

Gastropod Diversity and Physicochemical Water Analysis in the Selected Rivers of Mount Apo Natural Park

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ABSTRACT

This study examined freshwater gastropod diversity and its relationship with physicochemical water conditions in the Digos, Goma, and Balutakay Rivers of Mount Apo Natural Park. A descriptive nonexperimental quantitative design was used. Spatial random sampling was conducted in upstream, midstream, and downstream sections during September and October 2023. Gastropods were collected through 100-m belt transects, randomly positioned 1 × 1 m quadrats, handpicking, and sieving, while temperature, pH, electrical conductivity, turbidity, dissolved oxygen, and total dissolved solids were measured in triplicate. Diversity indices were computed using Paleontological Statistics software, and Pearson correlation was used to test associations between gastropod diversity and water properties. Eighteen species comprising 981 individuals were documented.

Balutakay River downstream had the highest richness and abundance ($S = 10$, $N = 893$), with Shannon $H = 1.509$, Brillouin = 1.479, electrical conductivity = 683.22 $\mu\text{S/cm}$, total dissolved solids = 341.89 mg/L, and turbidity = 37.73 NTU. Digos River upstream and Goma River downstream each had only two taxa and two individuals. Taxa, abundance, Brillouin, and Chao-1 were positively correlated with electrical conductivity and total dissolved solids, whereas evenness was negatively correlated with both parameters. *Neritina pulligera*, *Pomacea canaliculata*, *Faunus* sp., *Thiara scabra*, and *Melanoides maculata* emerged as potential bioindicators. The findings demonstrate that nutrient and ionic conditions can increase richness and abundance while promoting dominance by tolerant species, supporting the use of gastropods in river monitoring and conservation education.

Keywords: freshwater gastropods, biodiversity indices, bioindicators, water quality, Mount Apo Natural Park, physicochemical parameters

INTRODUCTION

Freshwater gastropods are ecologically important benthic organisms that contribute to decomposition, nutrient cycling, algal grazing, and food-web functioning. Their limited mobility and sensitivity to changes in water chemistry make them useful biological indicators of freshwater condition (Afwanudin et al., 2019; Bae & Park, 2020; Tallarico, 2015). Changes in species richness, abundance, dominance, and community composition may therefore reveal ecological stress that cannot be captured through a single physicochemical measurement.

Gastropod assemblages respond to habitat structure, flow, substrate, vegetation, temperature, pH, dissolved oxygen, electrical conductivity, turbidity, and total dissolved solids. Niche theory explains these patterns by proposing that species occur where environmental conditions and resource availability fit their physiological tolerance and ecological role (Cardinale, 2011; Gümüş et al., 2022). Consequently, river sections with apparently similar water conditions may support different communities because of variation in nutrient availability, substrate complexity, disturbance, and species tolerance.

Mount Apo Natural Park is a protected area and critical watershed that supports communities, agriculture, biodiversity, and multiple river systems. Nevertheless, its aquatic habitats are exposed to agricultural expansion, land conversion, settlement, sedimentation, and possible pollution. Baseline information on freshwater invertebrates remains limited despite the park's biodiversity and watershed importance (ASEAN Centre for Biodiversity, 2024).

Previous Philippine studies have documented relationships among gastropod communities, river habitat, and water quality in Bukidnon and Pangasinan (Galan et al., 2015; Velasco et al., 2018). However, the Digos, Goma, and Balutakay Rivers had not been comparatively assessed using multiple diversity indices and a common set of physicochemical parameters. Establishing such information is necessary for identifying high-diversity areas, detecting potentially disturbed sections, and supporting community-based monitoring.

This study identified and quantified gastropods in the three selected rivers, evaluated their diversity using richness, abundance, Shannon, Simpson, evenness, Brillouin, and Chao-1 measures, described six physicochemical water parameters, tested the relationships between biodiversity and water conditions, and developed an information, education, and communication material based on the findings.

Literature Review

Freshwater Gastropods as Bioindicators

Bioindicators provide evidence of environmental quality through the presence, absence, abundance, or condition of organisms. Freshwater gastropods are particularly useful because many species are closely associated with the substrate and cannot rapidly escape unfavorable conditions. Their assemblages may therefore integrate the effects of pollution, habitat alteration, and water-quality variation over time (Johnson et al., 2013; Srivastava & Singh, 2020).

Sensitivity differs among taxa. Some neritids are associated with rocky, well-oxygenated streams, while invasive apple snails and several thiarids tolerate nutrient-rich or disturbed conditions. The expansion of *Pomacea canaliculata* illustrates how highly adaptable species can occupy new environmental niches and alter native freshwater communities (Feng et al., 2023). Bioindicator interpretation must therefore consider both diversity and the ecological tolerance of dominant species.

Studies from the Philippines and neighboring countries have linked gastropod composition to vegetation, substrate, flow, dissolved materials, and anthropogenic disturbance. Galan et al. (2015) found that muddy substrate, riparian vegetation, and shallow-water algae supported greater abundance, while Velasco et al. (2018) reported higher diversity where vegetation and habitat complexity were more favorable.

Measurement of Gastropod Diversity

Species richness describes the number of taxa, whereas abundance records the number of individuals. Diversity indices combine richness and the proportional distribution of individuals. Shannon diversity increases when communities contain more taxa with relatively balanced abundances, while Simpson's 1-D expresses the probability that two randomly selected individuals belong to different species (Gauthier & Derome, 2021; Morris et al., 2014).

Evenness indicates how equally individuals are distributed among taxa. Brillouin diversity is useful when the sampled collection is treated as a complete assemblage, and Chao-1 estimates richness with particular attention to rare taxa. Menhinick and Margalef indices further relate richness to sample abundance (Kleine Bardenhorst et al., 2022; Mulya et al., 2021). Using several indices prevents interpretation from depending on only one aspect of community structure.

High evenness does not necessarily indicate a biologically rich community. A section containing only two equally represented species may obtain maximum evenness despite severe impoverishment. Richness, abundance, dominance, and evenness must therefore be interpreted together with site conditions and species identity.

Physicochemical Water Quality and Aquatic Communities

Temperature and pH influence metabolism, reproduction, shell formation, and chemical toxicity, while dissolved oxygen supports aerobic organisms. Electrical conductivity reflects dissolved ions, and total dissolved solids represent dissolved inorganic and organic materials. Turbidity indicates suspended particles that may reduce light penetration and alter habitat quality. Philippine Class C water guidelines provide ecological reference values for temperature, pH, dissolved oxygen, and total dissolved solids (Department of Environment and Natural Resources, 2016).

Increased conductivity and dissolved solids may indicate nutrient enrichment or anthropogenic inputs. Onwona Kwakye et al. (2021) showed that nutrient-loaded sites favored pollution-tolerant macroinvertebrates, while Luo et al. (2020) demonstrated that land use and urbanization can alter river chemistry and ecology. Such enrichment may increase abundance but decrease community evenness when a few tolerant taxa become dominant.

Gastropods can also influence water conditions. Grazing may stabilize sediment and reduce turbidity, while different benthic organisms can alter oxygen dynamics and primary production (Guo et al., 2022). The relationship between water quality and gastropod communities is therefore ecological and reciprocal, although a field correlation does not establish causation.

Mount Apo Natural Park and Freshwater Conservation

Mount Apo Natural Park is an ASEAN Heritage Site and a protected landscape that supplies water and other ecosystem services to communities in Mindanao. Its river systems originate from a biologically important mountain landscape, but lowland habitat conversion, agricultural activity, sediment input, and waste may affect freshwater habitats.

Conservation planning requires baseline information on species distribution and environmental conditions. Spatially explicit river sampling is appropriate when prior information about ecological variation is limited (Maduekwe & de Vries, 2019). Repeated measurements across upstream, midstream, and downstream sections can identify localized differences that broad watershed descriptions may overlook.

The present study connects biodiversity measurement with water-quality analysis to support monitoring, science education, and public awareness. This approach is consistent with the use of freshwater gastropods as indicators and with the need to protect high-diversity river sections while addressing potential pollution and habitat simplification.

CONCEPTUAL FRAMEWORK OF THE STUDY

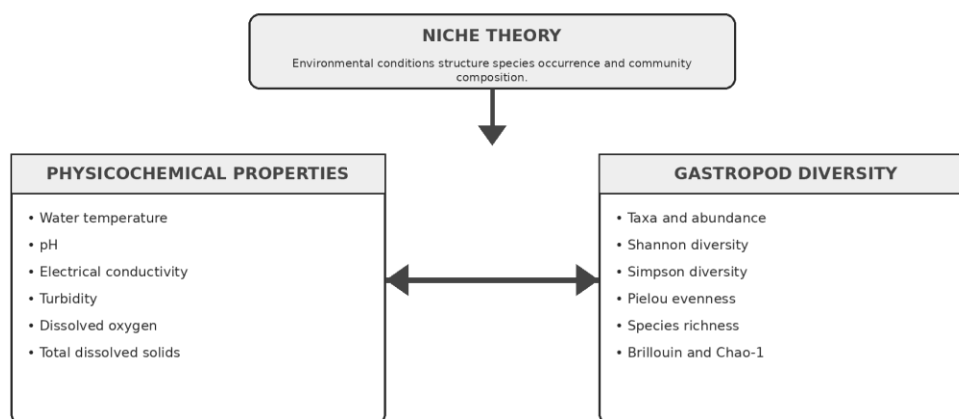


Figure 1. Conceptual framework linking physicochemical properties and gastropod diversity

METHODS

Research Design

The study used a descriptive nonexperimental quantitative design. It described gastropod composition, abundance, diversity, and water conditions without manipulating the river environment and tested the statistical association between two naturally occurring variable sets: gastropod diversity indices and physicochemical water properties (Bleske-Rechek et al., 2015).

Research Locale

Fieldwork was conducted in the Digos, Goma, and Balutakay Rivers within Mount Apo Natural Park. Each river was divided into downstream, midstream, and upstream stations. The sampling locations covered river sections in and around Digos, Bansalan, Kapatagan, Goma, and Balutakay.

Table 1. *Sampling stations and geographic coordinates*

River	Station	Latitude	Longitude
Digos River	Downstream	6.76048 N	125.35535 E
Digos River	Midstream	6.79273 N	125.33602 E
Digos River	Upstream	6.9161 N	125.3184 E
Goma River	Downstream	6.80440 N	125.30763 E
Goma River	Midstream	6.82376 N	125.30509 E
Goma River	Upstream	6.91696 N	125.28651 E
Balutakay River	Downstream	6.7147 N	125.3626 E
Balutakay River	Midstream	6.8273 N	125.2718 E
Balutakay River	Upstream	6.91107 N	125.27146 E

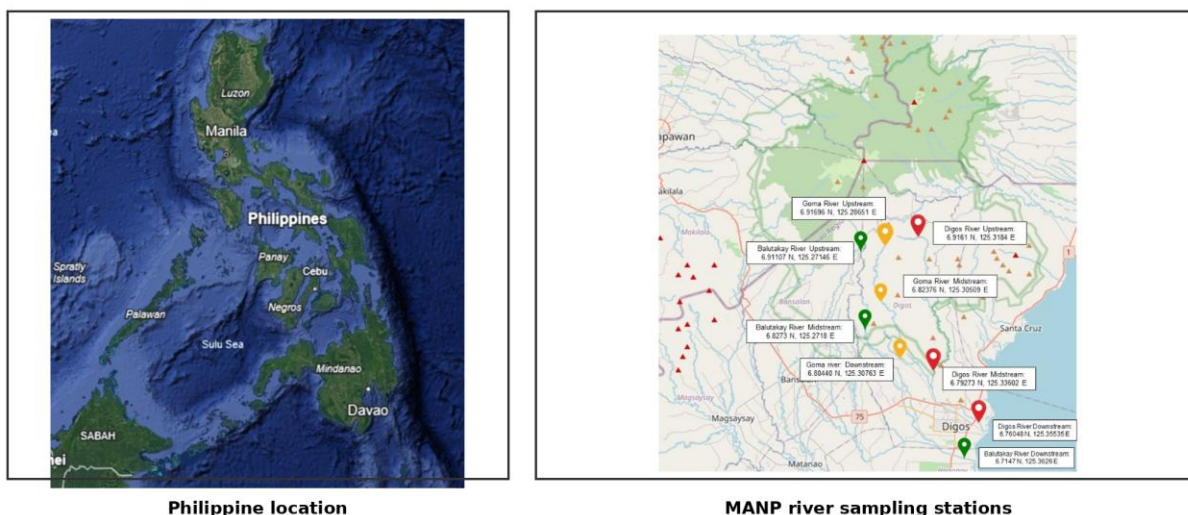


Figure 2. *Philippine and MANP maps showing the three rivers and nine sampling stations*

Population and Sampling Technique

Spatial random sampling was used because the environmental variability of the river systems was not known in advance. Data were gathered during September and October 2023 from approximately 7:30 a.m. to 12:00 noon. A 100-m belt transect was established along a riverbank at each section, and 1 × 1 m plots were randomly positioned along the transect. The source manuscript reports 30 gastropod sampling sites distributed across the nine river sections, with three replicates used to characterize each station.

Research Instruments

Temperature, pH, electrical conductivity, and total dissolved solids were measured using a calibrated pen-type water-quality meter. Dissolved oxygen was measured using a digital dissolved-oxygen meter, and turbidity was analyzed at the Davao del Sur State College Research and Laboratory Services Center. A global positioning system recorded station coordinates. Field forms, nets, sieves, quadrats, specimen containers, and 95% ethanol supported biological collection and preservation.

Data Gathering Procedure

Permissions were obtained from the DENR-Protected Area Management Board, the DA-Bureau of Fisheries and Aquatic Resources XI, barangay officials, and relevant tribal leaders before fieldwork. Water parameters were measured in situ, repeated at 30-minute intervals, taken in triplicate, and averaged. Samples for turbidity were transported for laboratory analysis.

After water measurements, live gastropods were searched for a maximum of 10 minutes per quadrat through handpicking and sieving of sediment, vegetation, and shallow water. Specimens were cleaned with river water, preserved in 95% ethanol, sorted, counted, and identified. The collection approach followed established freshwater macroinvertebrate and gastropod protocols (Flores & Zafaralla, 2012; Galan et al., 2015).

Taxonomic Verification

Initial identification used published references, the National Aquatic Ecological Monitoring Program database, and image-recognition support. Eric Claire T. Selpa, M.Sc., a zoologist and member of the pool of taxonomists at the Central Mindanao University Museum, formally verified the species identification. Voucher specimens were deposited at the Protected Area Management Office–Mount Apo Natural Park.

Data Analysis

Paleontological Statistics software was used to compute taxa, abundance, dominance, Simpson 1-D, Shannon H, evenness, Brillouin, Menhinick, Margalef, Equitability J, Fisher alpha, Berger–Parker, and Chao-1. Means, standard deviations, and ranges described the six water parameters. Pearson product–moment correlation, implemented through SPSS and XLSTAT, tested relationships between water properties and diversity indices. Statistical significance was interpreted at $p < .05$ and $p < .01$.

Ethical Consideration

The study observed applicable science-and-technology research ethics and animal-welfare requirements. Collection was undertaken only after official permits and local clearances were secured. The study applied the principles of reduction, refinement, and replacement by limiting collection to the specimens required for identification and analysis, using appropriate preservation and handling procedures, and coordinating with responsible supervisory authorities. The source manuscript did not report a separate institutional ethics approval number; therefore, no approval code is claimed in this article.

RESULTS AND DISCUSSION

Species Composition, Abundance, and Distribution

Table 2. *Gastropod abundance by river*

Species	Digos	Goma	Balutakay	Total
Bradybaena similaris	0	3	1	4
Clithon corona	0	0	28	28
Faunus sp.	0	0	399	399
Lissachatina fulica	0	1	0	1
Melanoides maculata	1	6	124	131

Melanoides crenulata	0	0	15	15
Melanoides tuberculata	2	12	2	16
Neritina coromandeliana	0	0	47	47
Neritina natalensis	0	0	14	14
Neritina pettiti	0	0	8	8
Neritina pulligera	14	0	27	41
Neritina waigiensis	0	0	5	5
Pomacea canaliculata	3	1	1	5
Pomacea insularum	1	0	0	1
Pomacea maculata	1	0	0	1
Septaria porcellana	5	0	0	5
Stenomelania torulosa	0	0	19	19
Thiara scabra	0	0	241	241

Eighteen gastropod species representing 981 individuals were recorded. Balutakay River accounted for 931 individuals, compared with 27 in Digos River and 23 in Goma River. The most abundant taxa were *Faunus* sp. ($n = 399$), *Thiara scabra* ($n = 241$), *Melanoides maculata* ($n = 131$), *Neritina coromandeliana* ($n = 47$), and *Neritina pulligera* ($n = 41$). The concentration of individuals in Balutakay downstream indicates a highly productive but uneven assemblage.

Neritina pulligera dominated the Digos downstream and Balutakay midstream sections, consistent with its association with rocky, flowing, and well-oxygenated habitats. *Melanoides tuberculata* was common in Goma midstream, while terrestrial or amphibious taxa such as *Lissachatina fulica* and *Bradybaena similis* were limited and may have entered river margins through runoff or nearby land activity. The occurrence of *Pomacea canaliculata* in multiple rivers is ecologically important because it is an invasive and highly adaptable species (Feng et al., 2023).

Gastropod Diversity across River Sections

Table 3. *Selected diversity indices by river section*

Section	Taxa	N	Shannon H	Simpson 1-D	Evenness	Brillouin	Chao-1
Digos D	3	22	0.9415	0.5498	0.8546	0.7591	3
Digos M	2	3	0.8032	0.6667	1.116	0.3662	2.333
Digos U	2	2	0.9431	1	1.284	0.3466	2.5
Goma D	2	2	0.9431	1	1.284	0.3466	2.5
Goma M	2	15	0.6132	0.419	0.9232	0.4813	2
Goma U	3	6	1.178	0.7333	1.083	0.6824	3.417
Balutakay D	10	893	1.509	0.7043	0.452	1.479	10
Balutakay M	2	29	0.2682	0.133	0.6538	0.2071	2
Balutakay U	2	9	0.4044	0.2222	0.7492	0.2441	2

Balutakay downstream had the highest richness and abundance ($S = 10$, $N = 893$), Shannon diversity ($H = 1.509$), Brillouin diversity (1.479), and Chao-1 richness estimate (10). Its Simpson 1-D value of 0.7043 indicated substantial diversity, but evenness was only 0.452 and the Berger–Parker value was 0.4468, showing that a few species dominated the assemblage.

Digos upstream and Goma downstream each had only two taxa and two individuals. Both obtained Simpson 1-D and Equitability J values of 1 because the two individuals belonged to different species. These maximum evenness values should not be interpreted as evidence of rich communities; the very low richness and abundance indicate ecological impoverishment. This illustrates why multiple indices must be interpreted together (Morris et al., 2014; Mulya et al., 2021).

Physicochemical Water Conditions

Table 4. Mean physicochemical parameters by river section

Section	Temp. °C	pH	EC $\mu\text{S/cm}$	Turbidity NTU	DO mg/L	TDS mg/L
Digos D	27.61	8.05	210.33	20.37	8.06	104.83
Digos M	26.96	8.15	179.33	12.21	8.20	89.78
Digos U	24.41	8.55	126.22	7.85	8.29	54.78
Goma D	26.47	8.24	176.33	31.40	8.21	89.44
Goma M	27.03	8.08	204.00	49.95	8.08	103.67
Goma U	23.04	8.64	106.25	10.17	8.67	53.00
Balutakay D	29.16	8.00	683.22	37.73	7.82	341.89
Balutakay M	28.92	8.00	288.33	21.87	7.97	144.33
Balutakay U	21.66	10.47	100.56	40.36	9.27	50.67

Balutakay downstream recorded the highest electrical conductivity (683.22 $\mu\text{S/cm}$) and total dissolved solids (341.89 mg/L), together with high turbidity (37.73 NTU) and a temperature of 29.16 °C. Its dissolved oxygen remained 7.82 mg/L. The elevated conductivity and dissolved solids suggest increased ionic and nutrient content, while turbidity above commonly cited ecological references indicates substantial suspended material. These conditions coincided with high gastropod richness and abundance.

Digos upstream had lower conductivity (126.22 $\mu\text{S/cm}$), TDS (54.78 mg/L), turbidity (7.85 NTU), and temperature (24.41 °C), while Goma downstream had moderate conductivity (176.33 $\mu\text{S/cm}$), low TDS (89.44 mg/L), and elevated turbidity (31.40 NTU). Both sections supported only two taxa and two individuals. Balutakay upstream had an unusually high pH of 10.47 and high turbidity of 40.36 NTU, emphasizing that different stressors occurred across the river network. Comparison with DENR standards supports continued monitoring rather than a single overall classification of the rivers (Department of Environment and Natural Resources, 2016).

Relationships between Diversity and Water Properties

Table 5. Statistically significant Pearson correlations

Diversity Measure	Water Parameter	r	p	Direction
Taxa richness	EC	.924	< .01	Positive
Taxa richness	TDS	.921	< .01	Positive
Abundance	EC	.953	< .01	Positive
Abundance	TDS	.950	< .01	Positive
Brillouin diversity	EC	.813	< .01	Positive
Brillouin diversity	TDS	.812	< .01	Positive
Chao-1	EC	.906	< .01	Positive
Chao-1	TDS	.902	< .01	Positive
Evenness	EC	-.711	< .05	Negative
Evenness	TDS	-.719	< .05	Negative

Electrical conductivity and total dissolved solids were the only water parameters significantly related to multiple diversity measures. Both parameters showed very strong positive correlations with taxa richness and abundance and strong positive correlations with Brillouin and Chao-1. Thus, sections with greater dissolved-ion and mineral content supported more taxa and many more individuals.

Evenness was negatively related to electrical conductivity and TDS. The combination of higher richness and lower evenness indicates that enriched conditions increased the number of organisms while disproportionately favoring a few tolerant taxa. This pattern is consistent with nutrient-loaded freshwater systems in which pollution-tolerant gastropods become abundant (Onwona Kwakye et al., 2021). Temperature, pH, turbidity, and dissolved oxygen did not show statistically significant correlations with the computed indices in this dataset. Because the study was nonexperimental and based on one sampling period, the correlations do not establish causal effects.

Potential Bioindicators and Conservation Implications

Table 6. *Potential bioindicator interpretation of selected taxa*

Taxon	Observed Ecological Association	Monitoring Interpretation
Neritina pulligera	Rocky, flowing, well-oxygenated sections	Potential indicator of comparatively favorable stream habitat
Pomacea canaliculata	Disturbed or nutrient-enriched freshwater	Invasive indicator requiring population monitoring
Faunus sp.	Sediment-rich and organically enriched conditions	High abundance may indicate productive but enriched habitat
Thiara scabra	Slow-moving, sediment-laden water	Tolerance supports use in disturbance monitoring
Melanoides maculata	Broad range of enriched freshwater habitats	Abundance may reflect organic and ionic enrichment

The identified taxa can strengthen biological monitoring when interpreted with water chemistry and habitat observations. *Neritina pulligera* was associated with rocky, oxygenated sections, whereas *Pomacea canaliculata* represented invasive-species pressure and disturbance tolerance. *Faunus* sp., *Thiara scabra*, and *Melanoides maculata* were highly represented in the enriched and sediment-influenced Balutakay downstream section.

The study's information, education, and communication material translated these findings into messages on clean water, biodiversity, pollution prevention, and community stewardship. Such material can support science teaching, barangay environmental programs, protected-area education, and participatory monitoring.

CONCLUSION

Freshwater gastropod communities in the selected rivers of Mount Apo Natural Park varied markedly across upstream, midstream, and downstream sections. Balutakay downstream supported the highest richness and abundance, but its community was dominated by a few tolerant taxa and occurred under elevated electrical conductivity, total dissolved solids, and turbidity. Digos upstream and Goma downstream were evenly represented but biologically impoverished, with only two taxa and two individuals in each section.

The significant positive relationships of electrical conductivity and TDS with taxa, abundance, Brillouin, and Chao-1, together with their negative relationships with evenness, show that greater ionic and nutrient content was associated with more organisms but stronger dominance. Gastropod diversity is therefore useful for interpreting river condition when species identity, community structure, water chemistry, and habitat complexity are evaluated together.

Neritina pulligera, *Pomacea canaliculata*, *Faunus* sp., *Thiara scabra*, and *Melanoides maculata* have practical potential as bioindicators in the studied river systems. The findings provide baseline information for protected-area management, freshwater conservation, science education, and community awareness, but they should be extended through seasonal, multi-year, and molecular investigations.

Recommendation

The downstream section of Balutakay River and other high-diversity habitats should receive focused protection, including maintenance of natural substrates and riparian vegetation and control of sediment and waste inputs. Regular monitoring should combine gastropod surveys with electrical conductivity, TDS, turbidity, pH, dissolved oxygen, and habitat observations.

Protected-area managers, local government units, schools, and communities should use the identified indicator species and the IEC material in environmental education and citizen-monitoring activities. Agricultural runoff, plastic waste, and other anthropogenic inputs should be reduced through local policy, enforcement, and stakeholder participation.

Future studies should include additional MANP rivers, wet- and dry-season sampling, replicated long-term monitoring, substrate and nutrient analysis, and molecular confirmation of species. Experimental or longitudinal designs are also needed before causal claims are made about the effects of individual water parameters on gastropod diversity.

Table 7. *Recommended monitoring and conservation actions*

Priority	Core Action	Lead Stakeholders	Expected Result
Habitat protection	Preserve riparian vegetation, rocky substrates, and natural flow in high-diversity sections	DENR-PAMB, LGUs, communities	Stable habitat and reduced disturbance
Routine biomonitoring	Survey indicator gastropods with EC, TDS, turbidity, pH, DO, and temperature	Protected-area staff, schools, researchers	Comparable seasonal river-health records
Pollution prevention	Control agricultural runoff, solid waste, and sediment inputs	LGUs, barangays, farmers	Lower anthropogenic pressure
Environmental education	Use the IEC material in science classes and community campaigns	Science teachers, youth groups, DENR	Improved freshwater stewardship
Research expansion	Add rivers, seasons, molecular identification, nutrients, and substrate analysis	Universities and research agencies	More robust biodiversity baseline

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