INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 26, No. 5, p. 119-128, 2025
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Layawan River, Polanco, Zamboanga Del Norte, Philippines: Resource utilization, environmental issues and water quality

Princess Krishyll B. Andong*[1], Christine Marie V. Casal[2], Wella T. Tatil[1], Armi G. Torres[1]

[1]*Department of Environmental Science, School of Interdisciplinary Studies, Mindanao State University, Iligan Institute of Technology, Tibanga, Iligan City, Philippines*

[2]*School of Environmental Science and Management (SESAM), University of the Philippines Los Baños, Philippines*

Article published on May 09, 2025

Key words: Freshwater, Layawan river, Utilization, Environmental issues

Abstract

The Layawan River is a vital freshwater ecosystem in Polanco, Zamboanga del Norte, Philippines. The Integrated Watershed Management Plan of Layawan River targets to establish conservation and protection efforts. However, information crucial for its management and conservation remains scarce. This study assessed the resource utilization, environmental issues and water quality along the lower reaches of Lawayan River in Polanco. The river supports subsistence fisheries and sand-gravel quarry industry and provides water for agricultural (irrigation) and domestic (cleaning, washing clothes, and bathing) use. Along with its contribution to the community lies the associated threats it faces. It is mainly threatened by unregulated disposal of garbage, sand and gravel quarry, and open defecation. While majority of the water quality parameters passed the national standard, concerns arise with its high phosphates, total suspended solids (TSS) and total coliform counts. Phosphates readings from 0.099 to 0.144 mg/L failed the 0.025 mg/L threshold, indicating excessive nutrients. TSS values reached up to 109 mg/L, exceeding the 50 mg/L limit. Total coliform counts ranging from 3,700 to 35,000 MPN/100 mL are appalling, indicating potentially extreme fecal contamination and posing health risk to the public. Efforts for sustainable management of Layawan River should focus on strict implementation and enforcement of environmental laws (e.g., R.A. 9275 Clean Water Act; R.A. 9003 Ecological Solid Waste Management), monitoring of water quality, IEC campaigns to raise the level of awareness and participation of the community, reforestation of riparian zones, and mitigation measures to address the potential health risk to the public.

***Corresponding Author:** Princess Krishyll B. Andong ✉ princesskrishyll.andong@g.msu.iit.edu.ph

Introduction

Rivers are significant in all aspects, whether historically, culturally, biologically, or geologically (Cuivillas *et al.*, 2016), and are essential to human survival (Basak *et al.*, 2021).

Living in a world with diminishing freshwater resources impacts human well-being and affects vital life-support systems at our end (Albert *et al.*, 2021). Having healthy rivers is crucial (Grill *et al.*, 2019), for it is considered the lifeblood of humans (Basak *et al.*, 2021).

The first-ever worldwide evaluation of the planet's surviving free-flowing rivers found that one-third (37%) of the world's longest rivers remain free-flowing, highlighting severe ecological degradation (Grill *et al.*, 2019). The State of Global Water Resources Report 2022 also revealed that the global catchment areas display an alteration from normal conditions and are observed as drier than usual (World Meteorological Organization, 2023).

Nearly 27% of freshwater species are in danger of extinction, and the rate of wetland loss, which includes rivers, is three times faster than that of forest decline (Stefanidis and Papastergiadou, 2024). In recent studies, 25% of the world's freshwater fauna, including fish, are threatened with extinction (Sayer *et al.*, 2025). However, despite their essential contribution to the well-being of humans and their necessity to global biodiversity (Darwall *et al.*, 2018), freshwater ecosystems are deemed to have less research embarking and conservation efforts when compared to both terrestrial and marine environments (Escatron *et al.*, 2022). Hydrological alterations, overexploitation, habitat degradation and loss, pollution, invasive species, and the multiple impacts of climate change are a few of the causes of these freshwater declines (Darwall *et al.*, 2018; Sayer *et al.*, 2025).

The growing human population and socioeconomic activities are the major contributors to the rising nutrient loads and pollutants, leading to severe deterioration of water quality across different countries worldwide (Albert *et al.*, 2021). Changes brought about by humans also significantly impact the provision of ecosystem services, which affects human welfare. Hence, conservation management must be implemented to enhance biodiversity, ecological quality, and the availability of clean water and other ecosystem services for human use (Stefanidis and Papastergiadou, 2024). River evaluation and threat identification are essential to rehabilitate and protect them adequately (Magbanua *et al.*, 2023).

Bohnet (2014) highlights that public perception and awareness of clean water are considered requisite parts of effective water resource management. To safeguard our freshwater ecosystem effectively, monitoring and managing it fairly to identify contaminants, address and control their effects, and assess the effectiveness of the existing environmental policies and protection programs for welfare and well-being is important.

In the Philippines, Layawan River is considered one of the sub-watersheds and serves as the primary source of sand and gravel in Zamboanga del Norte. In 2008, the Environmental Management Bureau (EMB) Region 9 classified Layawan River as a Class A water body. A Class A classification is a Public Water Supply Class II intended as sources of water supply requiring conventional treatment (coagulation, sedimentation, filtration, and disinfection) to meet the latest Philippine National Standard for Drinking Water (DENR Administrative Order No. 2016-08). Cuivillas *et al.* (2016) found that the river's water quality may be treated for potable use and is generally safe for recreational uses like swimming and bathing.

Human interventions over the years significantly contributed to the state of the Layawan River, making it a critical freshwater ecosystem. According to the Integrated Watershed Management Plan of Layawan River (IWMP), one

of its goals is to establish a dependable environmental conservation and protection measure in response to the need for the earth's global biosphere rehabilitation. However, there are limited studies on the current environmental condition of Layawan River. This study aimed to address these gaps by assessing the current utilization, threats, and water quality of the Layawan River, Zamboanga del Norte. This also provides valuable insights for improving the existing management strategies and policies of the Layawan River and ensuring that Layawan River is managed sustainably to maintain its biodiversity, secure this multiple-use resource for future generations, and prevent health risks to the community. This assessment aligns with the Sustainable Development Goal (SDG) 6.6, which seeks to protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers, and lakes. Additionally, it supports SDG Target 15.1, which focuses on conserving and restoring the terrestrial and freshwater ecosystem for sustainable use.

Materials and methods

Study area

The Layawan River is a stream in the Philippines' Zamboanga Peninsula in the Province of Zamboanga del Norte, with thirteen meters of estimated terrain elevation above sea level (Fig. 1). From Mt. Malindang in Misamis Occidental, the Layawan River travels to Sergio Osmeña and then to the Municipalities of Piñan and Polanco in Zamboanga del Norte, where it meets the Dipolog City River. This study was conducted in the lower reaches of the Layawan River in Polanco, Zamboanga del Norte. It traverses 13 barangays, namely De Venta Perla, Linabo, Macleodes, San Pedro, New Sicayab, Bethlehem, Dansullan, Lapayanbaja, Silawe, Labrador, Poblacion South, and Poblacion North.

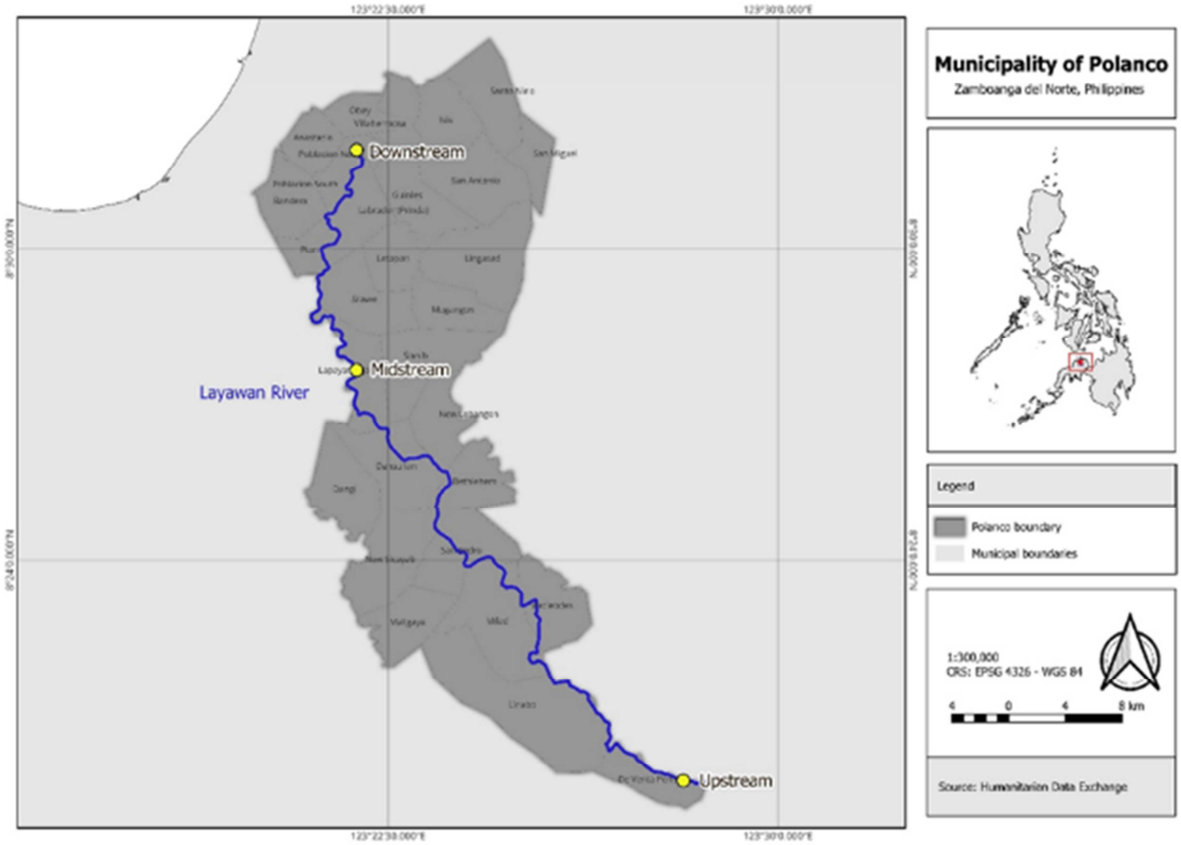

Fig. 1. Map of the study area in Layawan River, Polanco, Zamboanga del Norte, Philippines

Entry protocol and reconnaissance of the study area

A study permit was obtained from the local government unit through the Municipal Environment and Natural Resources Office (MENRO) in Polanco, Zamboanga del Norte.

Courtesy calls were made to the Mayor of the Municipality of Polanco and the barangay captains of the covered barangays. An ocular assessment was done to identify the appropriate sampling sites along the river and acquire an overview of river activities. Three sampling stations were chosen: upstream, midstream, and downstream within Polanco, Zamboanga del Norte.

Research design and data collection

Resource utilization and environmental issues

This study employed a descriptive-qualitative research design to assess the existing resource utilization and environmental issues along the lower reaches of the Layawan River. A combination of Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) was utilized to gather qualitatively relevant data. The KII comprised nine respondents, and the FGD comprised 15 local participants.

Key Informant respondents were selected stakeholders representing different government offices (Municipal Agriculture Office, Committee for Environmental Protection, Municipal Planning and Development Office, Municipal Environment Office, Office of the Barangay Captain), fishermen's sector, and private sector (Polanco Water District). Informants were chosen based on their roles and contributions to the Layawan River. The interview was conducted using a questionnaire divided into sections that included utilization of resources, environmental issues and threats, and the respondents' profiles**.**

On the other hand, the Focus Group Discussion was conducted at the Municipal Hall of Polanco, Zamboanga del Norte, with representatives from barangays through which the river traverses. The FGD participants were distinct from the KII respondents to ensure a diverse range of perspectives. FGD participants comprised local individuals directly benefiting from the Layawan River, including barangay officials, fishermen, residents, and youth representatives. Their insights contributed to a comprehensive understanding of the river's current state and informed strategic conservation measures. The discussion activities included resource mapping, problem and issue identification, and needs assessment with priority ranking. Resource mapping provided documentation of the resources found along the river that helped stakeholders visualize the distribution and utilization of the resources. Resources include flora and fauna like fish species, native vegetation, and biodiversity hotspots.

Furthermore, infrastructures in the area were also recorded, such as dams, irrigations, bridges, and waste disposal facilities. Problem and issue identification focused on assessing the key challenges local communities face over the past 5-10 years. This included environmental concerns such as pollution both in agriculture and domestically, loss of biodiversity, deforestation, and erosion. On the other hand, water-related issues encompass water quality.

After identifying the key issues, they were then categorized according to their severity of impact, such as how critical the issue is towards the environment and the community's well-being. It was based on public perceptions and urgency as perceived and evaluated by the residents. Finally, suggestions on how to address these issues were solicited from the participants.

Water quality analysis

Sampling for water quality analysis was done once a month in December 2024 and March 2025. Temperature, pH, and salinity were measured directly at the three sampling sites using a multiparameter digital water quality tester with three replicates for each parameter. Water transparency was determined using a Secchi disk, and color was visually observed at each sampling location. Water samples for phosphates, total suspended solids, dissolved oxygen,

and total coliform were collected using three replicates for laboratory analysis. The collected samples were transported to the Environmental Management Bureau, Dipolog Satellite office, as soon as possible to maintain appropriate conditions during transportation and prevent changes in sample composition.

The data for all physicochemical parameters were compared to the standards outlined in the DENR Administrative Order (DAO) 2016-08 and DENR Administrative Order 2021- 19 and DOH 2017-01.

Data analysis

Primary data, such as results from the conducted key informant interviews and focus group discussion employing the three activities (Resource mapping, problem and Issue identification, needs assessment, and ranking), were analyzed descriptively. The analysis focused on distinguishing the trends and common concerns covering the various stakeholders and emphasizing insights that will encompass the lived experiences of the community, which plays a vital role in gaining a clear understanding of the present situation of Layawan River.

The physicochemical parameters of the Layawan River were analyzed and compared to the water quality standards set by DENR Administrative Order 2016-08, DENR Administrative Order 2021-19, and Department of Health Administrative Order 2017-01.

Results and discussion

Resource utilization of Layawan river

The Layawan River is a multiple-use resource, contributing various benefits to the community of Polanco, Zamboanga del Norte, as shown in Table 1.

Table 1. Resource utilization of Layawan river

Activities	Goods and services	Respondents (%)
Fishing	Fishes	100
	Shrimps	
Quarry	Sand and gravel	88.9
Water extraction	Water for farm irrigation	55.6
	Water for domestic use	100
Swimming	Recreation	77.8
Navigation	Transportation	0

Key informants revealed that through the years, the Layawan River has served as a home for vital resources for the local community, providing a fishing ground, sand and gravel resources, and water sources for agricultural use specifically for irrigation and domestic use such as for cleaning, bathing, swimming, and washing clothes. Highlighting that the river supports a wide array of freshwater species, with 100% of the respondents considering the Layawan River as a fishing ground for fish and shrimps. Local fishermen can benefit the most from these resources as they can rely on them for food, greatly helping them achieve food security. It is also considered the primary source of sand and gravel by most of the respondents (88.9%). The majority of the respondents (55.6%) indicated that the river was used for irrigation, aiding farmers to maintain moisture for crop growth. It also supports domestic use, with 100% of the respondents saying so, as locals use it for bathing, swimming, and cleaning. The river today is not being used for navigation.

Environmental issues in Layawan river

Over time, key informants have observed significant changes occurring in the river. Compared to its previous state, the Layawan River faces multiple pressures as shown in Table 2.

Table 2. Environmental issues in Layawan River

Environmental issues	Respondents (%)
Sand and gravel quarry	77.8
Erosion	66.7
Cutting of trees	55.6
Flooding	55.6
Pollution (i.e., piggery and pesticides)	44.4
Illegal fishing (i.e., pagpangati, electrofishing)	11.1

Most of the KII respondents (77.8%) have identified sand and gravel quarry as the pressing environmental issue along with erosion (66.7%), which results in habitat destruction, biodiversity loss, decreased water levels, changes in river morphology, and the loss of local livelihood. Majority of the respondents (55.6%) claimed that their community experienced flooding and illegal cutting of trees. A considerable number of

respondents (44.4%) perceived that pollution threatens the integrity of the river. A significant portion of the informants (66.7 %) stated that they have experienced and observed these changes first-hand. During the FGD, six environmental issues were recognized by the participants (Table 3).

Table 3. Ranking of environmental issues in layawan river identified by FGD participants

Environmental issue	Rank
Unregulated disposal of garbage	1
Sand and gravel quarry	2
Open defecation	3
Illegal fishing (Pagpangati, electrofishing)	4
Pollution (piggery and pesticides)	5
Cutting of trees	6

Only four issues were commonly identified in the KII and FGD. Specifically, unregulated disposal of garbage and open defecation were known as among the pressing environmental issues in the river during the FGD. Participants in the FGD were asked to rate the priority ranking of various environmental issues (Table 3). The ranking was based on the perceived severity or urgency, with one being the most critical.

Holding rank one is the unregulated disposal of garbage. The throwing of household and personal wastes and the dumping of dead animals into the river contribute to pollution in the area. These practices were observed by the stakeholders from every area of the river. The typical litter they identified were plastic wrappers of detergents and powders, soaps, and food packaging. Dumping of dead animals was also rampant. They have observed several incidents in which they witnessed animals being carried out through the river's flow. These wastes contribute to pollution in the river, impacting water quality, which can threaten aquatic life. Second is the continuous extraction of sand and gravel in the river. As extraction is located in the lower stream of the Layawan watershed, Polanco will naturally receive all the accumulated sediments from upstream, leading to shallower water levels. Although it cannot be denied that river sediment extraction alters the morphology of the river and disrupts freshwater biota, it is also commonly the cause of the reduction of river flow in some areas, contributing to the increase in turbidity, collapse of riverbanks, and increased flood risks because it lowers the riverbed bed so much. Open defecation, holding rank 3, was also an issue, with locals often using the river as a toilet, potentially yielding severe water contamination problems and the possible spread of waterborne diseases. Participants pointed out that because not all houses have toilets, locals use the river for defecation. A study by Xie *et al.* (2022) stated that sewage discharge, in general, has been shown to increase pathogenic bacteria in rivers, and such practices affect the condition of the river. With the current population of Polanco at approximately 42,000, sanitation may be included as a crucial issue.

Moreover, the widespread use of non-traditional and potentially harmful fishing techniques is in rank 4. The application of chemical substances or physical stunning methods has been observed. Participants noted that most fishermen use these fishing methods to catch fish faster. These practices are non-selective in nature, posing threats to aquatic life, leading to mortality at varying developmental stages, injuries, and stress (Young *et al.*, 2023; Carneiro and Martins, 2022; Jawad, 2021; Wu *et al.*, 2021; Abbas and Aylan, 2020). In addition, agricultural pollution is a challenging issue. Pesticides were used in nearby farms that flow to the river as run-off, leading to water contamination and affecting aquatic life and water quality. Additionally, piggery waste was a common issue in these three sampling areas. The discharge of wastes from pig farms introduces pathogens and organic pollutants that may result in eutrophication and alter the condition of water. In the study of Ferreira *et al.* (2022), manure overapplication to agricultural soils leads to the discharge of phosphorous and nitrogen into the aquatic environment, causing a severe decline in water quality and eutrophication problems. Another pressing concern is the cutting of trees. The adverse impact of cutting trees causes erosion and soil loss, which subsequently promotes sedimentation in rivers that reduces biodiversity (Boyle, 2025).

The informants made significant suggestions in order to address these pressing issues, including crafting ordinances, policy, and legislation (22.2%), conducting orientation and seminars for locals for information dissemination (22.2%), seasonal extraction of sand and gravel (22.2%), and filing a petition to stop mining (11.1%) as shown in Table 4. There are 22.2% of the respondents who didn't give any suggestions to address these issues.

Furthermore, the Layawan stakeholders have identified relevant institutions and government agencies responsible for implementing, monitoring, providing funding, and crafting policies and ordinances to address these various environmental issues along Layawan River (Table 4). These include the Department of Environment and Natural Resources, Municipal Sanitary Office, Local Government Unit, Barangay Local Government Unit, Municipal Health Office, and the Department of Agriculture. Conducting seminars and creating and enforcing ordinances were suggested to address unregulated disposal of garbage and quarry operations.

Stopping the quarry operations was further endorsed. Building a common toilet was recommended to prevent and eliminate open defecation. Implementing and enforcing ordinances to combat illegal fishing practices and pollution was proposed. Reforestation of the riparian zones was also put forward.

Table 4. Suggested solutions to address environmental issues in Layawan River

Environmental Issue	Suggested solutions	Institution/Agency
Unregulated disposal of garbage	Conduct Seminars, Pass Ordinances, Imprisonment	DENR, Municipal Sanitary Office, BLGU
Sand and gravel quarry	Conduct Seminars, Pass Ordinances, Stop Operation	DENR, LGU, BLGU
Open toilet	Build Common Toilet	MHO, BLGU
Illegal fishing (Pagpangati, Electrofishing)	Ordinances	BLGU
Pollution (Piggery and Pesticides)	Ordinances	BLGU
Cutting of trees	Reforestation	DENR, DA, BLGU

As stipulated in the IWMP of the Layawan River the Department of Environment and Natural Resources (DENR) alone cannot address the wide range of issues found in the Layawan River. It should be collaborative and likewise initiated by other national government agencies and partners such as the Department of Agriculture (DA), Department of Social Welfare and Development (DSWD), Department of Public Works and Highways (DPWH), Department of Agrarian Reform (DAR), National Irrigation Authority (NIA), Municipal Local Government Unit (LGU) and Barangay Local Government Unit (BLGU) including NGOs. They must work together towards sustainable management of the Layawan River.

Water quality

The results of water quality are presented in Table 5. The physicochemical parameters of the Layawan River were compared to the water quality standards set by DENR Administrative Order 2016-08, DENR Administrative Order 2021-19, and DOH 2017-01.

The observed temperature, ranging from 28.3°C to 29.3°C, falls within the acceptable limit of 26–30°C, indicating a stable environment for aquatic life. Phosphate levels, measured between 0.099 and 0.144 mg/L, remain below the 0.025 mg/L minimum requirement, suggesting excessive nutrients and risk of eutrophication. Dissolved oxygen (DO) levels, ranging from 7.7 to 8.8 mg/L, were above the minimum standard of 5 mg/L at all monitoring stations. These high DO concentrations reflect a well-oxygenated environment conducive to sustaining aquatic organisms. Similarly, the pH values, between 7.84 and 8.39, were within the acceptable range, indicating a balanced level of acidity and alkalinity across the river.

Table 5. Physico-chemical parameters of Layawan river

Parameters	Unit	Station 1 (Upstream)	Station 2 (Midstream)	Station 3 (Downstream)	DENR and DOH Water quality standards (DAO 2016-08, DAO 2021-19 & DAO 2017-01)
Temperature	°C	28.4	28.3	29.3	26-30
Phosphates	mg/L	0.099	0.105	0.144	0.025
Dissolved oxygen	mg/L	8.8	8.1	7.7	5(minimum)
Total suspended solids	mg/L	7.67	109	34.7	50
pH		8.39	8.07	7.84	6.5-8.5
Salinity	ppm	0.19	0.07	0.07	-
Transparency	inch	29.5	9.3	26.1	-
Total coliform	MPN/100mL	3700	35000	7236.7	0*

*applies to drinking water

However, concerns arise with the Total Suspended Solids (TSS), particularly at the midstream (Station 2), where the value reached 109 mg/L, exceeding the 50 mg/L standard.

The high TSS level might be attributed to the sediments brought down by the water current from the upstream due to heavy rainfall during the sampling time. Regarding bacteriological quality, total coliform counts range from 3700-35000 MPN/100mL, indicating potentially extreme contamination linked to human and animal waste. Among the three stations, the midstream area (Station 2) is the degraded area, marked by the highest TSS and coliform counts alongside the lowest transparency.

Conclusion

The Layawan River is integral to the community's striving and functioning. It highlights its crucial role in providing a wide array of goods and services. It supports locals in Polanco by providing fishing grounds, sources of sand and gravel, and water for agricultural (irrigation) and domestic use (cleaning, washing clothes, and bathing).

However, the study revealed that the Layawan River is under threat, mainly due to the unregulated disposal of garbage, sand, and gravel quarry, and open defecation nowadays. While the majority of the water's physicochemical parameters are within the acceptable threshold, the high phosphate levels, excessive suspended solids, and alarmingly high coliform counts convey an important environmental concern. If these persist, this will lead to more extensive work in the future, affecting the general public's health and the river's integrity.

The results underscore the need to make a collective effort, from the people who live in the community to the national and local government units and other stakeholders. This study recommends the following: implementation and enforcement of environmental laws such as the Clean Water Act (R.A. 9275) and Ecological Solid Waste Management; rehabilitation of Layawan River; establishment of IEC campaign program to reinforce the community's understanding of their role in managing Layawan River; regular monitoring of water quality; reforestation of the riparian zone. Furthermore, this study suggests that LGU, in collaboration with other government agencies, should develop mitigation measures to address the health risk of the public due to high coliform contamination.

Acknowledgements

The first author would like to thank the Department of Science and Technology-Accelerated Science and Technology Human Resource Development Program (DOST-ASTHRDP), Philippines for the graduate research grant. I also thank the Local Government Unit (LGU) of Polanco for allowing me to conduct the study. Special thanks to my co-research team, the residents and local fishermen of Polanco, and to Rhabbie Quilona, Novalyn Quilona, Jerico Ballares, Jake Pedrabuena, Anylin Sanchez, Jared Andong, Richelle Cabañog, Kirby Garcia and Princess Estrada for their support during the field sampling.

References

Abbas AF, Aylan RA. 2020. Effect of electrofishing on some fish species in Qarmat Ali River and East Hammar marsh, Basrah, Iraq. MARSH BULLETIN **15**(2), 117–126.

Albert JS, Destouni G, Duke-Sylvester SM, Magurran AE, Oberdorff T, Reis RE, Winemiller KO, Ripple WJ. 2020. Scientists' warning to humanity on the freshwater biodiversity crisis. Ambio **50**(1). https://doi.org/10.1007/s13280-020-01318-8

Basak SM, Hossain MS, Tusznio J, Grodzińska-Jurczak M. 2021. Social benefits of river restoration from an ecosystem services perspective: A systematic review. Environmental Science and Policy **124**, 233–243. https://doi.org/10.1016/j.envsci.2021.06.005

Bohnet IC. 2025. Lessons learned from public participation in water quality improvement planning: A study from Australia. Society and Natural Resources **28**(2), 180–196. https://doi.org/10.1080/08941920.2014.941446

Boyle R. 2023. How does deforestation speed up the process of soil erosion? www.emission-index.com. https://www.emission-index.com/deforestation/soil-erosion

Carneiro M, Martins R. 2022. Destructive fishing practices and their impact on the marine ecosystem. Encyclopedia of the UN Sustainable Development Goals, 295–304. https://doi.org/10.1007/978-3-319-98536-7_10

Cuivillas DA, Naguit MR, Cuivillas A. 2016. Physico-chemical characterization of Layawan River. IOSR Journal of Environmental Science, Toxicology and Food Technology **10**(6), 69–75. https://doi.org/10.9790/2402-1006026975

Darwall W, Bremerich V, De Wever A, Dell AI, Freyhof J, Gessner MO, Grossart H-P, Harrison I, Irvine K, Jähnig SC, Jeschke JM, Lee JJ, Lu C, Lewandowska AM, Monaghan MT, Nejstgaard JC, Patricio H, Schmidt-Kloiber A, Stuart SN, Thieme M. 2018. The Alliance for Freshwater Life: A global call to unite efforts for freshwater biodiversity science and conservation. Aquatic Conservation: Marine and Freshwater Ecosystems **28**(4), 1015–1022. https://doi.org/10.1002/aqc.2958

Department of Economic and Social Affairs. n.d. Thriving and resilient rivers for future generations – Addressing the global water challenges. United Nations Sustainable Development Goals. https://sdgs.un.org/partnerships/thriving-and-resilient-rivers-future-generations-addressing-global-water-challenges

Department of Environment and Natural Resources (DENR). 2016. Water quality guidelines and general effluent standards of 2016 (DAO 2016-08). Philippines: DENR.

Department of Environment and Natural Resources (DENR). 2019. Updated water quality guidelines (WQG) and general effluent standards (GES) for selected parameters (DAO 2021-19). Philippines: DENR.

EMB-IX. State of Water – EMB.

Escatron MJ, Villamor V, *et al.* 2022. Water quality assessment of Surigao River, Surigao City, Philippines. Journal of Entomology and Zoology Studies **10**(5A), 38–45. https://doi.org/10.22271/j.ento.2022.v10.i5a.9038

Ferreira A, Figueiredo D, Cardeiras R, Nabais R, Ferreira F, Ribeiro B, Cordovil CMS, Acién FG, Gouveia L. 2022. Exploring different pretreatment methodologies for allowing microalgae growth in undiluted piggery wastewater. Agronomy **12**(3), 580. https://doi.org/10.3390/agronomy12030580

Grill G, Lehner B, Thieme M, Geenen B, Tickner D, Antonelli F, Babu S, Borrelli P, Cheng L, Crochetiere H, Ehalt Macedo H, Filgueiras R, Goichot M, Higgins J, Hogan Z, Lip B, McClain ME, Meng J, Mulligan M, Nilsson C. 2019. Mapping the world's free-flowing rivers. Nature **569**(7755), 215–221. https://doi.org/10.1038/s41586-019-1111-9

Magbanua FS, Hilario JE, Salluta JCRB, Alpecho BC, Mendoza SS, Lit IL. 2023. Freshwater biomonitoring with macroinvertebrates in the Philippines: Towards the development of the Philippine biotic index. Limnologica **102**, 126098. https://doi.org/10.1016/j.limno.2023.126098

Municipality of Polanco. n.d. Integrated Watershed Management Plan of Layawan River. Local Government Unit of Polanco, Zamboanga del Norte, Philippines.

Sayer CA, Fernando E, Jimenez RR. 2025. One-quarter of freshwater fauna threatened with extinction. Nature **638**, 138–145. https://doi.org/10.1038/s41586-024-08375-z

Stefanidis K, Papastergiadou E. 2024. Ecological monitoring and assessment of freshwater ecosystems: New trends and future challenges. Water **16**(11), 1460–1460. https://doi.org/10.3390/w16111460

World Meteorological Organization. 2023. State of Global Water Resources 2022. https://wmo.int/publication-series/state-of-global-water-resources-2022

Wu A-P, Ye S-Y, Wang Y-H, Cao T, Liu L, Zhong W, Qi L-Y, Deng Q-Y, Hu C-T. 2021. Electrofishing is a potential threat to the growth and metabolism of three submerged macrophytes. Marine and Freshwater Research **72**, 376–382.

Xie Y, Liu X, Wei H, Chen X, Gong N, Ahmad S, Lee T, Ismail S, Ni S-Q. 2022. Insight into impact of sewage discharge on microbial dynamics and pathogenicity in river ecosystem. Scientific Reports **12**(1), 6894. https://doi.org/10.1038/s41598-022-09579-x

Young RT, Boase JC, Buszkiewicz JT, Dean JC, McCarter JT. 2023. Field evaluation of electrofishing response thresholds for adult Grass Carp. North American Journal of Fisheries Management **43**(3), 859–868. https://doi.org/10.1002/nafm.10899