presented decreasing their value from March to July, except Mapura village. The

highest result was 99.44 kg/ha/year in Mapura Village station, while the lowest was middle of the lake, 39.60 kg/ha/year.

Table 6. Fish potential yield based on the Chlorophyll-a in Ayamaru lake

Stations	Fish Potential Yield (kg/ha/year)		
	March	July	Average
Semitu	62.5035	34.71	48.60675
Inlet Mosway	52.5285	32.9145	42.7215
Mapura Village	47.163	151.722	99.4425
middle of the lake	46.3965	32.82	39.60825
Johafah	55.563	47.058	51.3105
Average	52.83	59.84	56.33

Ayamaru lake is a mesotrophic lake based on the TSI analyses compared to the others inland waters in Indonesia (Table 7). Crismandha [17] predicted the Ayamaru was a mesotrophic lake based on its phytoplankton composition. This categorized has clear water characteristic. These lakes are less well defined than either oligotrophic or eutrophic lakes and are generally thought to be lakes in transition between the two conditions [18].

Ayamaru has 15 species and has good water quality for supporting fish life [19]. The fish potential yield was 56.33 kg/ha/year in 2019. If this result multiplies with the area, Ayamaru lake could produce fish biomass 55 tons/year. In 1996, this lake recorded high export of fishes about 150 tonnes.

Mapura village has the highest fish potential yield in Ayamaru lake because this area got nutrient runoff from the village and agriculture area. This runoff affected to the primary productivity, which supplies for the food web in this water body. Total phosphorus and total organic nitrogen were good predictors of relative fish biomass (CPUE estimated from gillnet catches) in lakes and reservoirs in Argentina [20].

Compare to other Indonesia inland water based on its trophic state (Table 7), Ayamaru lake could still be developed for the fisheries activity. These lakes are less well defined than either oligotrophic or eutrophic lakes and are generally thought to be lakes in transition between the two conditions.

Table 7. Trophic state in Indonesian inland waters.

No.	Inland waters	Type	Location	Trophic state	Source
1.	Towuti	Lake	South Sulawesi	Mesotrophic	[21]
2.	Ranau	lake	South Sumatera	Meso-eutrophic	[22]
3.	Sembuluh	Floodplain	Central Kalimantan	Eutrophic	[23]
4.	Malahayu	Reservoir	Central Java	Eutrophic	[24]
5.	Gajah Mungkur	Reservoir	Central Java	Eutrophic	[25]
6.	Kedung Ombo	Reservoir	Central Java	Eutrophic	[26]
7.	Tempe	Lake	South Sulawesi	Eutrophic	[27]
8.	Maninjau	Lake	West Sumatera	Eutrophic	[28]
9.	Sempor	Reservoir	Central Java	Eutrophic	[29]
10.	Batur	Lake	Bali	Eutrophic	[30]
11.	Rawa Pening	Lake	Central Java	Eutrophic	[31]
12.	Lindu	Lake	Central Sulawesi	Oligo-mesotrophic	[32]
13.	Kerinci	Lake	Jambi	Eutrophic	[33]
14.	Diatas	Lake	West Sumatera	Oligo-mesotrophic	[34]
15.	Ayamaru	Lake	Papua	Mesotrophic	Recent study

4. Conclusion

Based on the TSI analyses, the Ayamaru lake was categorized as mesotrophic lake with clear water body. There was 56.33 kg/ha/year or 55.2 ton/year of fish potential yield that could contribute to nutrition through people consumption.

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