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Trophic status analysis and estimation of fish production in Aneuk Laot Lake aquatic resources management, Sabang City

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ABSTRACT

Aneuk Laot Lake is located in Sabang City, Weh Island, Aceh Province. Changes in water quality can affect the life of aquatic organisms found in Aneuk Laot Lake. The purpose of this research estimates fish production and trophic status for the aquatic resource management of Aneuk Laot Lake, Sabang. This research was conducted in September 2019 in Lake Aneuk Laot using the TRIX, TSI (Trophic State Index) and Nygaard index methods to determine fish production and trophic status. Observation stations were determined using stratified random sampling method and analysis of chlorophyll-a was done using the Trichomatic method. The results showed that the waters of Aneuk Laot Lake can be categorized as eutrophic to hypereutrophic. The estimated value of fish production in Aneuk Laot Lake based on the chlorophyll-a approach is 109.84 kg/ha/year, with a lake area of 61.6 ha. Water quality parameters are still in a state that can be tolerated by aquatic organisms in Aneuk Laot Lake.

Introduction

Aneuk Laot Lake is located in Sabang City, Pulau Weh, Aceh Province. This lake was formed from volcanic activity in the past which has become dormant, and it was gradually filled with water until it becomes a lake (Widiyanto, 2017). Aneuk Laot Lake has no inlet and outlet. However, it is suspected that this lake has an outflow in the form of seepage, and water flows out through a gap or a fracture in the lake's bedrock (Yusifa et al., 2019). Aneuk Laot Lake has an important role in the life of the surrounding community through 3 main functions, namely ecological, social and economic. The ecological function of Aneuk Laot Lake is as a habitat for organisms, flood control, and in binding nutrients. The social function is as a place for people to bathe and wash clothes. Its economic functions is as a source of drinking water (PDAM), fishing areas, plantations and tourism (Nurfadillah et al., 2022)

Management of the lake's aquatic resources has long been carried out by the government, one of which is through Law No. 7 of 2004 concerning Aquatic Resources which regulates provisions on Aquatic Resources Conservation, Utilization of Aquatic Resources and Control of Water Damage Potential. However, currently the three main functions of Aneuk Laot Lake is not working in harmony due to the exclusion of ecological functions, as a result activities related to social and economic functions are thought to feed excess of organic and inorganic materials into the waters of Aneuk Laot Lake which can cause changes in water quality and water trophic levels. According to Pertiwi et al. (2017) the eutrophication due to the input of

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nutrients into the waters, especially nitrogen (N) and phosphorus (P) originating from industrial activities, agriculture and domestic waste may cause an increase in the development of phytoplankton, water pollution, and a decrease in fishery potential.

Changes in water quality can affect the life of aquatic organisms found in Aneuk Laot Lake. Mozambique tilapia (*Oreochromis mossambicus*), Nile tilapia (*O. niloticus*), Giant gourami (*Osphronemus goramy*), Snakeskin gourami (*Trichopodus pectoralis*) and snakehead (*Channa striata*) are the dominant species caught by fishermen in Aneuk Laot Lake. However, so far there has been no studies conducted to estimate fish production in this lake, even though this is important for the development of fishery potential in Aneuk Laot Lake. Estimation of fish production potential is needed to optimize the utilization and management of fish resources in a water body, in order to ensure its sustainability.

Several studies have been carried out including Samuel & Adiansyah (2016) in Danau Diatas Lake, West Sumatra Province using oligotrophic-mesotrophic trophic status with fish production in the lake reaching 44 kg/ha/year. This fish production is quite low compared to fish production in Lake Kerinci, Jambi Province, which has a eutrophicity rate of 307 kg/ha/year (Samuel et al., 2015). Fish and aquatic organisms need a good habitat to grow and develop so that indirectly if the water quality changes it will affect the production of fish in the lake (Wijaya et al., 2009). Based on research conducted by Edyanto (2006), the fertility level in Aneuk Laot Lake is at the oligotrophic level, which indicates that the waters are still clean and not yet polluted by nutrients. However, in 2017, research by Widiyanto (2017) found that the trophic status of Aneuk Laot Lake is already at the mesotrophic level increasing towards eutrophic level, which means that the waters have a moderate trophic status where the nutrients in these waters are still in the medium category but increasing towards high nutrient levels.

Changes in the trophic status of Aneuk Laot Lake within a period of 10 years resulted in a decrease in Aneuk Laot Lake water quality, namely an increase in water turbidity, decreasing water levels, mass death of fish, and loss of aquatic plant species that are habitat for several aquatic species. Therefore, this assessment on the trophic level status will be an important aspect for sustainably managing the aquatic resources. This study aims to estimate the fish production and trophic status in Lake Aneuk Laot Sabang using the TRIX, TSI (Trophic state index) and Nygaard index methods.

Materials and Methods

Location and time of research

This research was conducted in September 2019 at Aneuk Laot Lake, Sabang, Aceh Province. Determination of observation station locations was done using stratified random sampling method. The observation stations consist of four station points selected by taking into account activities around the lake border which include protected forest areas, recreation areas, drinking water facility intake areas and agricultural and livestock areas. The research map is presented in Figure 1.

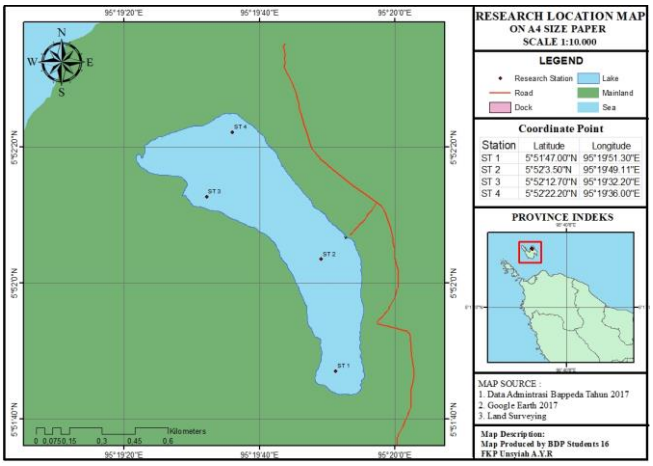

Figure 1. The research map.

Water and plankton sampling

Sampling in the water column was done using a Van Dorn water sampler. The measured and analyzed parameters included physical, chemical and biological parameters, namely temperature, brightness, dissolved oxygen (DO), pH, nitrate-nitrogen (NO3-N), total phosphate and chlorophyll-a. Sampling of plankton was carried out quantitatively by filtering plankton using plankton net number 25. Identification of plankton was carried out using identification reference books for identifying plankton (Shuters and Rissik, 2009), identifying marine diatoms and dinoflagellates (Hassle et al., 1996) and identifying marine phytoplankton (Hassle et al., 1996). The abundance of phytoplankton was calculated using the APHA equation (2005), namely:

$$N = n\,x\,\frac{a}{A}\,x\,\frac{v}{vc}x\frac{1}{V}$$

Information: N = Total number of phytoplankton (ind/l); n = Number of phytoplankton (ind); a = Cover glass area (mm^2); A = Wide field of view (mm^2); v = Concentrated water volume (ml); vc = Volume of water under the cover glass (ml); V= Filtered water volume (l).

Analysis of aquatic trophic level status

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The methods used to estimate the trophic level status of Aneuk Laot Lake were TRIX, TSI (Trophic state index) and Nygaard index. The trophic level of the lake can be formulated using the Trophic Index (TRIX) which is based on the presence of chlorophyll-a, the percentage of oxygen saturation (%DO) and nutrients (N and P) with a value scale of 0-10. TRIX can be used to evaluate the lake water trophic level in the long term (Vollenweider et al. 1998). TRIX trophic level status criteria can be seen in table 1. The TRIX index formula is presented as follows:

$$TRIX = \frac{k}{n}\sum_{i}^{n}\frac{(LOG\ M - LOG\ L)}{(LOG\ U - LOG\ L)}$$

Information: n = Number of variables; M = The mean value of the variable; U = Upper limit (mean + 2 Sd); L = Lower limit (mean -2Sd); k = Scalling factor (10).

The trophic level of lake waters calculated based on the calculation using Carlson's (1997) Trophic State Index (TSI) is a combination of the TSI values at Secchi disc depth (TSI-SD), TSI of chlorophyll-a TSI (TSI-Chl-a), and TSI of total phosphate (TSI-TP). The criteria for the fertility status of the Trophic state index (TSI) are presented in Table 1. The calculation for the mean TSI is:

TSI (SD) = 60 – 14,41 In (SD)
TSI (CHL) = 30,6 + 9,81 In (CHL)
TSI (TP) = 4,15 + 14,42 In (TP)

$$Mean = \frac{\text{TSI (SD)} + \text{TSI (CHL)} + \text{TSI (TP)}}{3}$$

Information: SD = Secchi disc (m); CHL = Chlorophyll-a (µg); TP = Total phosphate (µg/l).

The calculation of the Nygaard index (In) is done based on the composition of the number of phytoplankton species. The composition of phytoplankton species observed in Nygaard index calculation is obtained by counting the number of different phytoplankton species that belongs to the order Centrales under the Bacillariophyceae class and the number of species belonging to the order Pennales under the Bacillariophyceae class. Nygaard index (In) is an index that is used to determine trophic level status using biological parameters, namely phytoplankton (Nygaard, 1949). The criteria for trophic level status based on the Nygaard index can be seen in Table 1. The formula for calculating the Nygaard index (In) is presented as follows:

$$\text{In} = \frac{\sum \text{sp. ordo } Centrales}{\sum \text{sp. ordo } Pennales}$$

Chlorophyll-a analysis and estimation of fish production potential

Fish production potential can be estimated using chlorophyll-a parameter. The concentration of chlorophyll-a was calculated using the trichromatic method (spectrophotometric determination of chlorophyll-a, b and c) referring to APHA (2005) with the following formula:

$$\text{Chlor–a}(\mu g/l) = \frac{(C_a \text{ x } V_a)}{(\text{V})(\text{d})}$$

Information: Va = Volume Aceton (ml); V = Filtered water sample volume (ml); D = Diameter cuvet (1 mm); Ca = (11,6xE664) – (1,31xE647) – (0,14xE630); E = Absorbance at different wavelengths (corrected for a wavelength of 750 nm).

Fish production potential was estimated using the formula on the relationship between chlorophyll-a and fish production (kg/ha/year) (Boyd, 1990) with the following equation:

$$\hat{Y} = 1{,}43 + 24{,}48\,x - 0{,}15\,x^2$$

Information: $\hat{Y}$ =Fish production (kg/ha/year); x =Chlorofil-a (µg/l).

Results

The trophic level status of Aneuk Laot Lake has been analyzed using the TRIX index, TSI and Nygaard index. Based on the TRIX, TSI and Nygaard indexes, the trophic level status of Aneuk Laot Lake is in the eutrophic-hypereutrophic category. The trophic level status of Aneuk Laot Lake as determined using the three methods is presented in Table 2. The abundance of plankton in Aneuk Laot Lake is around 1,667 – 11,111 ind/l. The highest abundance of phytoplankton was observed at station 1, reaching 11,111 ind/l, while the lowest was at station 2 with a value of 1,667 ind/l.

Table 1. The criteria for trophic level status based on the TRIX, TSI and Nygaard index.

TRIX	TSI	Nygaard	Trophic level status
TRIX < 2	40	0 ≤ In ≤ 0,2	Oligotrophic;
2 ≤ TRIX < 4	40 - 50	0,2 ≤ In ≤ 2,5	Mesotrophic;
4 ≤ TRIX < 6	50 - 70	In > 2,5	Eutrophic;
TRIX ≥ 6	70 - 80		Hypereutrophic

Table 2. The value of the Aneuk Laot Lake fertility index based on the TRIX, TSI and Nygaard indexes.

Index	Station					Category
	1	2	3	4	mean	
TRIX	6,30	6,78	5,12	7,56	6,44	Hypereutrophic
TSI	63,86	64,56	64,50	67,08	65.00	Eutrophic
Nygaard	0,05	0	18	0,08	4,53	Eutrophic

Table 3. The results of the abundance of plankton.

Parameter	Station 1	Station 2	Station 3	Station 4
Plankton abundance (ind/l)	11.111	1.667	2.889	5.556

Table 4. Estimated fish production in Aneuk Laot Lake.

Lake area (Ha)	Fish production value		Chlorophyll-a (µg/l)
	Kg/ha/year	Ton/year	
61,6	109,84	6,7	4,56

Table 5. Water quality parameters.

Parameters	Station 1	Station 2	Station 3	Station 4
Temperature (°C)	29,44	29,42	30,37	30,36
Visibility (cm)	99,2	128,5	82	75,5
Depth (m)	12	16,82	12,32	8,15
Current (m/s)	0,02	0,31	0,18	0,36
pH	7,8	8	8	8,2
DO (mg/l)	7,15	6,95	6,85	7,1
Total phosphate (mg/l)	0,28	0,43	0,38	0,36
Total nitrogen (mg/l)	3,45	3,34	1,44	1,26
Chlorophyll-a (µg/l)	4,84	4,66	2,84	2,88

Observed plankton abundance in Aneuk Laot Lake is presented in Table 3. Estimated fish production and chlorophyll-a values of Aneuk Laot Lake are presented in Table 4. The water quality parameters during maintenance are still within the optimal range for biota aquatic. Water quality parameters observed in this study showed in Table 5.

Discussion

Trophic Level Status of Aneuk Laot Lake

The trophic level of Aneuk Laot Lake based on the TRIX index is classified as hypereutrophic with a value of 6.44. The TSI index value with a mean of 65 is classified as eutrophic and trophic level status based on the Nygaard index with a mean value of 4.53 is classified as eutrophic. Other lakes in Indonesia that are included in the eutrophic-hypereutrophic category include Lake Siombak with a phosphate concentration of 1.05 - 1.51 mg/l (Muhtadi, *et al.*, 2016); and the eutrophic Situ Cilala with a phosphate concentration of 0.027–0.042 mg/l (Pratiwi *et al.*, 2007).

According to Prayitno (2017) TRIX is considered to be more effective than other methods because it has several advantages, including being able to be used to determine trophic level status using more data so that it can be used to see changes in trophic levels from time to time. This is in accordance with what Radiarta and Sagala (2012) said that the trophic level of a lake can be expressed based on the content of total phosphate (TP), total nitrogen (TN), chlorophyll-a and phytoplankton biomass. According to Amin (2011) the presence of plankton in waters can be used to describe the trophic level condition characteristics of a water body.

Aneuk Laot Lake has experienced a significant decrease in water quality with increasing trophic level status from oligotrophic (Edyanto, 2006) to mesotrophic (Widiyanto, 2017) and towards mesotrophic-eutrophic in 2019 based community structure of plankton (Nurfadillah et al., 2022). This has an impact on the loss of plant vegetation around the lake, mass death of fish, and decreased water surface levels in Aneuk Laot Lake, where this impact is thought to be the result from activities carried out by local communities around the lake such as washing, bathing, disposing of waste from agricultural/plantation activities, which becomes a problem due to poor lake management. Therefore, the recommendations that can be given to improve the management of Aneuk Laot Lake in the future include increasing knowledge and awareness of the community and the government towards the lake, planting riparian plants, managing domestic waste disposed of by the community and tourist attractions, monitoring changes in lake waters and empowering lake management organizations. As stated by Permanasari et al., (2017) in lake management it is necessary to have an integrated management approach, to allow the preservation of the sustainable ecological and economic functions of these natural resources to support the lives of future generations. The success of the preservation and management of

natural resources will be the key to the fulfillment of the living necessities of the entire community.

Plankton Abundance

The high abundance of plankton indicates that at each station there are sufficient levels of nutrients that can support good plankton growth. According to Nurfadillah et al. (2019), the abundance of phytoplankton community in waters bodies is closely related to temperature and nutrient content such as phosphate, nitrate, silicate, and other nutrients. The total phosphate concentration in Aneuk Laot Lake ranged from 0.28 to 0.43 mg/l. According to Indrayani (2015) the total P-content in waters bodies is strongly influenced by particles from land that enter the waters due to erosion and human activities, the amount of available nutrients, and the water pH.

The composition of plankton in Aneuk Laot Lake is made up of species from 7 classes, namely Bacillariophyceae (11 genera), Dinophyceae (1 genus), Chlorophyceae (6 genera), Euglenoidea (1 genus), Cyanophyceae (5 genera), Zygnematophyceae (3 genera) and Crustaceae (4 genera). The most dominant plankton class in Aneuk Laot Lake is Bacillariophyceae, which is concurrent to the statement from Andriani et al., (2015) that Bacillariophyceae class is the dominant class and is commonly found in water bodies and able to adapt well to environmental conditions. The highest abundance of phytoplankton from the class Bacillariophyceae came from the genus Navicula. According to Adriansyah & Lovadi (2014) the high abundance of Navicula shows that this genus has a high level of adaptation and tolerance to the environment such as DO, CO^2, light, and water pH. Martin (2012) stated that Navicula has a slimy stem which it uses as a strong attachment to the substrate so that it can live in water bodies that are not flowing and those with high water flow. Nurfadillah, et al., (2012) stated that the Bacillariophyceae class is cosmopolitan, with high tolerance and adaptability to environmental conditions. This increase in the abundance of phytoplankton is strongly influenced by the eutrophication process.

Fish production estimation for Aneuk Laot Lake

Fish production potential in Aneuk Laot Lake was analyzed based on the mean content of chlorophyll-a. Chlorophyll-a is one of method that can be used to estimate the photosynthetic ability of phytoplankton in waters. According to Wijaya & Petrus (2009), the content of chlorophyll-a in water bodies can be used as a measure of the standing stock of phytoplankton, which can then be used as an indicator of the primary productivity for the respective water body. The higher chlorophyll-a phytoplankton content observed in a water body, the higher the productivity potential of the water body, which also means that the water body has a higher carrying capacity to support its biotic community (Wijaya et al., 2012). Therefore, based on the data of the chlorophyll-a content, it is possible to estimate the potential for fish production for each lake by using a relationship analysis between chlorophyll-a and fish production. The value of chlorophyll-a in Aneuk Laot Lake ranged from 2.84 - 4.84 µg/l. This can be compared to research conducted by Sulastri et al. (2016) in Lake Maninjau, West Sumatrea, where the chlorophyll value obtained is 2.6 – 3.22 g/l, and research by Sentosa et al. (2017) in Mantano Lake, South Sulawesi, which obtained chlorophyll-a values of <2.5 mg/m^3 . According to Yuliana (2006) the high and low distribution of chlorophyll concentration is closely related to the environmental conditions of water bodies. Chlorophyll-a makes up 1-2% of the total dry weight of phytoplankton, so that chlorophyll-a can be used as an indicator for the assessment of phytoplankton biomass and estimation for fish production (Adani et al., 2013).

The potential value of fish production in Aneuk Laot Lake reaches 109.84 kg/ha/year with an area of ± 61.6 ha of lake water surface, so that the potential fish production rate is 6.7 tons/year. The potential value of fish production in Aneuk Laot Lake is almost the same as the potential for fish production calculated for Lake Batur, Bali Province (Wijaya et al., 2012) with an area of 16.05 km^2 (221.2 – 270.3 kg/ha/year production potential), and Lake Danau Diatas (Samuel & Adiansyah, 2016) with an area of 1,230 hectares and a mean production potential of 44 kg/ha/year with oligo-mesotrophic state. Lakes and reservoirs with medium-high fish production potential include Lake Tempe 95 kg/ha/year with an area of 13,000 ha (Samuel et al., 2012), Lake Kerinci 307 kg/ha/year with an area of 4,200 ha (Samuel et al., 2015) and Aceh's Lake Laut Air Tawar which has a productivity potential range from 26.41-70.8 kg/ha/year and a mean potential of 43.73±16.90 kg/ha/year with an area of 7000 ha (Kartamiharjha et al., 1995). According to Susandra et al., (2014) the difference in the potential value of fish production can be caused by differences in the trophic status of the waters caused by the amount of organic matter that enters the water body. Based on these studies, the estimation of fish production in Aneuk Laot Lake is quite high considering the lake's area and its chlorophyll-a value.

Aneuk Laot Lake's Water Quality

Recorded water temperature during the research at noon in Aneuk Laot Lake ranged between 29,42 –

30,37 °C. According to Sitorus et al., (2018) water temperature range between 29 - 32 °C sufficiently supports phytoplankton and organism life within water bodies. The flow of water current in Aneuk Laot Lake ranged between 0,02 – 0,36 m/second. According to Aramita et al., (2015) water current has a very important role in water bodies, as it serves as a transportation media that allows phytoplankton movement.

The pH value in Aneuk Laot Lake ranged from 7.8 to 8.2, which is sufficient to support the growth and development of aquatic organisms. As stated by Samuel et al., (2012) water bodies with a pH value between 6-8 are ideal for supporting the life and growth of aquatic organism populations including fish, and other aquatic organisms that serves as their food. The value of dissolved oxygen in Aneuk Laot Lake ranged from 6.85 to 7.15 mg/l. The value of total nitrogen (TN) ranged from 1.26 to 3.45 mg/l. The value of nitrogen levels in Aneuk Laot Lake is considered quite high which is thought to be caused by the activities of the surrounding community that contribute towards domestic waste flowing into the waters such as bathing, washing, plantation activities and tourist attractions. The chlorophyll-a values obtained at each station in Aneuk Laot Lake ranged from 2.84 g/l – 4.84 g/l. Zulfiah & Aisyah (2016) stated that the concentration of chlorophyll-a in a water depends on the concentration of nitrogen and phosphate.

Conclusion

The status trophic of Aneuk Laot Lake is included in the eutrophic-hypereutrophic category based on the analysis of the TRIX, TSI and Nygaard indexes. Estimated fish production through chlorophyll-a value approach in the waters of Aneuk Laot Lake is 109.84 kg/ha/year with a lake area of 61.6 ha.

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