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BENTHIC MACROINVERTEBRATES AS ECOLOGICAL INDICATORS IN SAMPALOC LAKE, SAN PABLO CITY, LAGUNA

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_____
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DECLARATION

This is to certify that:

I. The special problem comprises only my original work towards the MENRM except where indicated in the Preface

II. Due acknowledgment has been made in the text to all other material used

III. The special problem is fewer than 25,000 words in length, exclusive of tables, maps, bibliographies and appendices.

_____

Medjel B. Lopez

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Abstract

The diversity of macrobenthic invertebrates is an effective biological indicator to assess the ecological status of the lake environment. In Sampaloc Lake, San Pablo City, Laguna, there is limited documentation of macrobenthic invertebrate diversity and ecological patterns.

A total of 8 quadrats (1m x 1m) in four established sampling stations were used to obtain samples with an abundance of 690 organisms that were classified into nine taxa (S=9). Most of the macrobenthic invertebrates found in the study were from phylum Annelida (Naididae), phylum Arthropoda (Chironomidae), and phylum Mollusca. The most abundant taxon was Naididae which is an effective indicator of water quality since they are usually found on organically polluted waters.

The overall status of macrobenthic fauna in Sampaloc Lake is **very low,** with a biotic index of **H'=1.942**, corresponding to a water quality classification of **"Moderately polluted".** The pollution level was supported by the Family Biotic Index result of **6.74** with the verbal interpretation **"poor water quality"**.

The biodiversity assessment of Sampaloc Lake indicates low species diversity, primarily due to high nutrient concentration or eutrophication brought by intensive aquaculture. Ammonia levels in Sampaloc Lake exceeded the recommended level and were found to be toxic on macrobenthic fauna affecting their reproductive capacity and species diversity.

Reducing anthropogenic pressures and adopting a holistic lake management approach are crucial to avert future deterioration and biodiversity loss.

Keywords: Macrobenthic Fauna; Sampaloc Lake Abundance; Taxa; Diversity; Family Biotic Index

I. INTRODUCTION

Freshwater ecosystems are one of the important natural resources which provide food, livelihood, and other ecosystem services. Limnological studies in the Philippines are said to be inconsistent and fragmented. Most of the studies documented were about aquaculture and fisheries, pollution, and eutrophication while limno-ecological and biodiversity studies are not prioritized (Papa & Mamaril Sr, 2011).

Majority of the Philippine lakes, about sixty-three percent, are small with an area ≤ 200 hectares or 2,000,000 m^2 (Brillo, 2016a). This suggests that small lakes are vital in biotic complexity and richness in the country. Both bigger lakes and small lakes are important areas of conservation. However, lesser limnological research and management attention are given to small lakes (Mendoza et al., 2019).

San Pablo City, a province of Laguna is known for its small freshwater lakes known as Seven Crater Lakes or Maar Lakes namely: Bunot Lake, Calibato Lake, Mohicap Lake, Palakpakin Lake, Pandin Lake, Sampaloc Lake and Yambo Lake. In 2014, the Germany-based Global Nature Fund (GNF) declared the seven Philippine crater lakes as the “Threatened Lake of the Year 2014” in its statement for World Wetlands Day (Cinco, 2014). Despite being declared as the threatened lakes, the Seven Crater Lakes of San Pablo has been undergoing urban expansion in 2018. The rapid growth of population has driven habitat alteration and habitat loss for organisms. Continued urban expansion threatens plant and animal biodiversity (Quintal et al. 2018).

The Laguna Lake Development Authority (LLDA) is the principal administrative agency that monitors and manages the seven crater lakes. According to its water quality report in 2018, the mean surface dissolved oxygen of the Seven Lakes was still above the recommended level of 5.0 ppm for class C water. However, the ammonia levels of the seven lakes which are toxic for fish and other aquatic organisms were too high,

exceeding 0.05 ppm level. Continuous monitoring and update on the status of the lake water quality is needed. The agency conducts quarterly monitoring of the lakes' water quality but to achieve a more holistic sustainable lake management the biological components also need to undergo comprehensive monitoring effort (Paller et al., 2021).

The study entitled *"The Seven Lakes of San Pablo: Assessment and Monitoring Strategies Toward Sustainable Lake Ecosystems"* proposed an ecosystem approach to lake management. It emphasized the importance of employing a holistic approach to lake management by considering the biophysical dimensions through different surveillance strategies such as biodiversity survey, assessment of chemical and endocrine disruptors contamination, detecting emerging waterborne pathogens, etc. (Paller et al., 2021). Furthermore, as recommended by the study, measuring the lake's macrobenthic fauna diversity is also a useful tool to assess the lake's environmental health.

Macrobenthic fauna, macrobenthos, or benthic macro-invertebrates are bottom-dwelling aquatic animals without backbones (invertebrates) that are large enough to be seen by the naked eye. They are organisms that live on or inside the deposit of a body of water and usually larger than 1 mm or 0.4 inch (Idowu & Ugwumba, 2005). Macrobenthic organisms are sensitive to environmental changes which makes them important indicators of ecosystem health. Unlike other aquatic organisms, they are nonmotile and more vulnerable to the effects of pollution (Benthic Macroinvertebrates - New River Gorge National Park & Preserve (U.S. National Park Service), n.d.).

Biodiversity studies in the Seven Lakes of San Pablo City focused only on survey of plankton, fish, fish parasite fauna, and malacofauna while limited documentation of macrobenthic fauna diversity and ecological patterns were recorded (Li & Morrison, 2011). One study documented only involves macro-gastropod communities in

Sampaloc Lake. The study recorded low diversity values of gastropods in Sampaloc Lake prompted by habitat degradation due to aquaculture and presence of abundant species (Adorable-Asis et al, 2016). The findings in Sampaloc Lake were considered new records due to lack of published literature on gastropod fauna.

Among the seven crater lakes, Sampaloc Lake was the largest. It is one of the pioneer sites for aquaculture in the 1970's. Lake Sampaloc was considered eutrophic with Class C waters (Tamayo-Zafaralla et al., 2013). According to the most recent study for the year 2018, Sampaloc Lake has the highest ammonia levels with 2.22 ppm which exceeded the recommended level of 0.05 ppm and phosphate level of 0.75 ppm which also exceeded the recommended level of 0.5 ppm (Paller et al., 2021). Intensive aquaculture practices were noted since 1980's resulting in increased organic matter and massive fish kills that pose risks of lake faunal extinction (Papa & Briones, 2017). These threatened Sampaloc's biodiversity and raised a gap between the previous records on the lake's biodiversity.

Establishing a baseline information on macrobenthos could help identify the stressors affecting the fauna community. It will also head start conservation measures and management strategies that will avert future deterioration and biodiversity loss.

II. REVIEW OF LITERATURE

Macrobenthic Fauna

The animal kingdom is composed of 35 phyla where the majority belongs to animals without backbone or invertebrates. Invertebrates account for about 97% of species diversity (Marine Invertebrates – Geological Oceanography Lab, 2016). Out of the 35 known phyla, 22 are exclusive for marine organisms wherein 11 phyla are limited to the benthic environment (Sinu, 2022). Most of the benthic organisms can be grouped into phylum Echinodermata, phylum Annelida (worms) such as polychaetes and oligochaetes, phylum Mollusca such as bivalves and gastropods, and phylum Arthropoda including crustaceans such as amphipods and decapods (Tagliapietra & Sigovini, 2010).

Benthic organisms are classified by size namely: microbenthos are aquatic animals smaller than 0.1 mm, meiobenthos are organisms larger than 0.1 mm but smaller than 0.5 mm, and macrobenthos are organisms larger than 0.5 mm (Stites, 2006). On other resources the classification varies wherein microbenthos is less than 0.063 mm, meiobenthos is between 0.063-1 (or 0.5) mm, macrobentos is greater than 1.0 (or 0.5) mm, and megabenthos greater than 10.0 mm (Tagliapietra & Sigovini, 2010).

Macrobenthic fauna, macrobenthos, or benthic macroinvertebrates are bottom-dwelling aquatic animals without backbones (invertebrates) that are large enough to be seen by the naked eye (Benthic Macroinvertebrates - New River Gorge National Park & Preserve (U.S. National Park Service), n.d.). They are organisms that live on or inside the deposit of a body of water and are usually larger than 1 mm or 0.4 inch (Idowu & Ugwumba, 2005). Most of them inhabit the intertidal zones of a coastal area (Walag & Canencia, 2016).

According to Warwick & Clarke (1993), there are 20 phyla that are likely to occur

in the macrobenthos. On their study entitled “Comparing the Severity of Disturbance: A Meta-analysis of Marine Macrobenthic Community Data” they encountered 14 phyla namely: Cnidaria, Platyhelminthes, Nemertea, Nematoda, Priapulida, Sipuncula, Annelida, Chelicerata, Crustacea, Mollusca, Phoronida, Echinodermata, Hemichordata, and Chordata. The other six phyla that can be included in the macrobenthos that were not encountered are Porifera, Entoprocta, Pogonophora, Echiura, Brachyopoda and Bryozoa.

Macrobenthic fauna are aquatic invertebrates that live in or on sediments ranging from 0.5 mm to 4.0 mm and can be retained in a 0.5 mm to 1 mm mesh (Abrogueña et al., 2021). Macrobenthos are an integral part of aquatic food webs as they provide food for many epibenthic crustaceans, shellfish, fish, and birds (Herman et al., 1999). They are classified into six functional feeding groups (FFGs): phytophages, filter feeders such as bivalves, deposit feeders such as gastropods, detritivores, and those that consume other fauna such as carnivores, and omnivores (Chen et al., 2022).

Macrobenthic organisms are important contributors to nutrient cycling, carbon cycling and storage. Most of this benthic organism recirculates unavailable nutrients from detritus (detritivores) and protein materials in other organisms (Walag & Canencia, 2016). They also facilitate transfer of energy on trophic levels by serving as a food source for a wide range of fishes (Sinu, 2022).

Macrobenthic organisms are sensitive to environmental changes, unlike other aquatic organisms, they are nonmotile, long-lived, and vulnerable to the effects of pollution. They are indicators of ecosystem health because their presence is a sign of good water quality (Benthic Macroinvertebrates - New River Gorge National Park & Preserve (U.S. National Park Service, n.d.).

Sajeeb (2021) described macrobenthic communities as the most used biological

indicator in lotic habitat worldwide since these organisms are highly sensitive to pollutants. The study of Kemabonta et al. (2020) utilized the macrobenthic fauna diversity in University of Lagos canal, Ogbe creek, and Abule-agege creek to assess heavy metals bioaccumulation. Findings showed that there are heavy metals present in the organism namely Cd, Pb, Zn, Nitrate, and Phosphate. Similarly, Chowdhury et al. (2024) used macrobenthic fauna to detect heavy metals and petroleum hydrocarbons in coastal waters of Malaysia. Given their role in the transfer of energy on trophic levels and aquatic food chains, protecting these organisms from pollutants and destructive anthropogenic activities is needed.

Anthropogenic impacts and environmental changes altered their structure and function at the community and ecosystem level. Jung et al. (2015) described the variation of the macrobenthic fauna structure on rocky shores after the Hebei spirit oil spill, west coast of Korea. The oil spill led to mass mortalities of the major macrobenthic fauna and revealed a distinction between the polluted sites and control sites in terms of the species composition and densities of dominant species. Moreover, Shi et al. (2023) studied the effects of eutrophication gradient in a semi-enclosed bay, China to the biological traits of macrobenthic fauna. The findings showed that there is a decrease in taxa showing high motility, but an increase in macrobenthic fauna with opportunistic traits such as higher larval dispersal ability.

Biodiversity studies of macrobenthic fauna are significant indicators of water quality and ecosystem health. Sajeeb (2021) proved that macrobenthos are useful bio-monitoring tools in karnafully river estuary. The results showed that microbenthic invertebrates preserve water quality through mineralization and organic matter recycling. Aside from water quality assessment, the biotic indices of these organisms were proven to be efficient in detecting habitat degradation (Borja et al., 2000).

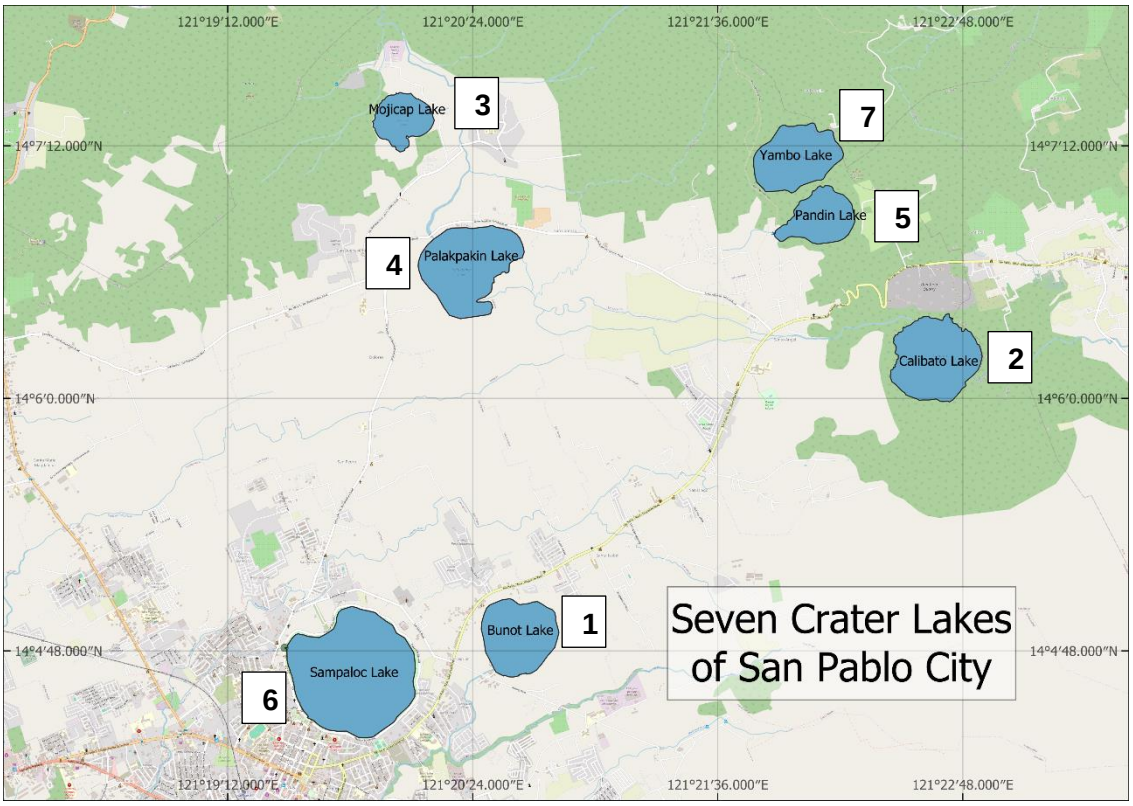
Seven Crater Lakes, San Pablo City

San Pablo City, a province of Laguna is known for its small freshwater lakes known as Seven Crater Lakes or Maar Lakes namely: Bunot Lake, Calibato Lake, Mohicap Lake, Palakpakin Lake, Pandin Lake, Sampaloc Lake and Yambo Lake.

Aquaculture and leisure activities have been the principal use of the crater lakes. As tilapia farming expanded in the late 1980s and early 2000s, additional fish pens and cages were built, surpassing the 10 percent area limit for aquaculture facilities set by the Fisheries Code of the Philippines (Republic Act 8550, section 51).

In 2014, the Germany-based Global Nature Fund (GNF) declared the seven Philippine crater lakes as the “Threatened Lake of the Year 2014” in its statement for World Wetlands Day (Cinco, 2014).

Figure 2.1. The Seven Lakes of San Pablo City, Laguna.



Note: Map created by the researcher using OpenStreetMap data in QGIS (Version 3.34.9). The Seven Crater Lakes shown are (1) Bunot, (2) Calibato , (3) Mohicap, (4) Palakpakin, (5) Pandin, (6) Sampaloc, and (7) Yambo Lake.

Management of the Seven Crater Lakes

The management and administration of the seven crater lakes are under the jurisdiction of two organizations. They are the Laguna Lake Development Authority (LLDA) and the San Pablo Municipal Government. The City of San Pablo was granted territorial jurisdiction or authority over the seven crater lakes as required by RA 7160, also known as the Local Government Code of 1991. By virtue of Republic Act 4850, also known as the Laguna Lake Development Authority Act of 1966, LLDA is regarded as the primary administrative agency of the seven crater lakes.

The LLDA was in charge of the development framework and evaluated the plans submitted by the City Government. It is regarded as the main administrative body that can accept or reject initiatives for development of the local government. The City Government was entrusted with carrying out the initiatives or projects that the LLDA had approved. To further the development objective of the LLDA, the municipal council implement the rules (Brillo, 2017).

Sampaloc Lake, San Pablo City

Sampaloc Lake is the largest lake among the seven having a total area of 104 hectares (1.04 km^2) and a maximum depth of 27 meters. It is at 14.0791° N latitude and 121.3299° E longitude (Laguna Lake Development Authority [LLDA], 2005). Sampaloc Lake is surrounded by rice fields and fruit plantations (Dimzon et al., 2018). It receives water from surface runoff, and nearby natural springs, with Sabang Creek serving as its only outlet (Brillo, 2016b).

The lake was mainly utilized in aquaculture production and recreational tourism. Intensive aquaculture changes the lake's environmental health and water quality. A comprehensive report on its water quality was given by LLDA (Laguna Lake

Development Authority [LLDA], 2005).

Laguna Lake Development Authority provided complete water quality data from 1996 to 2016 in terms of its abiotic aspects such as nutrient composition: ammonia, nitrate, phosphate, pH level, chlorophyll a, BOD, etc. As documented in the LLDA water quality report (1996-2005), it was found out that the yearly pH level values of Sampaloc Lake is within the acceptable range of 6.5-8.5, the nitrate is at 10mg/L which falls under class “C” waters, ammonia concentrations that indicate sanitary pollution increased from 0.002 in September 1996 to 4.4152 mg/L in January 2002, and inorganic phosphate found on detergents and other factors was higher than the criteria for class “C” waters which is at 0.1 mg/L. In terms of Biochemical Oxygen Demand (BOD), which can measure organic pollution, there were only few exceedances in the years 1999, 2002, 2004, and 2005. However, the report still showed the increasing trend of BOD during the study period.

Phytoplankton and zooplankton were used as a biological indicator on monitoring the ecosystem health. LLDA also provided information on its phytoplankton composition and zooplankton composition in Sampaloc Lake which entails the biotic aspect of lake evaluation. There is no definite trend in algal counts which fluctuate over the 10-year study period. No changes in zooplankton species composition were recorded but annual monitoring of the aquatic fauna revealed a decreasing trend from 1996 to 2005 (Laguna Lake Development Authority [LLDA], 2005).

Mendoza et al., (2019) delineate temperature and DO measurements for six lakes from August 2018. Findings using physiochemical parameters showed that there is a changing limnological status in the seven crater lakes. Dimzon et al. (2018) assessed Lakes Palakpakin, Sampaloc, and Pandin for emerging organic contaminants (EOCs) and it was found that pesticides such as chlorpyrifos were present. Additional

pollutants such as cypermethrin, picolinafen, and quinoxyfen are detected in Sampaloc Lake. According to the recent study for the year 2018, Sampaloc Lake has the highest ammonia levels with 2.22 ppm which exceeded the recommended level of 0.05 ppm and a 0.75 ppm phosphate level which exceed the 0.5 ppm recommended level (Paller et al., 2021).

Intensive aquaculture practices were noted since the 1980's resulting in increased organic matter and massive fish kills that pose risks of lake faunal extinction (Papa & Briones, 2017). This threatened Sampaloc's biodiversity and raised a gap between the previous records on the lake's biodiversity.

Limited biodiversity research is conducted on the seven crater lakes (Mendoza et al., 2019). Particularly, the area lacks documentation of macrobenthic fauna diversity and their ecological patterns (Li & Morrison, 2011). Only one study involving macro-gastropod communities was documented in Sampaloc Lake. The findings of the study showed low diversity values of gastropods which were prompted by habitat degradation due to aquaculture and presence of abundant species (Adorable-Asis et al., 2016). Aiming for a more holistic sustainable lake management involves comprehensive monitoring of its biological indicators.

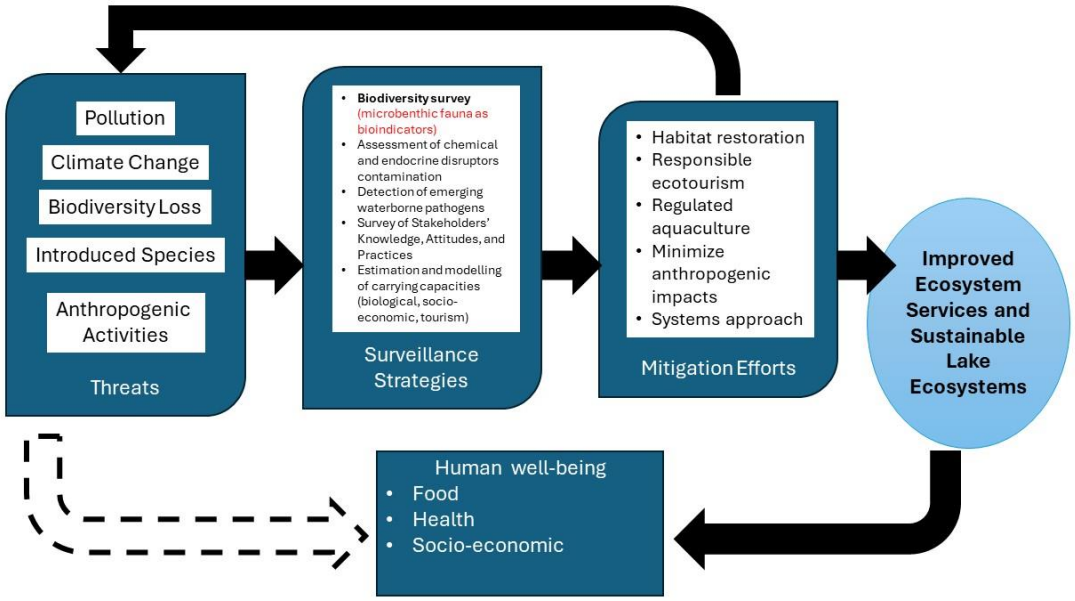
Assessment and Monitoring Strategies

The study entitled *"The Seven Lakes of San Pablo: Assessment and Monitoring Strategies Toward Sustainable Lake Ecosystems"* proposed an ecosystem approach to lake management. Paller et al. (2021) devised a strategic framework that identifies the threats to the lake environment, surveillance strategies to monitor the water quality and overall ecosystem health, and mitigation efforts to address the problems encountered in lake management.

It emphasized the importance of employing a holistic approach to lake

management by considering the biophysical dimensions through different surveillance strategies such as biodiversity survey not limited to plankton community (macrobenthic fauna as biological indicators), assessment of chemical and endocrine disruptors contamination, detecting emerging waterborne pathogens, etc. (Paller et al., 2021).

Figure 2.2. Strategic framework for the sustainable management of Seven Crater Lakes**.**



Note: Adapted from Paller et al. (2021)

Biodiversity Survey as Surveillance Strategy in Sampaloc Lake, San Pablo City

Biodiversity studies in the Seven Lakes focused only on surveys of plankton, fish, fish parasite fauna, and malacofauna. Limited documentation of macrobenthic fauna was recorded (Li & Morrison, 2011).

An ichthyofaunal survey was conducted in Sampaloc Lake and revealed that there are ten species and six species of fishes including *Leiopotherapon plumbeus*, *Glossogobius aureus*, and *Giuris margaritacea* as native fishes. The lake was found to have a fairly low diversity of freshwater fish species with a biodiversity index of H'=0.82-1.64 and primarily composed of non-native species such as *Oreochromis niloticus* or Nile Tilapia (Paller et al., 2017).

The zooplankton community in the lake belongs to three major groups namely Rotifera (42 taxa), Cladocera (8 taxa), and Copepoda (3 taxa). The study documented high species richness of R=5.018 but a relatively low biodiversity as indicated by the diversity index of H'=2.034. The notable abundance of rotifer species may be due to their ability to reproduce rapidly even under harsh environmental conditions (Coronado et al., 2011).

Adorable-Asis et al. (2016) conducted a study about the macro-gastropod fauna of aquaculture-intensive lakes in the Philippines including the Sampaloc Lake. The study documented low diversity values of gastropods which were attributed to habitat degradation from intensive aquaculture practices and the dominance of a few abundant species. The observations represent new records for the area, given the absence of previously published literature on the gastropod assemblage in the lake ecosystem.

The current and collective findings from biodiversity surveys indicate low levels of biodiversity among the lake's biotic components, highlighting concerns about the current ecological state of the lake. To further assess and achieve a holistic sustainable lake management, studying other biotic components were needed such as macrobenthic fauna. The results of biodiversity surveys ensure that conservation measures are tailored to promote a more sustainable and ecologically balanced environment.

III. STATEMENT OF THE STUDY

Continuous assessment and monitoring of the seven crater lakes is needed to ensure sustainability. The LLDA provides an annual water quality report and assessment of the seven crater lakes plankton community. However, limited biodiversity research is conducted. Biodiversity studies in the Seven Lakes of San Pablo City focused on survey of plankton, fish, fish parasite fauna, and malacofauna while limited documentation of macrobenthic fauna diversity and ecological patterns were recorded (Li., & Morrison, 2011).

Achieving holistic sustainable lake management equates to continuous monitoring including its biological aspect. Macrobenthic fauna is a potential bio-monitoring tool or indicator. They are significant indicators of water quality and ecosystem health. Their presence and abundance are a sign of good water quality. Aside from water quality assessment, the biotic indices of these organisms were proven to be efficient in detecting habitat degradation (Borja et al., 2000). However, limited documentation is present in Sampaloc Lake, San Pablo City.

This study answered the following research questions:

1. What macrobenthic fauna species are present in Sampaloc Lake, San Pablo City?
2. What is the status of macrobenthic fauna community in Sampaloc Lake, San Pablo City in terms of the following:

a) Species richness (the number of species)

b) the Abundance (the counts of individuals for every species)

c) Shannon-Wiener Biodiversity Index

3. What is the environmental status of Sampaloc Lake based on the FBI (Family Biotic Index)?
4. What organisms could affect the biodiversity of the macrobenthic fauna community in Sampaloc Lake, San Pablo City?

IV. OBJECTIVES OF THE STUDY

An ecosystem approach to lake management involves assessing the biophysical dimensions including water quality, aquaculture, open fishing, and biodiversity (Paller et al., 2021). Small lakes, such as Sampaloc Lake, are vital in biotic complexity and species conservation in our country. Assessing the macrobenthic fauna biodiversity can offer new information towards conservation of the lake environment and other species inhabiting the area.

The general objective of the study looks into the macrobenthic fauna biodiversity found in Sampaloc Lake, San Pablo City and its use as an ecological indicator.

Specifically, this research intends to:

- Describe the species composition of macrobentic fauna in Sampaloc Lake, San Pablo City.
- Determine the status of macrobenthic fauna community in Sampaloc Lake, San Pablo City in terms of:

a) Species richness (the number of species)

b) Abundance (the counts of individuals for every species)

c) Shannon-Wiener Biodiversity Index

- Determine the environmental status of Sampaloc Lake based on FBI (Family Biotic Index).
- Identify organisms that affects the biodiversity of the macrobenthic fauna community in Sampaloc Lake, San Pablo City.

V. RATIONALE

San Pablo City, Laguna is known for its seven crater lakes. The lakes were declared as threatened lakes of the Germany-based Global Nature Fund (GNF), an international organization in 2014 (Cinco, 2014). Among the seven crater lakes, Sampaloc Lake was the largest. It suffered from intensive aquaculture practices that led to its degradation (Papa & Briones, 2017).

Dimzon et al. (2018) assessed Lakes Palakpakin, Sampaloc, and Pandin for emerging organic contaminants (EOCs) and it was found that pesticides such as chlorpyrifos and additional pollutants such as cypermethrin, picolinafen and quinoxyfen are present in Sampaloc Lake. According to a recent study for the year 2018, Sampaloc Lake has the highest ammonia levels with 2.22 ppm which exceeded the recommended level of 0.05 ppm. Records showed that it also exceeded the recommended level of 0.5 ppm phosphate level with 0.75 ppm (Paller et al., 2021).

The study entitled *"The Seven Lakes of San Pablo: Assessment and Monitoring Strategies Toward Sustainable Lake Ecosystems"* proposed an ecosystem approach to lake management. It emphasized the importance of employing a holistic approach to lake management by considering the biophysical dimensions through different surveillance strategies such as biodiversity survey not limited to plankton community (macrobenthic fauna as biological indicators), assessment of chemical and endocrine disruptors contamination, detecting emerging waterborne pathogens, etc. (Paller et al., 2021).

Biodiversity studies in the Seven Lakes of San Pablo City focused on survey of plankton, fish, fish parasite fauna, and malacofauna while limited documentation of macrobenthic fauna diversity and ecological patterns were recorded (Li & Morrison, 2011).

Macrobenthic organisms are sensitive to environmental changes, unlike other aquatic organisms, they are nonmotile, long-lived, and vulnerable to the effects of pollution. The organisms are highly sensitive to pollutants, they can be used to detect heavy metals and petroleum hydrocarbons in coastal water (Chowdhury et al., 2024).

Species composition and abundance of macrobentic fauna can be used as a biological indicator of the health of lake ecosystems. Sajeeb (2021) proved that macrobenthos are useful bio-monitoring tools in karnafully river estuary. The results showed that macrobenthic invertebrates preserve water quality through mineralization and organic matter recycling. Aside from water quality assessment, the biotic indices of these organisms were proven to be efficient in detecting habitat degradation (Borja et al., 2000).

Establishing a baseline information of macrobenthic fauna is needed since there is a limited documentation in Sampaloc Lake, San Pablo City. The baseline information can be used to identify and effectively manage the stressors that affect the macrobenthic fauna community in the area. New records about the macrobenthic fauna can contribute significantly to achieving holistic and sustainable lake management.

VI. SCOPE AND LIMITATIONS

The study focuses on the analysis of macrobenthic fauna diversity in Sampaloc Lake, San Pablo City. Other classifications of benthic organism were not included, and it is limited to only one of the seven crater lakes due to time constraints and availability of publications during the conduct of the study.

The location of the study was chosen primarily because it is accessible and convenient for the researcher. Four sampling stations were established in Sampaloc Lake. Primary data were obtained through field collection of macrobenthic fauna on the four sampling sites in July 2024 while secondary data were collected from peer-reviewed academic publications. The specimens were identified through the aid of a portable digital microscope with 1600x magnification. The biotic diversity of the macrobenthic fauna was computed using the Shannon-Weiner diversity index and the FBI (Family Biotic Index) was used to determine the current water quality of Sampaloc Lake.

Scholarly articles were used to identify the organisms that prey on the macrobenthic fauna. Among the identified fish species Midas cichlids were chosen to be analyzed through a gut content analysis since their primary feeding habit includes mollusks, and other benthic materials.

VII. DESCRIPTION OF THE STUDY AREA

The study area is located at San Pablo City, Laguna. Sampaloc Lake is the largest lake among the seven having a total area of 104 hectares (1.04 km^2), mean depth of 17.6 meters, and a maximum depth of 27 meters. It is at 14.0791° N latitude and 121.3299° E longitude (Sta. Ana et al., 2005). The lake was mainly utilized in aquaculture production and recreational tourism.

Sampaloc Lake has class “C” waters and is considered eutrophic. It has one tributary flowing into the lake, its pH level is 7.3, and the amount of dissolved oxygen is 4.7 mg/L (Laguna Lake Development Authority [LLDA], 2005).

From the total surface area of 3.7 km, four sampling stations were established:

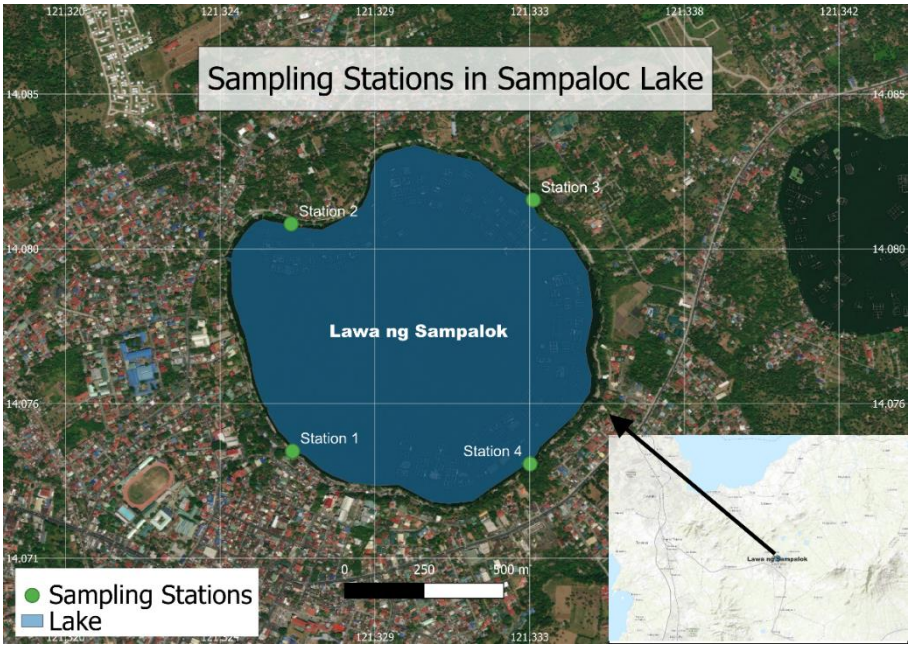
(1) boardwalk (14.074613° N, 121.326605° E)

(2) 1 kilometer from the boardwalk (14.081221° N, 121.326564° E)

(3) 2 kilometers from the boardwalk (14.08192° N, 121.333603° E)

(4) 3 kilometers from the boardwalk. (14.074242° N, 121.333514° E)

Figure 6.1. Sampling area in Sampaloc Lake, San Pablo City.



Note: Map created by the researcher using OpenStreetMap data in QGIS (Version 3.34.9).

VIII. METHODOLOGY

The study used a descriptive research design in analyzing the macrobenthic fauna diversity at Sampaloc Lake. Primary data were obtained through field collection of macrobenthic fauna on the four sampling sites while secondary data were collected from peer-reviewed scholarly articles.

A transect-quadrat method was used in assessing the macrobenthic fauna organisms in the established four sampling sites. The length of the transect was based on the length of the littoral zone. A 1-meter x 1-meter quadrat was placed 0.5 meter from both sides of the transect. The quadrats were one meter apart from each other.

Sample Collection

Samples were collected with the use of kick nets (1 mm in size). The collected samples were placed in a labelled ziplock bag and were fixed with 70% ethanol. The specimen was sieved using a 1 mm mesh to separate the macrobenthic fauna. All the materials retained by the mesh were stored in a container with proper label for analyzation. The sieved materials were sorted through hand picking. For macro mollusk, only live specimens and empty shells with intact periostracum were included to reduce bias (Gheoca et al., 2021). The specimens were identified through the aid of a portable digital microscope with 1600x magnification.

Identification of Macrobenthic Fauna

Macrobenthic fauna was identified at the lowest possible taxa using reference collection from Chapter 5 - Benthic Macroinvertebrates (n.d.), Pennsylvania Sea Grant, (2008), European Register of Marine Species (VLIZ, n.d.), Global Biodiversity Information Facility (GBIF, n.d.), *Molluscabase – Search* (n.d.), and Springteen et al. (1986). Malacofauna diversities were further classified using published studies from Adorable-Asis et al. (2016), Perez & Mendoza (2022), and a compendium of mollusk

preserved in museum collections. (Slieker, n.d.). The species list from AMBI analysis was also consulted in the identification of organism (Borja et al., 2000).

Determination of Key Descriptors

The main descriptors of macrobenthic fauna community that were obtained from the samples are: (a) Species richness (the number of species), (b) abundance (the number of individuals for every species), and the (c) biodiversity index (Shannon-wiener diversity index).

Species Richness- is the total number of unique species within a defined area (Rafferty, 2023).

S=N, where N is the number of species.

Abundance- total number of organisms in the area.

Relative abundance- is the number of organisms of a particular kind relative to the total number of organisms in the area (Walag & Canencia, 2016).

RA(%)= $\frac{Number\ of\ individual\ per\ species}{Total\ number\ of\ individuals}$ x100

Shannon's Wiener biodiversity index- commonly used biological index that considers both species richness and evenness (Walag & Canencia, 2016).

H' = -$\sum(\frac{ni}{N})\ ln\ (\frac{ni}{N})$

Where: n_i = number of each species (the ith species)

N = total number of individuals in the area

ln = the natural log of the number.

The biodiversity measures are computed using an online biodiversity calculator (Biodiversity Calculator | VIRTUE, n.d.). The Shannon-wiener biodiversity index was

used to assess the status of the macrobenthic community. It will be interpreted using the table below.

Table 6.1

Classification Scheme for the Shannon Diversity Index

Relative Values	Shannon-wiener diversity index (H')
Very High	3.50 and above
High	3.00-3.49
Moderate	2.5-2.99
Low	2.0-2.49
Very Low	1.99 and below

Note: Adapted from Fernando (1998)

Table 6.2

Classification of Pollution Level Based on the Value of Diversity Index

Range of ID	Class of water pollution
0< H' <1	Heavily polluted
1< H' <2	Moderately polluted
2< H' <3	Lowly polluted
3< H' <4	Slightly polluted

Note: Adapted from Setyono and Himawan (1998)

The species found were classified according to their pollution tolerance values at the family level shown in Table 6.3. Gastropods found in the study were categorized as gilled snail (right-handed snail with operculum) and lunged snail (left-handed snail including Planorbidae).

Table 6.3

Pollution Tolerance Values 'PTV' for Macrobenthic Invertebrates at the Family Level

Taxonomic Name	Common Name	Pollution Tolerance Value
Chironomidae	Midge	6
Prosobranch	Gilled snail	6
Pulmonate	Lunged snail	8
Oligochaeta	Aquatic worm	8
Sphaeriiddae	Fingernail clam	7

Note: Adapted from Mir et al. (2021)

Modified Family Biotic Index- used to assess the water quality of an aquatic body using the species level index. **FBI**= $\sum \frac{x_i t_i}{N}$ where, x_i= number of individuals within a taxon; t_i=tolerance value of a taxon, and N= total number of organisms.

The diversity of the macrobenthic fauna was used to assess the ecological status of Sampaloc Lake using the Family Biotic Index (FBI). Table 8.4. was used to interpret the results of the Family Biotic Index.

Table 6.4

Water Quality Based on the Family Biotic Index Values

Family Biotic Index	Water Quality
0.00-3.75	Excellent
3.76-4.25	Very good
4.26-5.00	Good
5.01-5.75	Fair
5.76-6.50	Fairly poor

6.51-7.25	Poor
7.36-10.00	Very poor

Note: Adapted from Hilsenhoff (1988)

All the secondary data was collected and interpreted using a qualitative analysis of data.

Gut Content Analysis

In this study, the stomach or gut content analysis was used to know the feeding habits of Midas Cichlids and their impacts to the population and diversity of macrobenthic fauna in Sampaloc Lake, San Pablo City.

Wild caught fish were obtained, and samples were collected using a fish cage trap. The specimens were measured in terms of length, weight, and gut weight. The gut was removed, dissected, and examined for large identifiable organisms. To aid in classifying the food contents a compound light microscope was used. Stomach content analysis was done through the occurrence method as indicated by Hyslop (1980).

Frequency of occurrence is calculated as:

$$\%F_i = \frac{Ni}{N} x100$$

where $\%F_i$ is the frequency of occurrence of given item, Ni is the number of stomachs where the given item occurs, and **N** is the total number of stomachs studied. (Manko, 1016)

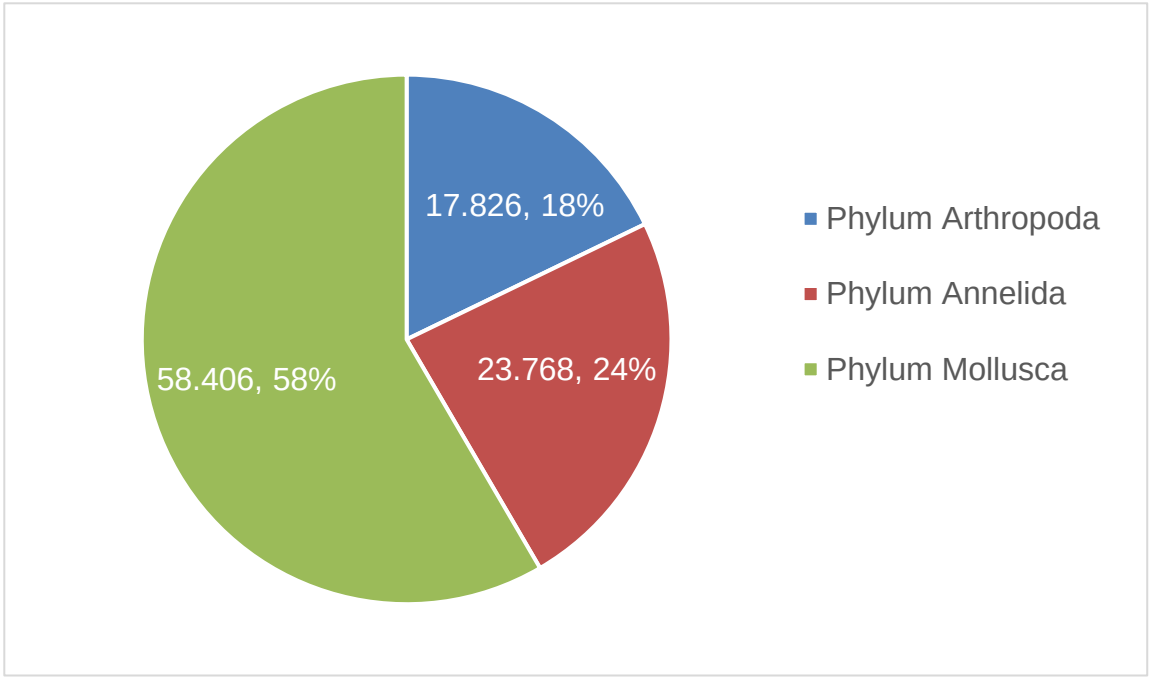
IX. RESULTS

Macrobenthic invertebrates are useful biological indicators to assess the ecological status of Sampaloc Lake in San Pablo City, Laguna. However, limited studies were conducted. Establishing baseline information is important for future studies and assessment. The findings of this study answered the following:

Species Composition of Macrobenthic Fauna in Sampaloc Lake

After conducting a field collection on the four sampling stations established in Sampaloc Lake it was found that most of the macrobenthic organisms identified belong to phylum Annelida such as oligochaetes, phylum Mollusca such as bivalves and gastropods, and phylum Arthropoda. The overall macrobenthic fauna recorded is presented in Figure 9.1. The majority of organisms are under phylum Mollusca (58.406%), followed by phylum Annelida (23.768%), and phylum Arthropoda (17.826%).

Figure 9.1. The major taxa of macrobenthic organisms found in Sampaloc Lake, San Pablo City.



A total of 123 midge fly larvae were identified under the family Chironomidae, Phylum Arthropoda. Tubificid worms were also seen accounting for 164 organisms under family Naididae, Phylum Annelida. Most of the organisms in Phylum Mollusca belong to class Gastropoda with 380 organisms while class Bivalvia only listed 23 organisms. *Corbicula fluminea* is the only species encountered under class Bivalvia. The gastropods found in the study area were *Melanoides tuberculata, Tarebia granifera, Mieniplotia scabra, Physella acuta,* and micro mollusks under Family Planorbidae, and Family Stenothyridae. Some representative macrobenthic organisms are shown in Figure 9.2.

Figure 9.2. Representative macrobenthic fauna in Sampaloc Lake, San Pablo City.



Status of the Macrobenthic Fauna in Sampaloc Lake

Nine taxa were identified, and a total of six hundred ninety (690) organisms were retrieved from the study area. Results of the Shannon-Wiener biodiversity index showed that all the four sampling stations have a very low macrobenthic fauna diversity. Sampling station 1 has the highest species richness (S=9), abundance (n=325), and diversity index (H'=1.981) while sampling station 3 has the lowest species richness (S=4), abundance (n=25), and diversity index (H'=1.159). The overall status of macrobenthic fauna in Sampaloc Lake is very low with a diversity index of H'=1.942.

Table 9.1

Summary of the Key Descriptors of Macrobenthic Fauna in Sampaloc Lake, San Pablo City

Species Name	Station 1			Station 2			Station 3			Station 4			Abundance (per species)
	a	b	total	a	b	total	a	b	Total	a	b	total	
ARTHROPODA													
Chironomidae	28	15	43	1	2	3	3	4	7	37	33	70	123
ANNELIDA													
Naididae	28	11	39	21	10	31	6	6	12	30	52	82	164
MOLLUSCA													
Bivalvia													
Corbicula fluminea	11	12	23	0	0	0	0	0	0	0	0	0	23
Gastropoda													
Family Thiaridae													
Melanoides tuberculata	27	23	50	5	5	10	4	1	5	6	3	9	74
Tarebia granifera	38	31	69	6	1	7	0	1	1	1	19	20	97
Mieniplotia scabra	7	6	13	1	0	1	0	0	0	0	1	1	15
Family Physidae													
Physella acuta	5	1	6	1	0	1	0	0	0	0	0	0	7
Family Planorbidae	8	4	12	32	27	59	0	0	0	0	1	1	72
Family Stenothyridae	53	17	70	7	32	39	0	0	0	3	3	6	115
Abundance (per station)	325			151			25			189			690
Richness	9			8			4			7			9
H'	1.981			1.508			1.159			1.278			1.942
Interpretation	**Very low**			**Very low**			**Very low**			**Very low**			**Very low**

The most abundant species were Naididae (n=164) followed by Chironomidae (n=123), and Stenothyridae (n=115). Stenothyridae was the most abundant species

under the phylum Mollusca which is similar with the results of Perez & Mendoza (2022) on their study *"Mollusk diversity patterns in seven tropical Maar lakes of San Pablo City, Laguna, Philippines".* The least abundant species was from the family Physidae, *Physella acuta* (n=7).

Table 9.2

Relative Abundance of Macrobenthic Fauna in Sampaloc Lake

Species Name	**Station 1**	**RA %**	**Station 2**	**RA %**	**Station 3**	**RA %**	**Station 4**	**RA %**	**Abundance (n)**	**RA %**
ARTHROPODA										
Chironomidae	43	13	3	2	7	28	70	37	123	18
ANNELIDA										
Naididae	39	12	31	21	12	48	82	43	164	24
MOLLUSCA										
Bivalvia										
Corbicula fluminea	23	7	0	0	0	0	0	0	23	3
Gastropoda										
Family Thiaridae										
Melanoides tuberculata	50	15	10	7	5	20	9	5	74	11
Tareb	69	21	7	5	1	4	20	11	97	14

ia grani fera										
Mieni plotia scabr a	13	4	1	1	0	0	1	1	15	2
Famil y Physi dae										
Phys ella acuta	6	2	1	1	0	0	0	0	7	1
Famil y Plano rbida e	12	4	59	39	0	0	1	1	72	10
Famil y Sten othyr idae	70	22	39	26	0	0	6	3	115	17

The abundance of species differs on the four sampling stations. The most abundant species in sampling station 1 is Stenothyridae with a relative abundance of 22%. On sampling station 2, Planorbidae with a relative abundance of 39%, comprised the majority of the organisms. While Naididae is the most abundant species for stations 3 and 4 with a relative abundance of 48% and 43% respectively.

Environmental status of Sampaloc Lake based on FBI (Family Biotic Index)

The diversity, abundance, and presence or absence of pollution-sensitive and pollution-tolerant macrobenthic invertebrates may indicate the water quality and ecological status of aquatic ecosystem. Biotic indices give numerical scores that can be used for bioassessment. Table 9.3 shows the environmental status of Sampaloc Lake based on the Family Biotic Index.

Table 9.3

The Water Quality of Sampaloc Lake Based on the Family Biotic Index

Taxonomic Name	PTV	Number of Species				Total	$x_i t_i$	$\frac{x_i t_i}{N}$
		Station 1	Station 2	Station 3	Station 4			
Chironomidae	6	43	3	7	70	123	738	1.07
Prosobranch	6	202	57	6	36	301	1806	2.62
Pulmonate	8	18	60	0	1	79	632	0.92
Oligochaeta	8	39	31	12	82	164	1312	1.90
Sphaeriiddae	7	23	0	0	0	23	161	0.23
					N	690	**FBI**	6.74
			Interpretation					**Poor**

The tolerance values of organisms based on Hilsenhoff (1988) ranges from 0 (very intolerant) to 10 (highly tolerant). The pollution tolerance value of the organisms in this study ranges from 6-8. Based on the results, Sampaloc Lake exhibits poor water quality with a family biotic index of 6.74.

Organisms that Prey on the Macrobenthic Fauna in Sampaloc Lake

Results of biodiversity studies in Small Maar Lakes (SLMs) showed that species of shrimp ***Macrobrachium mammillodactylus* (Thallwitz, 1892)** formerly known as *Palaemon talaverae* (Blanco, 1939) was found in Sampaloc Lake (Mendoza et al., 2019). Shrimps under the family Palaemonidae (such as shrimps under the *Macrobrachium* genus) tend to cannibalize on epibenthic animals such as polychaetes, mollusks, and other crustaceans (Joseph et al., 2013).

Figure 9.3. *Macrobrachium mammillodactylus* caught in Sampaloc Lake, San Pablo City.



Paller et al. (2017) conducted a two-year ichthyofaunal survey in Seven Lakes of San Pablo and accounted four species in Sampaloc Lake. Species of native fish such as ***Giuris margaritacea*** (Snakehead gudgeon), endemic species such as ***Leiopotherapon plumbeus*** (Silver perch), and non-native species such as ***Oreochromis niloticus*** (Nile tilapia), and ***Parachromis managuensis*** (Jaguar guapote) were listed in lake Sampaloc.

Snakehead gudgeon (*Giuris margaritacea*) is a carnivorous fish. Makmur et al. (2019) conducted a gut analysis of snakehead gudgeon in Tolando Lake, Indonesia and recorded that they prey mainly on shrimps (IP = 75%), snails (IP=12.5%), and worms (IP=12.5%).

Silver perch (*Leiopotherapon plumbeus*) was introduced in 1950s in Sampaloc Lake (Quilang et al., 2007). Kock et al. (2000) found that zooplankton serves as the major food source of ayungin in open waters. Insects such as chironomid larvae make a small fraction of their diet. Species near to fish pens consume benthic organisms more frequently.

Nile tilapia (*Oreochromis niloticus*) fed mainly on phytoplankton, periphyton, aquatic plants, small invertebrates and benthic fauna, detritus and bacterial films (El-Sayed, 2019).

Jaguar guapote (*Parachromis managuensis*) gut content analysis of Miller and Hyslop (2022) revealed that jaguar guapote fed mainly on invertebrates which include insects, ostracods, and **gastropods**.

Aside from the fish assemblage accounted by Paller et al. (2017), a new invasive species which is believed to be Midas cichlids (*Amphilophus citrinellus*) were caught by the fisherfolks. Locals in the area call it flowerhorns or hybrid cichlids (Yan, 2023).

The gold morphs of Midas Cichlids, *Amphilopus citrinellus* exhibit territorial aggression even outside their native environment (Aqmal-Naser & Ahmad, 2024). In fact, the non-native morph dominated a range of habitats in Lake Batur, Bali, Indonesia. It accounted for about sixty percent of the lake's fish population (Gustiano et al., 2024). The species are highly aggressive and can compete over limited resources which pose a threat to the natural fauna and biodiversity of a lake ecosystem.

Midas Cichlids are opportunistic omnivores and could greatly affect the macrobenthic fauna community. The results from Anderson et al. (1984) indicate that the food habit of cichlids in Florida was primarily mollusks and other benthic material. They also feed on small fishes, mollusks such as snails, insect larvae, worms, and other bottom dwelling organisms (Poniente et al., 2019).The recent stomach content analysis of Aqmal-Naser & Ahmad (2024) on the golden morphs in agroecosystems in Malaysia also revealed that they prey on fish, amphibians, and gastropods.

Figure 9.4. Fish Assemblage in Sampaloc Lake, San Pablo City.

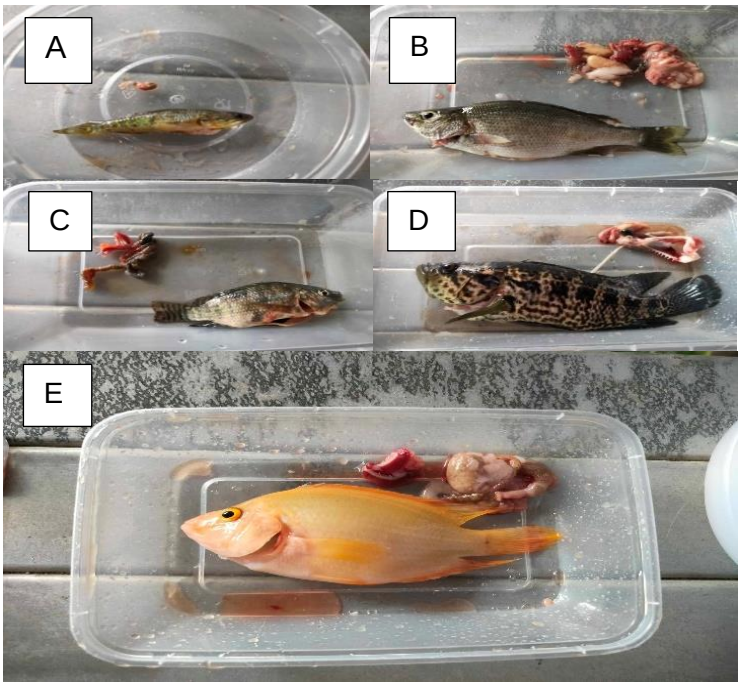
(a) *Giuris margaritacea;*

(b) Leiopotherapon plumbeus

(c) Oreochromis niloticus

(d) Parachromis managuensis

(e) *Amphilophus citrinellus* (flowerhorn)



Gut Content Analysis of *Amphilophus citrinellus*

Midas cichlids are known to be benthic feeders and analyzing their diet could potentially explain the decrease in biodiversity of the macrobenthic fauna community.

The diet of Midas cichlids in this study includes algae (%F_i=58.33%), worms (%F_i=50%), larvae, and fishes (%F_i=41.67%). Insects and mollusks were also observed with a frequency of occurrence equivalent to 16.67%. Other benthic materials such as sediments were also seen on the fish stomachs.

Majority of fishes studied rely mainly on algae, which could also suggest that it is the most abundant food source in the lake ecosystem. This idea could be supported by the continuous increase in nutrient and Chlorophyll *a* concentration recorded in Sampaloc Lake by Briddon et al. (2023).

Table 9.4

Frequency Occurrence of Food Items on the Gut Content Analysis of Midas Cichlids

Fish	Macroalgae (aquatic weeds)	Microalgae	Worms	Larvae	Fishes	Insects	Mollusk	Other benthic material (Sedi-ments)
1	√	√	√	√				
2			√					√
3	√	√	√					√
4	√	√	√	√	√	√		
5								
6	√	√	√	√	√		√	
7	√	√		√				
8	√	√	√	√	√			
9	√	√			√			√
10					√			
11							√	√
12						√		√
%F_i	**58.33%**	**58.33%**	**50%**	**41.67%**	**41.67%**	**16.67%**	**16.67%**	**41.67%**

X. ANALYSIS AND DISCUSSION

Before the conduct of this study there was a limited documentation of macrobenthic fauna in the seven crater lakes. Similar to the findings of Tagliapietra & Sigovini (2010) on their publication most of the macrobenthic fauna found on the study were from phylum Annelida, phylum Arthropoda, and phylum Mollusca. Majority of the organisms are under phylum Mollusca with a relative abundance of 58.406%. Mollusks are highly diverse which can be found in almost all freshwater and marine environments. Being the second largest animal phylum with over 100, 000 species including clams, snails, slugs, tusk shells, chitons, and squid. The diversity of phylum Mollusca makes it the most abundant phyla in the study (*Phylum Mollusca | manoa.hawaii.edu/ExploringOurFluidEarth*, n.d.).

The most abundant taxa were Naididae (n=164) followed by Chironomidae (n=123), and Stenothyridae (n=115). Tubificid worms under **family Naididae** and midges under **family Chironomidae** are both **tolerant species to pollution**. Whereas **Stenothyridae** is a **medium tolerant species to pollution** (Gao et al., 2023).

Niadidae or tubificid worms are not inherently invasive species, but they are able to survive polluted environments with low dissolved oxygen due to their external gills (Glasby et al., 2021). While Chironomids are highly diverse and exemplify the characteristics of invasive species. They have high fecundity and can compete with other benthic organisms for food which enables them to thrive in undesirable locations (Failla et al., 2015).

Furthermore, Leynen et al. (1999) and Martins et al. (2008) described Tubificidae or sludge worms as effective indicators of water quality since they are found to be abundant in organically polluted waters. Martins et al. (2008) added that a decrease in the diversity of benthic species followed by an increase in densities of aquatic worms

indicate pollution by organic matter.

Sampling station 1 has the highest species richness (S=9), abundance (n=325), and diversity index (H'=1.981). The abundance of species in station 1 is a result of the innovations mentioned in the Tourism Management Plan in Sampaloc Lake 2015-2020 which involves the construction of facilities and infrastructures such as the boardwalk. (Calanog, n.d.) The infrastructures which aim at promoting ecotourism also minimize the vulnerability of biodiversity to anthropogenic activities.

Sampling station 3 has the lowest species richness (S=4), abundance (n=25), and diversity index (H'=1.159). Station 3 is the most disturbed area since it is near to a recent project of the Department of Public Works and Highways entitled "Construction of Slope Protection Works at Sampaloc Lake, San Pablo City, Laguna" (Department of Public Works and Highways [DPWH], 2024).

Both Station 3 and 4 are abundant of Naididae. The stations experience a decrease in species richness and an increase in the number of aquatic worms which is an indication of organic pollution. Among the four stations, stations 3 and 4 are the most disturbed and polluted areas.

The overall status of macrobenthic fauna in Sampaloc Lake is **very low** with a diversity index of **H'=1.942**. A notable decrease in gastropod species richness and diversity index was also observed when comparing the data from Adorable-Asis et al. (2016) collected in July 2016 to the data from this study collected in July 2024. (see Appendix B)

Biotic indices are good indicators of habitat degradation. Farukuzzaman et al. (2023) described the Shannon-wiener biodiversity index as a consistent measure and sensitive indication of pollution. Sampaloc Lake's classification of water pollution level based on the value of diversity index falls under **"Moderately polluted"** (Setyono &

Himawan, 2018).

The current pollution level and degradation of water quality in Sampaloc Lake was supported by the Family Biotic Index result of **6.74**, which is indicative of **poor water quality**. Previous studies have reinforced the current classification. For instance, Dimzon et al. (2018) found organic contaminants (EOCs) such as pesticides (chlorpyrifos) and additional pollutants such as cypermethrin, picolinafen and quinoxyfen that were present in Sampaloc Lake. These chemical pollutants were said to be associated with farming, aquaculture, domestic, and eco-tourism activities. Among the seven crater lakes, it also has the highest ammonia levels with 2.22 ppm exceeding the recommended level of 0.05 ppm and 0.75 ppm phosphate level exceeding the recommended level of 0.5 ppm (Paller et al., 2021).

Moreover, elevated nutrient concentrations have been recorded in Sampaloc Lake, a trend linked to intensive aquaculture activities. Briddon et al. (2023) reported that nutrient concentrations were statistically lower in lakes with low levels of aquaculture, such as Yambo and Pandin Lakes, but significantly higher in those with intensive aquaculture practices. In a recent study comparing water chemistry data from the Laguna Lake Development Authority (LLDA) collected between 1996 and 2016 to samples taken in May 2017, elevated levels in key nutrient in Sampaloc Lake were found: phosphate ($P–PO_4^{3-}$) levels rose from 559.18 µg/L to 1086.43 µg/L, ammonia ($N–NH_3$) levels increased from 1338.54 µg/L to 1929.17 µg/L, and a slight increase in nitrate ($N–NO_3^-$) levels. Additionally, the lake exhibited a Chlorophyll-a concentration of 16.77 µg/L which is second highest among the seven crater lakes following Bunot Lake (Briddon et al., 2023).

Pollution and predation are one of the key factors that affect the abundance and diversity of organisms in the environment. Many organisms such as shrimps

(*Macrobrachium mammillodactylus*), and fishes (Snakehead gudgeon, silver perch, Nile tilapia, Jaguar guapote, and Midas Cichlids) are relying on the macrobenthos for food.

Midas Cichlids are opportunistic omnivores, and their food habit was primarily composed of mollusks and other benthic material (Anderson et al., 1984). The gut content analysis of Midas Cichlids (*Amphilophus citrinellus*) revealed that they are preying on macrobenthic fauna, however majority of the fishes studied rely on algae which could indicate that it is the most abundant food source in the lake ecosystem.

Briddon et al. (2023) observed that the nutrient concentration is increasing in Sampaloc Lake. When nutrient concentration exceeds the capacity of the ecosystem to absorb them it leads to an increase in biomass and algae. The increasing eutrophication is further shaping the diversity and structure of macrobenthic community. In fact, Zhou et al. (2024) unveil on their study that an increase in eutrophication leads to the decrease on abundance of the macrobenthic fauna. Polluted environment only allows pollution tolerant organisms to thrive. The possible reason why Naididae and Chironomidae are the most abundant macrobenthic organisms in Sampaloc Lake.

In addition to eutrophication, Zhang et al. (2023) found that high concentrations of ammonia are toxic for macrobenthos causing tissue damage which affects their health and survival capabilities. The toxic effects of ammonia on fish have been studied for over 50 years, however it was only found recently that aquatic invertebrates are most vulnerable to these contaminants. As reported by Paller et al. (2021), Sampaloc Lake has the highest ammonia level at 2.22 ppm, exceeding the recommended level.

Ammonia exists naturally in surface waters and wastewaters, and it is the primary waste product of fish. It is generated through protein catabolism or when

uneaten feed or other organic matter in an aquarium decomposes. High concentrations of ammonia in the water make it difficult for fish to excrete ammonia from their bodies, leading to toxicity and eventually causing death (Florida Department of Agriculture and Consumer Services, n.d.).

The Water Quality Report on Sampaloc Lake listed other possible sources of ammonia such as sewage and industrial waste. The relatively large amounts were from the discharge of liquid manure or through the leaching of fertilizers from the soil (Water Quality Report on Sampaloc Lake, 1996).

Prolonged exposure to high concentrations of ammonia has the most significant effect on the aquatic invertebrates' reproductive capacity and growth of offspring which led to population decline and reduction in species diversity. (Zhang et al., 2023) While humans and organisms at higher trophic levels are generally less sensitive to ammonia, prolonged exposure to water with over 1 mg/L (ppm) of ammonia may pose health risks, potentially affecting internal organs (Oregon Department of Human Services, 2000).

For an example, the Bureau of Fisheries and Aquatic Resources in Camarines Sur (BFAR) warns the public on consuming fish from a fish kill caused by high levels of ammonia. Ammonia can accumulate in fish tissues, making it unsafe for human consumption. Eating contaminated fish may lead to food poisoning or other health complications (BFAR 5 Regional Website, 2024).

Aside from high concentrations of ammonia, the presence of organic chemical pollutants in Sampaloc Lake recorded by Dimzon et al. (2018) pose risk to human health since they can also be absorbed by fish bodies and move up to higher trophic level. Exposure to the said pollutants would result in problems such as cancer, obesity, endocrine disruption, and other disorders (Ray & Shaju, 2023).

The pressing concerns in Sampaloc Lake, including threats to human health, food security, and overall ecosystem health demand immediate attention. These issues should urge all relevant agencies and sectors to evaluate the effectiveness and enforcement of existing programs and policies related to the management and zoning of aquaculture structures, particularly those mentioned in Memorandum Circular No. 2017-03 and the Comprehensive Land Use Plan (CLUP) of San Pablo City for 2015–2025.

Both management frameworks emphasize that all regulations must align with Republic Act 8550, or the Fisheries Code of the Philippines. It aims to reduce aquaculture coverage from 19% to 10% of the lake's total area. However, problems in Sampaloc Lake such as elevated nutrient concentrations, increasing eutrophication, and declining biodiversity continue to be largely attributed to intensive aquaculture practices.

Addressing the issues concerning Sampaloc Lake demands collaborative effort from various stakeholders in an Integrated Lake Management. For instance, the Sampaloc Lake Fish Farmer Marketing Cooperative (SLFFMC) has organized monthly clean-up drives since 2011 for the seven lakes of San Pablo. The cooperative coordinates with local fisherfolk and their families to conduct regular lake clean-ups (Villar, 2013).

In addition to these cleaning efforts, the use of bioremediation techniques can speed up the recovery of water quality. One technique that can be implemented involves the use of biofilters that utilize biological films (biofilms) composed of bacteria specifically nitrifying bacteria. These bacteria feed on specific pollutants in the water, improving the quality of polluted waters (Hammes & Juhna, 2011).

In Sampaloc Lake, the Rotary Club of San Pablo City initiated a Floating Garden

Filter (FGF) to remove pollutants such as excess nutrients using plants. The said project promotes a healthier and more balanced ecosystem (Tomandao, 2024).

By limiting anthropogenic pressures and adopting a holistic approach to lake management, the conservation and sustainable use of our finite natural resources will be possible.

XI. RECOMMENDATION AND CONCLUSION

Aiming for a more holistic sustainable lake management involves comprehensive monitoring of its biological indicators. Macrobenthic invertebrates are useful biological indicators in assessing the ecological status of Sampaloc Lake in San Pablo City, Laguna. A total of six hundred ninety (690) organisms that are divided into nine (9) taxa were retrieved from the study area. The most abundant taxon was Naididae which are effective indicators of water quality since they are usually found on organically polluted waters. Among the four stations, stations 3 and 4 have the highest abundance of Naididae indicating that they are the most disturbed and polluted areas.

The overall status of macrobenthic fauna in Sampaloc Lake is **very low,** with a biotic index of **H'=1.942**, corresponding to a water quality classification of **"Moderately polluted".** The pollution level was supported by the Family Biotic Index result of **6.74** with the verbal interpretation **"poor water quality"**.

Macrobenthos are vital to aquatic ecosystems by ensuring the stability of food chains and food webs as well as providing ecosystem services such as nutrient cycling. Many organisms in Sampaloc Lake such as shrimps and fishes are feeding on macrobenthic fauna.

The gut content analysis of Midas Cichlids identified as opportunistic omnivores and benthic feeders revealed that they do not rely heavily on macrobenthos. The majority of their diet is comprised mainly of algae, suggesting it is the most abundant food source in the lake ecosystem.

Higher concentrations of ammonia, nitrate, and phosphate have been documented in Sampaloc Lake which leads to an increase in algal biomass and eutrophication. In addition, ammonia levels in Sampaloc Lake exceeded the recommended level and were found to be toxic on macrobenthic fauna harming their

reproductive capacity and species diversity.

It is recommended to conduct more sampling to further assess the species composition of the macrobenthic fauna in Sampaloc Lake and to generate more conclusive data on the current biodiversity. It is also suggested to classify the organisms to the lowest possible taxa because due to the limitations to facilities and instruments arthropods, annelids, and micro mollusk were only classified by their families. In addition, correlational studies with the physico-chemical parameters and macrobenthic invertebrates are suggested. This might explain the diversity patterns of the fauna.

Moreover, the findings of this study should be used to start conservation measures and management strategies in Sampaloc Lake. Based on the results, authorities must assess the effectiveness and adherence to the management and zoning of aquaculture outlined in Memorandum Circular No. 2017-03 and the Comprehensive Land Use Plan (CLUP) of San Pablo City for 2015–2025. It is highly recommended to create a management plan based on Integrated Lake Management (ILM) which involves the active participation of various stakeholders, and bioremediation strategies, such as the development of biofilters. It would help address the increasing nutrient concentrations and mitigate eutrophication within the lake ecosystem.

Finally, this study should be replicated to the rest of the seven crater lakes or areas with similar conditions.

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Appendices

APPENDIX A

Approved Letter from the Tourism Office of San Pablo

Medjel B. Lopez
Brgy. San Ignacio
San Pablo City, Laguna, 4000
mblopez@up.edu.ph
09950062427

Tourism Office San Pablo
Doña Leonila Urban Park, City Hall Compound
San Pablo City, Laguna, 4000

Dear Sir/Ma'am,

I hope this letter finds you well. My name is Medjel B. Lopez, and I am a student from the University of the Philippines Open University. I am currently pursuing a research study on the macrobenthic fauna in Sampaloc Lake, San Pablo City. The purpose of this study is to take a biodiversity survey and account the number of species found on the area. Macrobenthic fauna or bottom dwelling invertebrates (e.g. insects, worms, etc.) can serve as biological indicators to assess the ecological status of the lake environment.

I am writing to seek your permission to conduct this research within Sampaloc Lake. Specifically, I would like to obtain samples or specimen within the shore or areas with shallow water. The study is expected to take place between July 6 to July 31.

I assure you that this study will adhere to all ethical guidelines, and no one will be harmed during the conduct of the study.

The findings of this research will contribute to the assessment of the water quality or ecological status of Sampaloc Lake. I am happy to share the results with your organization and discuss any potential collaboration or involvement you might find beneficial.

I would greatly appreciate your support and permission to carry out this research. Please let me know if you require any further information or if there are specific forms or procedures I need to follow to obtain your approval. Thank you for considering my request. I look forward to your positive response.

Attached here is a copy of my ID and enrollment form. Thank you!

Sincerely,

Received by: /
7/11/24

Medjel B. Lopez
Brgy. San Ignacio
San Pablo City, Laguna, 4000
mblopez@up.edu.ph
09950062427

APPENDIX B

Comparison of Gastropod Diversity in Sampaloc Lake from the July 2016 to July 2024 Data

Taxa	July 2016	July 2024
Family Ampullaridae		
Pomacea canaliculata	158	
Family Lymnaeidae		
Bullastra cumingiana	26	
Family Pachychilidae		
Jagora asperata	1	
Physastra hungerfordiana	19	
Family Thiaridae		
Melanoides maculata	45	
Melanoides tuberculata	67	74
Melanniodes cf turriculus	42	
Tarebia granifera	17	97
Plotia scabra	44	15
Thiara winteri	27	
Family Viviparidae		
Cipangopaludina chinensis	136	
Filopadulina javanica	28	
Family Physidae		
Physella acuta		7
Family Planorbidae		72
Family Stenothyridae		115
Abundance	**610**	**380**
Richness	**12**	**6**
H'	**2.126**	**1.545**

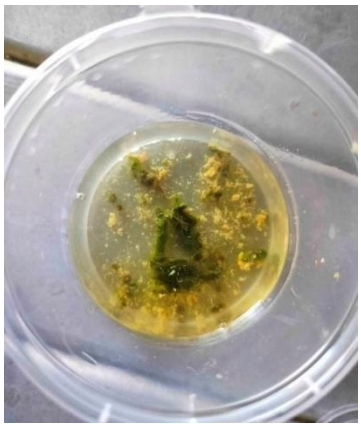
APPENDIX C

Length, Weight, and Gut Weight of Midas Cichlids

Fish	Length (cm)	Weight (g)	Gut Weight (g)
1	176 cm	89.6 g	4.5 g
2	108 cm	20.9 g	1.1 g
3	110 cm	21.3 g	1.2 g
4	183 cm	101.4 g	4.7 g
5	137 cm	45.7 g	2.6 g
6	126 cm	32.1 g	1 g
7	104 cm	26.2 g	1.8 g
8	120 cm	29.3 g	1.5 g
9	124 cm	30.3 g	2 g
10	102 cm	21.8 g	1.2 g
11	106 cm	21.8 g	1.1 g
12	106 cm	22.6 g	1.2 g

APPENDIX D

Gut Contents of Midas Cichlids

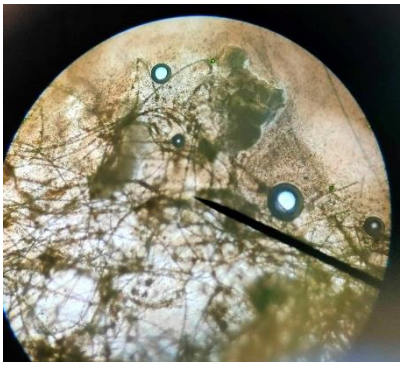




Stomach with algae



Stomach with fish scale



Macroalgae and microalgae

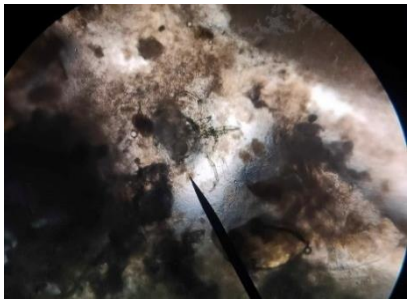


Fish scale

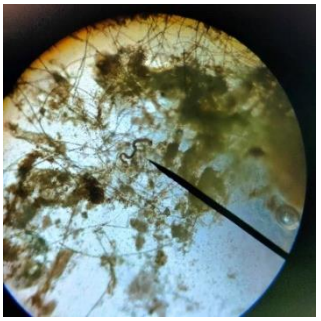


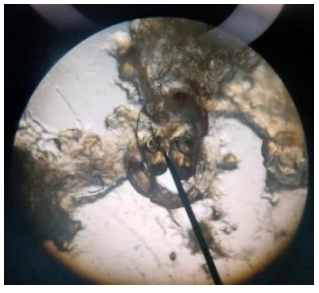
Worms



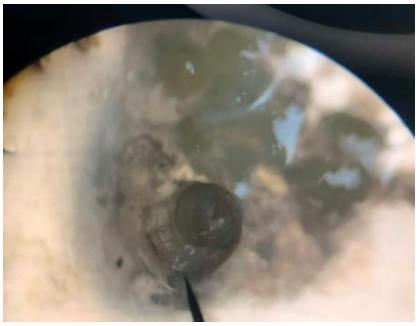


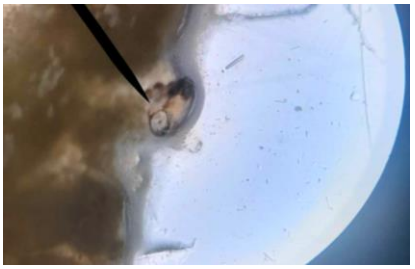
Insects





Larvae





Mollusk