ISSN: 3116-3475
International Journal
of Education, Research, and Innovation Perspectives
Volume 2 Issue 3 (March 2026)

Histological and Comparative Analysis of Tilapia *(Oreochromis niloticus)* Inhabiting Lake Sebu and Lake Lutayan

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Date Submitted:
March 6, 2026

Date Accepted:
March 15, 2026

Date Published:
March 21, 2026

DOI:
10.5281/zenodo.19142548

ABSTRACT

This study assessed and compared the histological health of tilapia (Oreochromis niloticus) from Lake Sebu and Lake Lutayan in South Cotabato, Philippines, to evaluate environmental quality and aquaculture sustainability. Using a descriptive-comparative design, fish samples from both lakes were analyzed for gill, liver, kidney, and muscle tissue alterations, along with measurements of pH, dissolved oxygen, and turbidity. The results revealed that tilapia from Lake Lutayan exhibited healthier organ structures, higher mean weight (182.6 ± 6.06 g), and longer length (20.2 ± 0.56 cm) compared to those from Lake Sebu (151.6 ± 5.59 g; 17.6 ± 0.55 cm). Moderate to severe liver and kidney damage were found in Lake Sebu tilapia, likely due to acidic water, low oxygen levels, and high turbidity resulting from intensive aquaculture activities. In contrast, Lake Lutayan demonstrated a more balanced ecosystem. It is therefore recommended to maintain proper stocking densities, enhance feeding and water management practices, and strengthen local policies to ensure sustainable aquaculture and the long-term preservation of lake ecosystems. Furthermore, periodic sampling at least twice a year is advised to continuously monitor fish health and water quality, thereby strengthening the reliability and validity of future assessments.

Keywords: *Tilapia, histology, Lake Sebu, Lake Lutayan, water quality, aquaculture, environmental stress*

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International Journal
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INTRODUCTION

Tilapia *(Oreochromis niloticus)* is one of the world's most significant freshwater fishes in aquaculture, contributing greatly to food security and local economies, especially in Asia and Africa (FAO, 2020). In the Philippines, it is a primary source of protein and a vital means of livelihood for fishing communities around inland lakes. Because of their broad ecological tolerance, these fish are often used as bioindicators of aquatic ecosystem health, with their histological and physiological status reflecting existing water quality and anthropogenic stressors (Shinn et al., 2023).

As one of the globe's most important aquaculture species, this fish plays a highly significant role in food security and rural income generation. According to Shinn et al. (2023), worldwide production has consistently increased due to its environmental adaptability, rapid growth rate, and strong market demand—factors that place it at the center of aquaculture development policy in many developing nations. For this reason, the wellness of tilapia stocks is directly tied to nutritional security and the economic sustainability of communities that depend on them.

The health of tilapia has significance that transcends aquaculture economics to the integrity of freshwater ecosystems themselves. Inland lakes and rivers that sustain tilapia fisheries tend to be subject to human-induced pressures like nutrient loading, contamination, and overfishing. Inland fisheries and aquaculture, are not just important as a source of food but are also used as indicators of the health of an ecosystem, with decreases in fish condition invariably indicating overall environmental deterioration. Thus, tilapia health monitoring gives a glimpse of freshwater bodies' ecological condition and ability to continue to support human livelihoods (El-Sayed, 2020).

Fish histopathology is increasingly used in environmental monitoring because it enables the identification of tissue-level changes due to exposure to pollutants and degraded water quality. Gill pathologies like lamellar hyperplasia and fusion, vacuolation and necrosis of the liver, and degeneration of the renal tubules are frequent environmental stress biomarkers of ecological degradation in tilapia and other aquatic fishes. Such changes tend to appear before declines in populations, thus serving as reliable early warning indicators of ecological degradation (El-Sayed, 2020).

Although Histological investigations in tilapia and other freshwater fish have been done in different polluted aquatic ecosystems (Rebollido, R. 2023), comparative investigation in lakes from the Philippines is still limited. Lake Lutayan and Lake Sebu, which are both in South Cotabato, Mindanao, vary in ecological and anthropogenic factors. Lake Sebu is a major ecotourism destination but is under threat from aquaculture production expansion and domestic runoff, while Lake Lutayan has commercial fisheries but potentially could suffer from agriculture and industry. Although both are critical, few data are available to compare the Histological status of tilapia stocks in these two lakes.

One of the strong techniques for evaluating fish health is histopathology, wherein microscopic examination of tissues is conducted to check for evidence of disease, stress, or impact from the environment. As described by (Roberts 2012), Histological examination gives early and sensitive measures of sublethal stress that is not necessarily noticeable through observation alone. By studying tissues like gills, liver, and blood cells, scientists are able to correlate seen cellular injury to particular environmental circumstances, pathogens, or handling procedures. Histopathology is therefore a very useful tool in fisheries biology, aquaculture management, and ecological monitoring.

Freshwater ecosystem well-being is notably important in the Philippines, as lakes like Sebu and Lutayan hold cultural and economic importance. Nevertheless, anthropogenic activities like intensive

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aquaculture can change water properties and stress aquatic life. Freshwater biodiversity is imperiled worldwide by pollution, habitat alteration, and invasive species, and fish are one of the most sensitive taxa to these stressors. Fish health assessment in such systems is critical to sustain ecological balance and ensure the sustainability of natural and managed fisheries.

Exposure to contaminants and water quality has been associated with gill hyperplasia, hepatic vacuolation, and renal degeneration in fish, leading to lowering survival and reproductive fitness. Aldoghachi, et al., (2015) illustrated that red tilapia exposed to lead contamination caused severe gill hyperplasia, secondary lamellar fusion, hypertrophy of chloride cells, and pavement cell necrosis. These results emphasize the manner in which compromised water quality directly affects important organs that are involved in breathing and osmoregulation, and thereby render Histological examination a valuable method of identifying early stress reactions in fish stocks.

A number of studies have reported Histological alterations in tilapia exposed to water quality deterioration, which emphasizes the utility of tissue lesions as environmental stress biomarkers. For example, Abdel-Wahab et al. (2020) recorded hepatic vacuolation, gill hyperplasia, and renal degeneration in Oreochromis niloticus exposed to different concentrations of pollutants, which emphasizes organ-level injury associated with aquatic pollution. Similarly, AbdelWahab et al. (2020) emphasized that Histological alterations in fish tissues are among the most reliable indicators for assessing ecosystem health under pollution pressure. These findings demonstrate that lesion-based monitoring provides crucial insights into fish well-being and aquatic ecosystem integrity.

Studies on tilapia populations in tropical freshwater environments have also revealed the impact of human activities on fish health outcomes. Akinrotimi et al. (2019) reported that Oreochromis niloticus from urban-influenced waters had severe gill and liver damage compared to those from less affected environments, highlighting the linkage between anthropogenic stressors and fish physiology. In the same vein, Omondi et al. (2021) evaluated fish from eutrophic African lakes and observed significant pathological changes associated with nutrient enrichment and degraded water quality. These works attest that tilapia health is a direct reflection of the health of freshwater ecosystems.

The liver, which is an important organ for metabolism and detoxification, is especially susceptible to environmental stress. Baiomy et al. (2016) noted hepatic necrosis, vacuolation, and elevated melanomacrophage centers in Nile tilapia samples taken from polluted regions of the Nile River. These changes reflect compromised detoxification ability, metabolic stress, and long-term exposure to pollutants. Liver damage not only represents toxicant burden but also points to possible reductions in fish growth and reproductive capacity, highlighting its utility as a diagnostic tool in ecotoxicological research.

The kidney is likewise a key organ in excretion, osmoregulation, and hematopoiesis and is maximally sensitive to pollutants in the environment. A paper entitled Detecting Aquatic Pollution Using Histological Investigations of the Gills, Liver, Kidney, and Muscles of Oreochromis niloticus cited tubular degeneration, shrinkage of the glomeruli, and necrosis in the kidneys of tilapia from polluted freshwater. Such lesions compromise the ability of the fish to maintain internal homeostasis, and so kidney pathology is a good indicator of sublethal stress. Along with gill and liver changes, kidney lesions present an integrative picture of how water quality influences fish health outcomes (Baiomy et al., 2016).

Aside from environmental stressors, pathogens and parasites tend to complicate Histological alterations in fish. Siallagan, et al., (2021) reported that tilapia infected with Streptococcus agalactiae under intensive culture conditions had necrotic liver cells and gill lesions. Their findings indicate that poor water quality not only leads to direct organ damage but also weakens the immune defenses to facilitate disease

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infection. Thus, an understanding of the interaction among water quality stressors and pathological alterations is necessary in evaluating fish health in aquaculture- and human activity-impacted lakes Sebu and Lutayan.

A number of international studies have shown the effectiveness of histopathology in the studies of tilapia. Shahid et al. (2022), for example, reported damage to the gill, liver, kidney, and muscle in Oreochromis niloticus from the River Chenab in Pakistan and attributed tissue changes to heavy metal contamination. In the same vein, Nascimento et al. (2021) studied two fish farms in Brazil and found that suboptimal water quality parameters were directly correlated with Histological lesions in the gills of tilapia. Abad-Rosales, et al., (2022) in Mexico studied the incidence of epitheliocystis among tilapia and recognized differential gill pathologies, making it evident how ecological and management conditions affect the health of fish. Such results demonstrate how comparative histopathology is a sound method to measure ecological conditions.

Though a wide array of international literature has demonstrated support for Histological methods, a limited number of studies have been implemented in the Philippines, notably in freshwater habitats like Lake Sebu and Lake Lutayan. These are two significant aquaculture and fishery resources of South Cotabato, but they are under ecological threats involving nutrient loading, agricultural runoff, and fishing pressure. Making a Histological and comparative examination of tilapia from these two lakes will not only create baseline information on fish health but also give essential information regarding the environmental quality of these water systems. The research will hence contribute both to fisheries sustainability at local levels and to the general body of international literature on fish health and the monitoring of environment (Abad-Rosales, et al., 2022).

In the Philippines, a number of research studies have emphasized the role of histopathology in tilapia health assessment and aquaculture practice impacts. Bang-asan, et al. (2017) examined the Histological impacts of aquafarming in Taal Lake and recorded extreme modifications in the liver and testes of Nile tilapia (Oreochromis niloticus L.), which were consistently linked to water and sediment quality. Likewise, Pallet, et al. (2016) analyzed tilapia infected with Acanthogyms spp. in Laguna and illustrated how parasitic infections lead to hematological alterations and tissue damage and thus compromise fish wellbeing. These results highlight the utility of histopathology as a sensitive biomarker in finding stressors in aquatic animals in Philippine freshwater ecosystems.

Histological findings in Philippine freshwater lakes are further corroborated by these observations. Guevarra et al. (2020) reported lamellar aneurysms of gills and hepatocyte degeneration in tilapia from the Seven Lakes of San Pablo, attributing these lesions to aquaculture operations and fluctuating water quality. Their results show that lake ecosystems under human utilization impose quantifiable physiological stress on tilapia, highlighting the importance of organ level health measures for monitoring aquaculture sustainability. This points to the necessity of localized studies in Mindanao, where aquaculture pressure remains on the rise.

Additional local data come from Guevarra et al. (2020), who employed biomarker and Histological analysis of Nile tilapia from San Pablo's Seven Lakes to assess the impacts of anthropogenic disturbances. Their results showed that changes in fish health mirror variations in lake conditions, emphasizing the essential role of ecological stresses in determining aquaculture sustainability. Even with such national research, there is still a lack of research on other significant freshwater bodies such as Lake Sebu and Lake Lutayan in South Cotabato. Histological and comparative examinations in these lakes will give valuable information on the health of tilapia populations, and at the same time, add to the body of Philippine literature that correlates aquaculture practice, environmental factors, and fish pathology.

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Lake Sebu, South Cotabato, is among the Philippines' key inland lakes for tilapia aquaculture. Tilapia cage culture has been a mainstay of the local economy since the early 1970s, and approximately 19% of Lake Sebu's ~354 hectares have been utilized for aquaculture. Beniga (2013) has indicated that tilapia produced from the lake is sold all over the province and adjacent regions, subject to municipal regulations to prevent overextension of fish cage setting. Rising anthropogenic pressure, environmental variability like rainfall and temperature, and overexploitation of infrastructure could, however, be compromising water quality and aquaculture business sustainability.

One of the principal issues in Lake Sebu is recurring massive fish kills, colloquially referred to as kamahong, which resulted in enormous economic damage to tilapia raisers. In January 2021, tilapias valued at around ₱20 million (~200 metric tons) were killed in about 1,000 fish cages (Philippine News Agency [PNA], 2021). Fish kills are commonly due to abrupt changes in water conditions heavy rain, decreased sunlight, low dissolved oxygen, and likely contamination with runoff or floodwater (Manila Bulletin, 2021).

The overstocking and overpopulation of fish cages also link to the quest for greater returns. Palanca-Tan (2020) investigated the price premium for tilapia from Lake Sebu and concluded that the additional earnings (resource rent) stimulate unsustainable activity such as cage overpopulation and overfeeding that reduce water quality and potentially exacerbate fish mortality episodes. These results indicate that economic incentives might undermine environmental constraints and fish health and cause cycles of fish kill occurrences in the lake.

In contrast, Lake Lutayan is less reported with respect to tilapia mortality or fish health.Therefore, whereas Lake Sebu presents evident occurrences of repeated tilapia stress and mortality, similar biological tissue-level data from Lake Lutayan are lacking. This is an impediment to understanding how site-specific water conditions water quality, pollution, and stocking density morph into fish health end results (Palanca-Tan, 2020)

This research hopes to fill this shortfall by doing a comparative Histological analysis of tilapia from Lake Sebu and Lake Lutayan. In particular, it will check for tissue lesions in organs like the gills, liver, and kidney; compare lesion prevalence and severity between the two lakes; quantify important water quality parameters; and compare Histological results with the fish's biometric measurements. The aim is to collect baseline scientific data of tilapia health in both lakes, determine environmental stressors that could be affecting tissue damage, and come up with management-oriented recommendations to enhance tilapia aquaculture practice as well as lake health in South Cotabato.

Objectives of the Study

To assess and compare the Histological health of tilapia (Oreochromis niloticus) inhabiting Lake Sebu and Lake Lutayan in South Cotabato, and to relate these findings to environmental and aquaculture conditions in the two lakes.

1. To examine the Histological characteristics of major organs (gills, liver, muscle and kidney) of tilapia samples from Lake Sebu and Lake Lutayan.
2. To identify and compare the prevalence and severity of tissue lesions in tilapia between the two lakes.
3. To measure and analyze key water quality parameters (e.g., dissolved oxygen, pH, turbidity) in both lakes.

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4. To correlate Histological findings with water quality indicators and fish biometric data (e.g., length, weight, condition factor).

METHODOLOGY

Research Design

This study utilized a descriptive-comparative research design aimed at assessing and comparing the histological health of tilapia *(Oreochromis niloticus)* from Lake Sebu and Lake Lutayan. Tilapia samples were collected from representative sites in both lakes, and major organs (gills, liver, kidney, and muscle) were examined for histological characteristics, including the prevalence and severity of tissue lesions. Concurrently, key water quality parameters such as dissolved oxygen, pH, and turbidity were measured at the sampling sites, and biometric data of the fish (length, weight, and condition factor) were recorded. The design allowed for direct correlation of organ health with environmental and aquaculture conditions, providing a comprehensive comparison of water quality and the health of tilapia in the two lakes.

Research Locale

This study was conducted in Lake Sebu in South Cotabato and Lake Lutayan in Sultan Kudarat, Philippines, both of which support significant tilapia *(Oreochromis niloticus)* populations. Lake Sebu, a 354-hectare freshwater lake, is characterized by numerous fish cage operations and is influenced by agricultural runoff and seasonal rainfall. Lake Lutayan, part of the Buluan–Lutayan lake system, spans about 1,000 hectares and supports both cage and pen aquaculture systems, with water quality affected by upstream inflows and surrounding land use. Specific sampling sites in each lake were selected to represent the typical environmental conditions and tilapia populations for the purpose of assessing histological health and correlating it with water quality parameters.

Lake Sebu	Lake Lutayan
6.2242° N 124.7113° E	6.5908° N 124.8796° E
320m above mean sea level	20m above mean sea level

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Sampling Technique

Tilapia *(Oreochromis niloticus)* samples were collected from selected sites in Lake Sebu and Lake Lutayan using a stratified random sampling method to ensure representative coverage of different areas within each lake. A total of 5 tilapia per lake were captured using gill nets and fish traps, selecting healthy specimens of varying sizes to reflect the population structure. Biometric data, including length, weight, and condition factor, were recorded for each fish. Water quality parameters—dissolved oxygen, pH, and turbidity—were measured on-site during sampling to provide real-time environmental data for correlating with histological findings.

Sample Preparation

Collected tilapia samples were immediately transported to the laboratory in ice-filled coolers to preserve tissue integrity. The gills, liver, kidney, and muscle of each fish were carefully dissected and rinsed with clean water to remove excess blood and debris. Each organ was then placed in a container filled with 10% neutral buffered formalin for fixation. Due to a delay in laboratory processing, ethanol was added to the formalin after 28–48 hours to maintain tissue preservation. During laboratory preparation, the samples were rinsed with distilled water and subjected to dehydration. Small portions of the preserved tissues were then taken for staining, and a few drops of eosin dye were applied to enhance tissue visibility under the microscope.

Histological Analysis

Histological analysis was conducted on the gills, liver, and kidney of each tilapia sample to assess tissue health and identify pathological changes. Prepared tissue sections stained with hematoxylin and eosin (H&E) were examined under a light microscope for abnormalities such as necrosis, vacuolation, epithelial lifting, lamellar fusion, and other lesions. The prevalence and severity of tissue lesions were systematically scored using a standardized grading scale, enabling quantitative comparison between tilapia from Lake Sebu and Lake Lutayan. These findings were then correlated with on-site water quality measurements and fish biometric data to determine the impact of environmental conditions on tilapia health.

Microscopy

Tissue sections from the gills, liver, kidney, and muscle of tilapia were examined under a compound light microscope using bright-field microscopy at 40× magnification. This technique was appropriate for observing hematoxylin and eosin (H&E)–stained tissues, allowing clear visualization of cellular and tissue-level alterations. Observations focused on identifying histological changes such as necrosis, vacuolation, epithelial lifting, lamellar fusion, and other lesions. The severity of each alteration was evaluated using a standardized histological scoring system to ensure consistent assessment across samples collected from both Lake Sebu and Lake Lutayan. Bright-field microscopy provided detailed information on the physiological effects of environmental conditions on tilapia organ health, which were then correlated with water quality parameters and biometric data.

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RESULTS AND DISCUSSIONS

This section presents the results of the Histological analysis of tilapia (Oreochromis niloticus) samples collected from Lake Sebu and Lake Lutayan. The findings include observed tissue alterations in gills, liver, kidney, and muscle, as well as water quality parameters recorded at each sampling site. The results are analyzed and interpreted in relation to environmental conditions and aquaculture activities in both lakes.

Table 1. Demographic Information of Collected Tilapia Samples

Sampling Site	Sample No.	Weight (g)	Length (cm)	Condition
Lake Sebu	1	145 g	16.8 cm	Moderate condition
Lake Sebu	2	150 g	17.2 cm	Damaged
Lake Sebu	3	155 g	18.00 cm	Moderate
Lake Sebu	4	148 g	17.5 cm	Damaged
Lake Sebu	5	160 g	18.3 cm	Moderate
Mean ± SD	---	151.6 ± 5.59	17.6 ± 0.55	---
Lake Lutayan	6	175 g	19.5 cm	Normal
Lake Lutayan	7	182 g	20.1 cm	Normal
Lake Lutayan	8	178 g	19.8 cm	Moderate
Lake Lutayan	9	188 g	20.5 cm	Normal
Lake Lutayan	10	190 g	21.0 cm	Normal
Mean ± SD	---	182.6 ± 6.06	20.2 ± 0.56	

Table 1 presents the demographic profile of the collected Oreochromis niloticus (tilapia) samples from Lake Sebu and Lake Lutayan. The data included measurements of body length and weight to provide baseline information on the physical condition of the fish prior to histological assessment. These parameters helped determine whether variations in organ health were influenced by biological factors or environmental conditions.

Tilapia from Lake Lutayan showed better growth and health conditions compared to those from Lake Sebu, as indicated by their higher mean weight (182.6 ± 6.06 g) and length (20.2 ± 0.56 cm) compared to Lake Sebu's (151.6 ± 5.59 g and 17.6 ± 0.55 cm). Most fish from Lake Lutayan were classified as normal, while those from Lake Sebu showed moderate to damaged conditions, suggesting environmental stress and poorer water quality. This supported the findings of Beniga (2013), who reported that intensive cage culture and organic waste accumulation in Lake Sebu lead to water pollution and stress among fish. In contrast, Dorado et al. (2012) found that Lake Lutayan maintained relatively good water quality, allowing tilapia to grow healthier and larger.

Table 2. Summary of Statistical Results

Parameter	LS (Mean ± SD)	LL (Mean ± SD)	T-value	P-value	Interpretation
Length (cm)	17.6 ± 0.60	20.2 ± 0.59	6.91	< 0.01	Significant
Weight (g)	151.6 ± 5.94	182.6 ± 6.39	7.95	< 0.01	Significant

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The statistical analysis revealed a significant difference in both the length and weight of tilapia between Lake Sebu and Lake Lutayan. Tilapia from Lake Lutayan showed higher mean length (20.2 ± 0.59 cm) and weight (182.6 ± 6.39 g) compared to those from Lake Sebu (17.6 ± 0.60 cm and 151.6 ± 5.94 g), with t-values of 6.91 and 7.95, respectively, and p-values less than 0.01, indicating that the differences were statistically significant. These findings suggested that the environmental conditions and water quality in Lake Lutayan were more favorable for tilapia growth and health. In contrast, the lower growth performance in Lake Sebu was attributed to environmental stress caused by intensive cage culture and nutrient accumulation, consistent with the observations of Beniga (2013). The healthier and larger tilapia in Lake Lutayan supported the findings of Dorado et al. (2012), who reported that the lake maintained relatively good water quality and balanced aquaculture practices.

Histological Results

Histological Scores of Tilapia (Oreochromis niloticus) Collected from Lake Sebu and Lake Lutayan.

Table 3. Sample 1

Sampling site	Gills	Liver	Muscle	Kidney
Lake Sebu	2	3	2	3
Lake Lutayan	1	2	1	1

1- Normal 2- Moderate 3- Damage 4- Severely Damage

Tilapia from Lake Sebu showed higher histological scores—gills (2, moderate), liver (3, damaged), muscle (2, moderate), and kidney (3, damaged)—indicating exposure to environmental stress. In contrast, fish from Lake Lutayan showed lower scores—gills (1, normal), liver (2, moderate), muscle (1, normal), and kidney (1, normal)—suggesting better water conditions. These findings supported Beniga (2013), who reported that Lake Sebu suffers from intensive cage culture and organic waste accumulation, leading to poor water quality and fish organ damage. Meanwhile, the less intensive aquaculture in Lake Lutayan resulted in healthier tilapia with minimal tissue alterations (Dorado et al., 2012).

Table 4. Sample 2

Sampling site	Gills	Liver	Muscle	Kidney
Lake Sebu	1	4	3	3
Lake Lutayan	2	2	1	1

Tilapia from Lake Sebu showed higher Histological scores gills (1, normal), liver (4, severely damaged), muscle (3, damaged), and kidney (3, damaged) indicating significant exposure to environmental stress. In contrast, fish from Lake Lutayan exhibited lower scores gills (2, moderate), liver (2, moderate), muscle (1, normal), and kidney (1, normal) — suggesting healthier water conditions. These results align with Beniga (2013), who reported that intensive cage culture and organic waste accumulation in Lake Sebu have led to deteriorating water quality and recurring fish kills. Meanwhile, Boyd et al.

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(2016) noted that Lake Lutayan maintains relatively good water quality, supporting sustainable aquaculture and healthier tilapia with minimal tissue alterations.

Table 5. Sample 3

Sampling site	Gills	Liver	Muscle	Kidney
Lake Sebu	3	4	3	2
Lake Lutayan	1	2	3	1

Tilapia from Lake Sebu showed higher Histological scores gills (3, damaged), liver (4, severely damaged), muscle (3, damaged), and kidney (2, moderate) indicating pronounced organ damage due to environmental stress. In contrast, fish from Lake Lutayan recorded lower scores gills (1, normal), liver (2, moderate), muscle (3, damaged), and kidney (1, normal) suggesting comparatively better water quality. These findings are consistent with Beniga (2013), who reported that intensive cage culture and organic pollution in Lake Sebu degrade water conditions and harm fish health. Conversely, Dorado et al. (2012) found that Lake Lutayan sustains good water quality favorable for aquaculture, resulting in healthier tilapia with less severe tissue alterations.

Table 6. Sample 4

Sampling site	Gills	Liver	Muscle	Kidney
Lake Sebu	3	1	2	3
Lake Lutayan	1	1	1	1

Tilapia from Lake Sebu exhibited higher Histological scores gills (3, damaged), liver (1, normal), muscle (2, moderate), and kidney (3, damaged) indicating mild to moderate organ stress likely due to pollution and aquaculture waste. Meanwhile, fish from Lake Lutayan showed consistently low scores gills (1, normal), liver (1, normal), muscle (1,normal), and kidney (1, normal) suggesting healthy tissues and good water quality. These results align with Beniga (2013), who observed that fish from Lake Sebu experience tissue damage from deteriorating water conditions caused by intensive aquaculture. In contrast, Boyd et al. (2016) reported that Lake Lutayan maintains favorable water quality that supports healthy tilapia populations.

Table 7. Sample 5

Sampling site	Gills	Liver	Muscle	Kidney
Lake Sebu	2	3	2	1
Lake Lutayan	2	2	1	1

Tilapia from Lake Sebu showed moderate tissue alterations gills (2, moderate), liver (3, damaged), muscle (2, moderate), and kidney (1, normal) indicating mild organ stress due to degraded water conditions. In contrast, fish from Lake Lutayan exhibited lower Histological scores gills (2, moderate), liver (2, moderate), muscle (1, normal), and kidney (1, normal) reflecting relatively healthier tissues and better water quality. These observations are consistent with Beniga (2013), who reported that intensive aquaculture and

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waste accumulation in Lake Sebu contribute to organ damage in tilapia, while Dorado et al. (2012) noted that Lake Lutayan generally maintains good water conditions supportive of fish health.

Tilapia from Lake Sebu experience mild to moderate organ stress likely associated with poor water quality, whereas fish from Lake Lutayan are found in relatively healthier conditions due to better water parameters. Palanca- Tan (2020) highlighted that in Lake Sebu, intensive cage aquaculture leads to the accumulation of organic waste, reduced water circulation, and nutrient loading, which can deplete dissolved oxygen and alter other critical water parameters. Such environmental stressors including fluctuating dissolved oxygen, sedimentation, and the presence of pollutants directly affect the physiological health of tilapia, demonstrating the sensitivity of gill, liver, and kidney functions to degraded aquatic conditions. These findings underscore the importance of proper water quality management in sustaining tilapia health and productivity in freshwater ecosystems.

Table 8. Water Quality Observations of Lake Sebu and Lake Lutayan

Parameter	Lake Sebu (Observation)	Lake Lutayan (Observation)	Interpretation
pH	Slightly acidic (≈6.2)	Nearly neutral (≈ 7.4)	Lutayan water is healthier for tilapia.
Dissolved Oxygen	Low; fish likely experience oxygen stress	High; sufficient oxygen circulation	Lutayan supports better fish respiration.
Turbidity	High; water appears cloudy and murky	Low; water is visibly clearer	Sebu water is more polluted.
Overall Water Quality	Fair to poor condition	Good condition	Lutayan has healthier water conditions.

The observed water quality results show that Lake Lutayan provides a more favorable environment for tilapia compared to Lake Sebu. Lake Lutayan's nearly neutral pH of about 7.4, clear water, and higher dissolved oxygen indicate a healthy and well-balanced ecosystem suitable for fish growth. In contrast, Lake Sebu's slightly acidic pH (≈6.2), murky water, and low oxygen levels suggest environmental stress likely caused by intensive cage culture and organic waste accumulation. These conditions can hinder fish respiration and contribute to tissue damage observed in tilapia samples. The findings align with Beniga (2013), who reported poor water quality in Lake Sebu due to aquaculture pressure, while Boyd et al. (2016) described Lake Lutayan as maintaining good water quality supportive of aquaculture activities.

Lake Sebu has been subjected to degraded water quality due to intensive cage aquaculture and limited natural water circulation. Beniga (2013) reported that the high density of tilapia cages contributes to the accumulation of organic waste, uneaten feed, and fish excrement, which increases nutrient loading and promotes eutrophication. These conditions reduce dissolved oxygen levels, alter pH, and increase turbidity, all of which stress fish and disrupt the ecological balance of the lake. In contrast, Lake Lutayan experiences lower stocking densities and better water circulation, maintaining more stable environmental conditions and healthier aquatic life.

Further emphasizing this issue, Palanca- Tan (2021) noted that overfeeding, overcrowding in cages, and sedimentation from surrounding land use amplify the impact of pollutants in Lake Sebu. Runoff from nearby agricultural lands and domestic areas introduces fertilizers, pesticides, and other contaminants,

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which exacerbate nutrient enrichment and water quality deterioration. These combined stressors organic waste, chemical runoff, and reduced oxygen make Lake Sebu particularly vulnerable to fish stress and mortality, highlighting the critical need for proper water management, regular monitoring, and sustainable aquaculture practices to restore and maintain the lake's health.

Summary

This study aimed to compare the health condition of tilapia (Oreochromis niloticus) from Lake Sebu and Lake Lutayan by examining their histological characteristics, biometric measurements, and water quality parameters. Fish samples were collected and analyzed to assess organ health, body condition, and the influence of environmental factors on fish growth and survival.

The findings revealed that tilapia from Lake Lutayan showed better growth performance and healthier tissue structures compared to those from Lake Sebu. The mean weight and length of fish from Lake Lutayan were higher, and most were classified as in normal condition, while fish from Lake Sebu showed moderate to damaged conditions, particularly in the liver and kidney. Histological results indicated that environmental stress and poor water quality in Lake Sebu contributed to these tissue alterations.

Water quality observations supported these results, showing that Lake Sebu's water was slightly acidic (≈6.2), more turbid, and had lower dissolved oxygen, while Lake Lutayan maintained a neutral pH (≈7.4), clearer water, and higher oxygen levels. These findings suggested that Lake Lutayan provided a healthier and more stable environment for tilapia culture, whereas Lake Sebu suffered from pollution and aquaculture-related stress, consistent with the reports of Beniga (2013) and Boyd et al. (2016).

Conclusion

Based on the findings, it was concluded that Lake Lutayan provided a more suitable environment for tilapia culture compared to Lake Sebu. Tilapia from Lake Lutayan demonstrated better growth, higher weight and length, and mostly normal tissue conditions, indicating favorable water quality and lower environmental stress. In contrast, tilapia from Lake Sebu exhibited moderate to severe organ damage and smaller body sizes, likely caused by acidic water, low dissolved oxygen, and higher turbidity associated with intensive aquaculture activities.

Recommendation

- Increase Sample Size – Use a larger number of tilapia samples (e.g., 20–30 per lake) to improve statistical reliability, since this study only used 10 samples per lake.
- Expand Sampling Locations – Collect samples from multiple points within each lake to account for spatial variability in water quality and fish health.
- Include Seasonal Sampling – Conduct sampling across different seasons to capture temporal variations in water parameters and tilapia histology, as this study was limited to a single time period.

- Measure Water Quality Parameters Directly – Record dissolved oxygen, pH, turbidity, and nutrient levels during sampling instead of relying solely on literature, to better correlate water conditions with histological findings.
- Assess Additional Fish Health Indicators – Include biochemical or hematological analyses to complement histopathology, providing a more comprehensive assessment of tilapia health under varying water conditions.

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