Assessment of fish species richness and physicochemical parameters of Mt. Hamiguitan Range Wildlife Sanctuary river systems in Mindanao, Philippines

MARK LLOYD G. DAPAR1,2,3,*, APRIL JOIE D. LAGUMBAY1,3, JULIUS PARCON4, ROMEO M. TUBONGBANUA JR.1, VICTOR B. AMOROSO1,2
1Center for Biodiversity Research and Extension in Mindanao (CEBREM), Central Mindanao University, University Town, Musuan, Bukidnon 8714, Philippines, *email: f.marklloyd.dapar.g@cmu.edu.ph
2Microtechnique and Systematics Laboratory, Natural Science Research Center, Central Mindanao University, University Town, Musuan, Bukidnon 8714, Philippines
3Department of Biology, College of Arts and Sciences, Central Mindanao University, University Town, Musuan, Bukidnon 8714, Philippines
4Museum of Natural History, University of the Philippines Los Baños, Laguna 4031, Philippines

Manuscript received: 2 October 2021. Revision accepted: 21 November 2021.

Abstract. Dapar MLG, Lagumbay AJD, Parcon J, Tubongbanua Jr. RM, Amoroso VB. 2021. Assessment of fish species richness and physicochemical parameters of Mt. Hamiguitan Range Wildlife Sanctuary river systems in Mindanao, Philippines. Intl J Bonorowo Wetlands 11: 58-68. Being a UNESCO World Heritage Site, Mt. Hamiguitan Range Wildlife Sanctuary (MHRWS) is an exceptional area of diverse flora and fauna with conservation concerns. MHRWS river systems provide significant spawning and nursery grounds for freshwater fishes. However, anthropogenic activities may result in the degradation of fish habitats which calls for conservation. This study provides an updated assessment of the fish diversity of selected MHRWS river systems and recommends policies for the proper management of the rivers and riparian ecosystems. An inventory of fish species and an assessment of the physicochemical parameters were conducted in the three river systems of Mt. Hamiguitan Range Wildlife Sanctuary. A series of line transect of 100 m were established along the banks of the three rivers in three sampling stations (upstream, midstream, and downstream). Results showed that Dumagooc River has the highest number of fish species compared to Maug and Banahaw River. Generally, the species richness increased from upstream to downstream. The high species richness observed upstream and midstream is due to the presence of an intact forest with areas far from human disturbances. A total of 31 species in 11 families comprising 121 individuals were collected and identified. Of these, one endemic species, 29 native species and two introduced species were identified, representing 4.16% of 48 species recorded in the country. As to the physicochemical characteristics of the three river systems, the results showed that the temperature, pH, NTU and DO values of the sampling sites are within the minimum acceptable limit to be considered as within the standards for class AA, A, and B rivers.

Keywords: Endemic, introduced, inventory, native, policies, water quality

INTRODUCTION

The Philippines is one of the mega-diverse countries recognized by the United Nation Environment Programme (UNEP) World Conservation Monitoring Centre and, at the same time, a biodiversity hotspot (Heaney et al. 2004; Mallari et al. 2001). The Philippines hosts about 3,010 fish species (Bagarinao 2001; Cagauan 2007). Several studies on freshwater fish were conducted in the rivers and lakes of Mindanao. Manacop (1953) studied the life history and habits of gobies in Cagayan River while Myers (1960) examined the endemic fish fauna of Lake Lanao. Recent studies were conducted by Vedra et al. (2013) on the goby population in Mandulog River at Iligan City and its potential in the fishery resources (Vedra and Ocampo 2014). Uy et al. (2015) studied the productivity and biodiversity of Lake Mainit, including the fish inventory in the lake and its outlet. The most recent study
on freshwater fish was conducted by Quim pang et al. (2015) in the five long-term ecological research (LTER) sites in Mindanao, including selected rivers of Mt. Hamiguitan Range Wildlife Sanctuary (MHRWS).

Mt. Hamiguitan Range Wildlife Sanctuary, located in Davao Oriental Province, Mindanao, is a protected area covering 6,834 ha between 6°40'N to 6°47'N and 126°09'E to 126°13'E with the highest elevation of 1,637 masl. (Karger et al. 2012). It was designated as a UNESCO World Heritage Site in June of 2014 and is known as the Mindanao Long Term Ecological Research Site (Amoroso and Aspiras 2011). Mt. Hamiguitan serves as headwater of several major rivers such as Bitaogan River, Tibanban, Maua River, and Dumagooc and numerous creeks with discharge points to the Davao Gulf on the West and the Philippine Sea on the East. The three major rivers are the source of water to irrigate the lowlands of the municipality of Governor Generoso. The river systems emanate from usually forested hinterlands and receive inputs of organic materials to be recycled and contribute to the river’s energy and support its high biodiversity and productivity (Giller and Malmqvist 1998) and serve as food sources, primarily for fishes (Vannote et al. 1980). Thus, the freshwater fish assessment provides information about their community, structure, and composition. It will also give an update on the new list of freshwater fish found in the area.

This study, therefore, aims to assess the species richness of the fish in relation to physicochemical characteristics of the river systems and recommend policies for the conservation and proper management strategies.

MATERIALS AND METHODS

Study area

Freshwater fishes were inventoried in the three river systems of Mt. Hamiguitan Range Wildlife Sanctuary as described in Table 1.

Maug River is a 10 km river located in Sitio Tumalit (06°69.776’N, 126°05.517’E), San Isidro, Davao Oriental, Philippines. It has a primary and secondary forest in the upstream (Puting Bato), secondary forest with an agroecosystem in the midstream. Small scale quarry, residential area, and high valued crops are present downstream (Table 1). Dumagooc river is in Barangay Osmeña (06°41.903’N, 126°06.596’E), Governor Generoso, Davao Oriental. It has a thick primary forest upstream. Homes such as residential areas, schools and bridges are observed near the midstream area with few trees such as fig trees (Ficus spp.) and kalingag (Cinnamomum sp.) and coconuts. Some of the residents do their laundry in the river. The center of the barangay is located near the downstream area, where there are many houses, schools, and bridges. Banahaw river is in Barangay Surop, Governor Generoso, Davao Oriental. This location is an agroecosystem forest with a wide plantation of coconut. The downstream is also located at the center of the barangay where some of the residents do their laundry.

The study was conducted from August 2019 to January 2021 at Dumagooc river of Brgy. Osmeña, Governor Generoso, Maug of Sitio Tumaliti, San Isidro, Davao Oriental, and Banahaw River, Barangay Surop, Governor Generoso, Davao Oriental, Philippines (Figure 1). Three stations were assigned (Upstream, Midstream, and Downstream) to collect fish and water quality parameters. Each station was sampled equally during the dry season of the year to avoid possible floods and landslides in the area.

Entry protocol

Gratuitous Permit (GP) was obtained from the Department of Environment and Natural Resources-Protected Areas Management Board (DENR-PAMB). The study was accompanied by representatives from the DENR-PAMB and the Provincial Environment and Natural Resources (PENRO) of DENR XI.

Sampling design

Three stations were selected for each of the three sites (Figure 1). Using a measuring tape, a 100-meter stream reach was selected at each station (upstream, midstream, and downstream). Prior to fish collection, parameters like water temperature, pH, electrical conductivity (EC), turbidity, dissolved oxygen (DO), and total dissolved solids (TDS) were measured in situ using a Pro DSS multi-parameter probe. In every river sampling station, nine sampling points were randomly selected close to the right and left riverbanks and in the middle of the river with triplicates.

| Site                  | Elevation (m. asl.) | Location          | Surrounding land uses                                      |
|-----------------------|---------------------|-------------------|-----------------------------------------------------------|
| Maug River            |                     |                   |                                                           |
| MUS                   | 240                 | 06°69.776’        | 126°15.020’      | Primary forest (Puting Bato)                              |
| MMS                   | 131                 | 06°43.735’        | 126°07.786’      | Secondary forest                                          |
| MDS                   | 44                  | 06°41.968’        | 126°05.517’      | Small scale quarry, residential area and high             |
| Dumagooc River        |                     |                   |                                                           |
| DUS                   | 209                 | 06°41.903’        | 126°09.029’      | Primary forest thick                                      |
| DMS                   | 115                 | 06°40.571’        | 126°07.715’      | Few fig-trees, kalingag trees, coconut trees, residential |
| DDS                   | 80                  | 06°40.134’        | 126°06.596’      | Bridge, residential area, barangay hall, laundry area     |
| Banahaw River         |                     |                   |                                                           |
| BUS                   | 280                 | 06°28.426’        | 126°11.641’      | Secondary forest                                          |
| BMS                   | 132                 | 06°27.696’        | 126°10.122’      | Shrubs and coconut trees                                  |
| BDS                   | 17                  | 06°26.841’        | 126°07.492’      | Bridge, washing/laundry area, residential area near the   |

Note: US: Upstream, MS: Midstream, DS: Downstream
Fish collection, identification, and preservation

The collection of fish was done along with the three sampling stations within the river gradient using a low voltage (10V) improvised backpack electrofishing gear accompanied by a gill net with approximately 1.2mm x 1.2mm mesh size employed in the down part of the river’s gradient (Figure 2.A). Line transect of 100m was established along the banks of the three rivers of each sampling station viz., upstream, midstream, and downstream. The electric fishing method was intentionally used to catch specific fish species of interest where seine netting is not applicable (Paller et al. 2011).

The stunned fishes caught by this method were immediately put in a bucket, documented, and initially identified in the field. Description of the live fish was done by noting their color, the number of fins and barbels if present, the shape of the tail and head, body structure, and mouth. Voucher specimens for each species were preserved in a 10% formalin solution, and other stunned fish were returned to the water after their recovery from the current shock.
Collected specimens were identified and classified up to species level using the Philippine freshwater fish taxonomic keys of Herre (1953), Hubilla (2007), Paller et al. (2011), and Froese and Pauly (2018). Other published articles on fish species in Mindanao Island by Quimpang et al. (2015) and Quimpang et al. (2016) were also used for identification. Consultation with experts was also done for the verification of species. The collected voucher specimens were deposited in CMU museum for further taxonomic analysis and identification. Fish specimens were compared with the existing literature and Pisces collection of CMU museum for proper identification.

Fish species indicators

The fish status, whether native, endemic, or introduced, was noted based on the listing and classification of Fishbase ver.10, 2015.

RESULTS AND DISCUSSION

A total of 122 individuals of freshwater fish comprising 25 species representing 11 families were sampled from three river systems of MHRWS. Family Gobiidae was the most represented family with nine species recorded from all sites, followed by Syngnathidae (pipefishes) with four species then by Eleotridae (3 spp.), and then Cyprinidae (2 spp.). Other families such as Ambassidae, Anguillidae, Butidae, Kuhliidae, Muraenidae, Poecillidae and Rhyacichthyidae were represented by a single species. Among all species observed, Barbodes bantolanensis was the most numerous (n=20) and constituted 23.7%. It was found abundant upstream of Dumagoooc river, few in Maug river and not observed in Banahaw river. Anguilla marmorata (Mottled eel) was the second most abundant species (n=14) comprising 11.4% which was observed in all sites, except in the midstream of Maug and Banahaw river. The third abundant species was Stiphodon atropurpureus (Blue neon goby/balolo) with a relative abundance of 10.6% (n=13). All species were identified as native in the Philippines except Poecilia reticulata (Guppy/Butitirot) which was introduced to the country.

This study presents an updated list of species identified in the free-flowing sections of the MHRWS river systems as well as information on the composition of fish species along a longitudinal gradient of the river. This fish species richness assessment provides a basis for long-term monitoring of the MHRWS headwaters and their tributaries which constitutes a reference status for future similar assessments of other river systems in Mindanao, Philippines. Although current environmental monitoring of the MHRWS river systems primarily focuses on physicochemical parameters and fish species richness, the biological quality elements and surrounding land uses are also being monitored in the area (Table 1). The continuing biodiversity assessments of fish species and physicochemical parameters will provide valuable insights on the impact of currently implemented management and conservation strategies, as well as the potential effects of climate change.

When compared to the study of Quimpang et al. (2016), this study exhibited lower species richness. However, there were several misidentified species in the study, such as Schismatogobius marmoratus which was identified as Gobioderus mindanaoensis; Lutjanus argentimaculatus identified as Waigieu seaperch; and Ryhacichthys aspro identified as Pterygoplichthys pardalis (Table 3**). Moreover, some species identified in the previous study were not recorded in the list of freshwater fishes in the Philippines. Hence, verification of species must be conducted to prove the occurrence of these species in the country. Interestingly, this study added 14 additional species to the diversity of freshwater fishes in MHRWS (Figure 3).

No reported indigenous or traditional management practices were practiced and implemented in the MHRWS river system to conserve its fish biodiversity. The locals have traditional and customized fishing gears for fishing and exploitation of the stocks. Anthropogenic activities and environmental disturbances identified in the surrounding area may affect the fish diversity and the physicochemical values in the three river systems.
Table 2. Diversity of freshwater fish in Dumagooc, Maug and Banahaw River, Philippines

| Family/species | DDS | DMS | DUS | MDS | MMS | BDS | BMS | BUS |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|
| AMBASSIDAE     |     |     |     |     |     |     |     | 1   |
| Ambassis interrupta Bleeker, 1853 |     |     |     |     |     |     |     | 1   |
| ANGUILLIDAE    |     |     | 3   | 4   | 2   | 1   | 2   | 1   |
| Anguilla marmorata Quoy & Gaimard, 1824 |     |     |     |     |     |     |     |     |
| BUTIDAE        |     |     |     |     |     |     |     | 1   |
| Oxyeleotris sp. |     |     |     |     |     |     |     |     |
| CYPRINIDAE     |     | 2   | 20  | 1   | 1   |     |     |     |
| Barbodes bantolanensis Day, 1914 |     |     |     |     |     |     |     |     |
| Anguilla marmorata Quoy & Gaimard, 1824 |     |     |     |     |     |     |     |     |
| ELEOTRIDAE     | 4   | 3   | 1   | 2   | 3   | 1   |     |     |
| Eleotris acanthopoma Bleeker, 1853 |     |     |     |     |     |     |     |     |
| Eleotris acanthopoma Bleeker, 1853 |     |     |     |     |     |     |     |     |
| ELEOTRIDAE     |     | 1   |     |     |     |     |     |     |
| Eleotris acanthopoma Bleeker, 1853 |     |     |     |     |     |     |     |     |
| ELEOTRIDAE     |     | 3   | 1   | 2   | 3   | 1   |     |     |
| Eleotris acanthopoma Bleeker, 1853 |     |     |     |     |     |     |     |     |
| ELEOTRIDAE     |     | 1   |     |     |     |     |     |     |
| Eleotris acanthopoma Bleeker, 1853 |     |     |     |     |     |     |     |     |
| ELEOTRIDAE     |     | 2   | 1   | 3   | 3   | 2   | 1   |     |
| Eleotris acanthopoma Bleeker, 1853 |     |     |     |     |     |     |     |     |
| GOBIIDAE       |     |     | 1   |     |     |     |     |     |
| Glossogobius celebius Valenciennes 1837 |     |     |     |     |     |     |     |     |
| Lentipes mindanaensis Chen, 2004 |     |     | 1   | 2   | 1   |     |     |     |
| Schismatobagius marmoratus Peters, 1868 |     |     | 1   | 2   | 1   |     |     |     |
| Sicyopterus lagoccephalus Pallas, 1770 |     |     |     | 1   | 1   |     |     |     |
| Sicyopterus longifilis de Beaufort, 1912 |     |     |     | 1   | 1   |     |     |     |
| Sicyopterus micrurus Bleeker, 1853 |     |     |     |     |     |     |     |     |
| Sicyopus zosterophorus Bleeker, 1856 |     |     |     | 1   |     |     |     |     |
| Stiphodon atropurpureus Herre, 1927 |     |     | 1   |     |     |     |     |     |
| Stiphodon elegans Steindacher, 1879 |     |     | 2   | 1   | 3   |     |     |     |
| KUHLIDAE       |     |     |     |     |     |     |     | 1   |
| Kuhlia marginata Cuvier, 1829 |     |     |     | 1   |     |     |     |     |
| MURAENIDAE     |     | 1   |     |     |     |     |     |     |
| Gymnothorax sp. |     |     |     |     |     |     |     | 3   |
| POECILIIDAE    |     |     |     |     |     |     |     |     |
| Poecilia reticulate Peters, 1859 |     |     |     |     |     |     |     |     |
| RHYACICHTHIDAE |     |     | 1   | 1   |     |     |     |     |
| Rhacichthys aspro Valenciennes, 1837 |     |     | 1   | 1   |     |     |     |     |
| SYNGNATHIDAE   |     |     |     |     |     | 1   |     |     |
| Doryichthys boaja Bleeker, 1850 |     |     | 1   |     |     |     |     |     |
| Hippichthys heptagonus Bleeker, 1849 |     |     | 2   |     |     |     |     |     |
| Hippichthys sp. |     |     | 1   |     |     |     |     |     |
| Microphis brachyurus Bleeker, 1854 |     |     |     | 1   |     |     |     |     |
| Grand total    | 18  | 14  | 32  | 21  | 10  | 13  | 7   | 7   |

Note: DDS: Dumagooc Downstream; DMS: Dumagooc Midstream; DUS: Dumagooc Upstream; MDS: Maug Downstream; MMS: Maug Midstream; MUS: Maug Upstream; BDS: Banahaw Downstream; BMS: Banahaw Midstream; BUP: Banahaw Upstream

The number of fishes collected in this study is lower compared to previous collections as 33 species were recorded by Quimpang et al. (2016) in the Maug and Dumagooc in Mt. Hamiguitan. However, the present collection is higher than the 16 species recorded by Paller et al. (2011) in Mt. Makiling Forest Reserve and five species reported by Hansel et al. (2004) in Lake Duminagat, Mt. Malindang Range Natural Park. The Maug, Dumagooc and Banahaw rivers support one endemic species, 29 native species and one introduced species which represents 4.16% of 48 species recorded in the country. The native species represents 14.02% of 221 native fish species here in the Philippines, while the endemic species Puntius bantolanensis represents 2.27% of 44 fish species. Mostly geographically isolated freshwater systems are home to many native and endemic species of fish. Some species remain unknown and potentially face a great threat from extinction (Herre 1953; Butler 2006). Members of the family Gobiidae, Oxudercidae and Syngnathidae exhibited the highest species richness. Habitat loss, human interventions, pollution, and the introduction of alien species contribute to the major threats to country’s freshwater diversity (Guerrero 2002; Vidthayanon 2007).

Physicochemical properties of the river

The summary of the mean average values of physicochemical parameters of Dumagooc, Maug and Banahaw River. This is shown in Table 2.

Temperature

An increasing level of temperature from upstream (21.18 °C and 23.8 °C, respectively) to a downstream station (25.3 °C, 26.6 °C, and 27.5 °C, respectively), was observed in Maug and Banahaw rivers (Figure 4.A).
Figure 3. Additional fish species in Mt. Hamiguitan Range Wildlife Sanctuary, Philippines. A. Ambassis interrupta Bleeker, 1853, B. Oxyleotris sp., C. Puntius sp., D. Glossogobius celebus (Valenciennes, 1837), E. Linitpes mindanaoensis Chen, 2004, F. Sicyopterus longifinis de Beaufort, 1921, G. Sicyopus zosterophorus Bleeker, 1856, H. Schismatogobius marmoratus (Peters, 1868, I. Stiphodon elegans (Steindachner, 1879), J. Gymnothorax sp., K. Rhacichthys aspro (Valenciennes, 1837), L. Hippichthys heptagonus (Bleeker, 1849), M. Hippichthys sp., N. Microphis brachyurus (Valenciennes, 1842)
| Family/Species | Quimpang et al. 2016 | On this present study | Assessment |
|---------------|---------------------|----------------------|------------|
| **Ambassidae** |                     |                      |            |
| Ambassis dussumieri (Cuvier, 1828)* | x | x | x | x | Native |
| Ambassina interrupta Bleeker, 1853 | x | x | x | x | Native |
| **Anguillidae** |                     |                      |            |
| Anguilla marmorata Quoy & Gaimard, 1824 | x | x | x | x | Native |
| **Butidae** |                     |                      |            |
| Oxyeleotris lineolata (Steindachner, 1867)* | x | x | x | x | Native |
| **Cyprinidae** |                     |                      |            |
| Barbodes bantolanensis (Valenciennes, 1842) | x | x | x | x | Native |
| Puntius sp. | x | x | x | x | Native |
| **Eleotridae** |                     |                      |            |
| Allomogurnda insularis (Allen, 2003)* | x | x | x | x | Native |
| Eleotris oxyccephala (Temminck & Schligel, 1845)* | x | x | x | x | Native |
| Ophicephalus striatus (Bloch, 1793)* | x | x | x | x | Native |
| Ophichthus apicalis (Bennett, 1830)* | x | x | x | x | Native |
| Ophichthus hoja (Bleeker, 1854) | x | x | x | x | Native |
| Hippichthys lamptagonus (Bleeker, 1849) | x | x | x | x | Native |
| Hippichthys sp | x | x | x | x | Native |
| Microphus brachyurus (Valenciennes, 1842) | x | x | x | x | Native |
| Bhanotia fasciolata (Dumirel, 1870)* | x | x | x | x | Native |
| **Hemiramphidae** |                     |                      |            |
| Hypochromis affinis (Stephanidis, 1971) | x | x | x | x | Native |
| **Kuhliidae** |                     |                      |            |
| Kuhlia marginata (Cuvier, 1829) | x | x | x | x | Native |
| **Latidae** |                     |                      |            |
| Waigieu seaperch (Cuvier, 1828) | x | x | x | x | Native |
| **Loricaridae** |                     |                      |            |
| Pterygophichthys pardalis* | x | x | x | x | Native |
| **Mugilidae** |                     |                      |            |
| Chelon subviridis (Valenciennes, 1836)* | x | x | x | x | Native |
| **Muraenidae** |                     |                      |            |
| Gymnothorax sp | x | x | x | x | Native |
| **Ophichthyidae** |                     |                      |            |
| Ophichthus apicatus (Bennett, 1830)* | x | x | x | x | Native |
| **Ophichthidae** |                     |                      |            |
| Pseudochilichthys affinis (Baird & Girard, 1853) | x | x | x | x | Native |
| **Pryidae** |                     |                      |            |
| Pterygophichthys pardalis* | x | x | x | x | Native |
| **Sillaginidae** |                     |                      |            |
| Sillago sihama (Forsskal, 1775) | x | x | x | x | Native |
| **Terapontidae** |                     |                      |            |
| Terapon jarbua (Forsskal, 1775) | x | x | x | x | Native |

Note: *Not Listed in the Philippines Freshwater Fishes (www.fishbase.com). **Corrected identification from Quimpang et al. (2016)
This could be due to the fact that the upstream stations were dominated by trees, shrubs, ferns, and lycophytes, and were in higher elevations. Whereas in downstream stations, open grassland with human settlements was observed and the river flow was leading to the open ocean. These observations contradict the study of Quimpang et al. (2020) in the two rivers of Mt. Apo, where the temperature of upstream stations of the two rivers is much higher compared to their downstream stations.

The optimal temperature for tropical freshwater fish species ranges from 24-27°C depending on the species. Most stations have suitable temperatures for fish except downstream of Banahaw river with slightly hot temperatures which are possibly not suitable for some species (Table 4). Water temperatures higher than 32°C might cause fish to die.

**Total Dissolved Solids (TDS)**

A higher recorded level of Total Dissolved Solids (TDS) was observed downstream of Maug (229.67 mg/L) and Banahaw (263.67 mg/L) rivers (Figure 4G). The recorded temperature level in Dumagooc river midstream station was 23.7 °C, much cooler than its upstream. This was due to the level of dissolved solids of around 169 mg/L in the area, where soil erosion happened during road construction. According to the study of Martinez et al. (2011), the increase in dissolved and suspended solids can increase the level of temperature mainly because the dissolved solids absorb more heat.

**Turbidity**

Turbidity level in the midstream station of Maug River was around 3.26 NTU (Table 4). The high turbidity level indicates the presence of colloidal particles from discharges of sewage and industrial waste, from silt and clay during rainfall, or the presence of many microorganisms (Olatayo 2013). Hence, the landslides and soil erosion from the ongoing road widening may contribute to the turbid water of the midstream station of Maug River.

**Dissolved Oxygen (DO)**

The DO is one of the important regulators of chemical processes and biological activity of the river systems and the most essential parameter for all aerobic organisms (Tumanda et al. 2003). Furthermore, this parameter can also be used as an index of water quality, primary production, and pollution.

Fluctuating measurements of Dissolved Oxygen (DO) were recorded in the three rivers. Moreover, in the case of Dumagooc River, a higher DO with 7.99 mg/L was observed in the midstream station with a lower temperature level (Figure 4F). This observation supports the study of George et al. (2003) stating that low DO concentrations reveal higher temperature.

The water conductivity in Maug River was increasing from upstream with 76.18 mV to downstream with 150.23 mV average measurements (Figure 4C). According to Goncharuk et al. (2010) the oxidation-reduction potential or ORP, an essential indicator of natural and wastewater values ranging from 76 mV to 344.6 mV verifies the observed data. Furthermore, George et al. (2013) stated the inverse relationship of ORP and temperature; as the ORP value decreases, the temperature level increases.

**pH**

The pH means a value of the three rivers, namely Maug, Dumagooc, and Banahaw fall within the set standard by DENR and DOH (Table 4). Almost the same range of pH was also observed in the study of Quimpang et al. 2018 in Lake Duminaogat, Mt. Malindang. Maug and Banahaw Rivers both have lower pH readings downstream, with an average of 7.52 and 7.54, respectively (Figure 4B), while Dumagooc River has a lower average pH value of 8.08 in the midstream station. Heavy rainfall was observed during the reading of the water quality parameters. This event could be the reason for the lower pH reading in these rivers. This observation correlates to the study of Davie (2008) that rainfall naturally lowers the pH value. Moreover, Cuivillas et al. (2016) stated that the water pH in a river is mainly affected by its age and the chemicals discharged from communities and industries. Moreover, pH of water is an important parameter that influences other components of water quality.

| Parameter | Dumagooc River | Maug River | Banahaw River |
|-----------|----------------|------------|---------------|
|           | DUS | DMS | DDS | MUS | MMS | MDS | BUS | BMS | BDS |
| Temperature °C | 24.10 | 23.70 | 25.30 | 21.18 | 23.20 | 26.60 | 23.80 | 24.80 | 27.50 |
| pH | 8.18 | 8.08 | 8.31 | 8.27 | 8.17 | 7.52 | 8.08 | 8.26 | 7.54 |
| ORP mV | 78.34 | 134.28 | 136.01 | 76.18 | 85.77 | 150.23 | 200.76 | 142.09 | 152.78 |
| SPC-μS/cm | 0.24 | 0.26 | 0.26 | 0.21 | 0.25 | 0.35 | 0.26 | 0.34 | 0.41 |
| Turbidity (NTU) | 0.17 | 0.42 | 0.45 | 2.06 | 3.26 | 1.82 | 1.05 | 0.78 | 0.97 |
| DO mg/L | 7.84 | 7.99 | 7.91 | 7.51 | 8.16 | 7.07 | 7.72 | 7.89 | 6.61 |
| TDS mg/L | 176.11 | 169 | 172 | 138 | 163.56 | 229.67 | 168 | 227.11 | 263.67 |

Note: DUS: Dumagooc Upstream, DMS: Dumagooc Midstream, DDS: Dumagooc Downstream, MUS: Maug Upstream, MMS: Maug Midstream, MDS: Maug Downstream, BUS: Banahaw Upstream, BMS: Banahaw Midstream, BDS: Banahaw Downstream
Discussion

As to the physicochemical characteristics of the three river systems, the results showed that DO of the sampling sites is within the minimum acceptable limit of 5mg/L to be considered as within the standards for class AA, A, and B rivers. This implies that the level of organic substances in all the sampling sites, has not influenced the level of DO in the water. For the NTU, the concentration of all sites reached up to the standards which range from 0.17mg/L to 3.26 mg/L for class AA, A, B rivers. The NTU provides the visual quality of the water with higher concentration signifying highly turbid water. The rest of the parameters, such as the pH and temperature, are within the standard ranges of DAO 2016-08 (DENR, 2016), and the TDS of DAO 34 (DENR, 1990). The scale morphology is recommended for future study as scale characters may constitute criteria for differentiating fish species within and among populations (Dapar et al. 2012).

Furthermore, it is evident that these riparian sites face threats brought by human activities like the conversion of nearby lands to agricultural areas clearing the natural vegetation. The riparian ecosystems give direct benefits to the community like a source of potable water for the municipality of San Isidro, Governor Generoso Mati City Davao Oriental, hence riparian ecosystems should be included as a vital component in the management plan of the different LGU’s with DENR by planting of indigenous tree species along the riparian zone.

Policy recommendations

Each river system should be mapped to indicate the areas that are still intact, disturbed, and denuded areas (i). The disturbed and denuded areas of the riparian ecosystems should be planted with indigenous/endemic tree species on each site and not exotic or introduced species (ii). Each riparian site is recommended to have a nursery of indigenous tree species as a source of seedlings to rehabilitate denuded or disturbed areas of the riparian ecosystem (iii). Cultivation of cash crops should be at least 20 meters away from the riverbanks (iv). Local communities should be involved in the riparian rehabilitation with the local government units in coordination with the DENR spearheading the activity (v). The management plan should be strategized with the stakeholders through the planting of indigenous tree
species along the riparian zone for future environmental sustainability (vi).

The present study presents an updated assessment of the fish species richness and physicochemical characteristics of selected river systems of Mt. Hamiguitan Range Wildlife Sanctuary (MHRWS). To conclude, the MHRWS supports diverse and abundant populations of freshwater fishes that include one endemic species, 29 native species, and two introduced species. As for the physicochemical properties of the water, there is no significant difference between the three river systems. Habitat disturbance, the presence of introduced species, and other environmental factors could have influenced the species richness of the three study sites. Anthropogenic activities were also observed which pose threats to the MHRWS river systems. Hence, the local government unit (LGU) and stakeholders must initiate effective ecological management for the future protection and sustainability of fish species.

ACKNOWLEDGEMENTS

The researchers are grateful to the Biodiversity Management Bureau (BMB) and the Department of Environment and Natural Resources (DENR) of Region XI for the gratuitous permit, Central Mindanao University (CMU), Philippines, under Dr. Jesus G. Derije administration, Center for Biodiversity Research and Extension in Mindanao (CEBREM) and Local Government Units of San Isidro, Governor Generoso and Mati for the logistics support. Most of all, sincere and utmost gratitude is conveyed to the funding agency Department of Science and Technology - Grants in Aid (DOST-GIA).

REFERENCES

Allen NJ, Meyer JP. 1991. A three-component conceptualization of organizational commitment. Human Resour Manag Rev 1 (1): 61-89. DOI: 10.1016/1053-4822(91)90011-Z.

Amoroso VB, Obioma LD, Adialejo JD, Aspiras RA, Capili DP, Polizon JIA, Sunale EB. 2009. Inventory and conservation of endangered, endemic and economically important flora of Hamiguitan Range, Southern Philippines. Blumea 54 (1-3): 71-76. DOI: 10.3767/000651909X474113.

Bagarinao TU. 2001. The decline of native fishes and fisheries and the rise of aquaculture in lakes and rivers in the Philippines. In: Santiago CB, Cuvin AB, Basiao ZU (eds) Conservation and Ecological Management of Philippine Lakes in Relation to Fisheries and Aquaculture. Proceedings of the National Seminar Workshop, 21-23 October 1997.

Butler R. 2006. List of freshwater fishes for Philippines 1994-1995 generated from FishBase.org. http://www.fishmongabay.com. [17-9-2021]

Cagauan AG. 2007. Exotic aquatic species introduction in the Philippines for aquaculture - A threat to biodiversity or a boon to the economy? J Environ Sci Manag 10 (1): 48-62. DOI: 10.47125/jesam.

Cuivillas DA, Nagut V, Cuivillas AM. 2016. Physico-chemical characterization of Layawan River. IOSR J Environ Sci Toxicol Food Technol (IOSR-JESTFT) 6 (2): 69-75. DOI: 10.9790/2402-1006026975.

Dapar MLG, Torres MAJ, Fabricante PK, Demayo CG. 2012. Scale morphology of the Indian goatfish, Parapeneus indicus (Shaw 1803) (Perciformes: Mullidae). Adv Envi Bio 6 (4): 1426-432. DOI: 10.22587/aeb.

Davie T. 2008. Fundamentals of Hydrology. 2nd Edition, Routledge, New York. DOI: 10.4324/9781400336364.

Froese R, Pauly D. 2011 ed. FishBase. World Wide Web Electronic Publication. http://www.fishbase.org.

Froese R, Pauly D. 2018 ed. FishBase. World Wide Web Electronic Publication. http://www.fishbase.org.

George T, Franklin LR, David HS. 2003. Wastewater Engineering Treatment and Reuse (4th ed). Metcalf and EddyInc.

Giller PS, Malmqvist B. 1998. The Biology of Streams and Rivers. Oxford University Press, Oxford.

Goncharuk NV, Bagrii VA, Mel’nik LA, Chebotareva RD, Baishan SY. 2010. The use of redox potential in water treatment processes. J Water Chem Technol 32 (1): 1-9. DOI: 10.3103/S1063455X10010017.

Guerrero RD III. 2002. Invasive Aquatic Animals in the Philippines. Special Report on their impacts and management. ASEAN Biodiversity, Oct-Dec 2002.

Karger DN, Kluge J, Abrahamczyk S, Salazar L, Hohmueier J, Lehner M, Amoroso VB, Kessler M. 2012. Bryophyte cover on trees as proxy for air humidity in the tropics. Ecol Ind 20: 277-281. DOI: 10.1016/j.ecolind.2012.02.026.

Heaney LR. 2001. Small mammal diversity along elevational gradients in the Philippines: an assessment of patterns and hypotheses. Global Ecol Biogeogr 10 (1): 15-39. DOI: 10.1046/j.1466-822x.2001.0027.x.

Herre AWCT. 1953. A Checklist of Philippines Fishes. Research report. Washington, D.C. Fish and Wildlife Service, Unit of States Department Interior, Government Publishing Office.

Hubilla MFK, Primaveria J. 2007. Janitor fish, Pterygoplichthys disjunctivus in Agusan Marsh: A threat to freshwater biodiversity. J Environ Sci Manag 10 (1): 10-23. DOI: 10.47125/jesam.

Kang B, He D, Perrett L, Wang H, Hu W, Deng W, Wu Y. 2009. Fish and fisheries in the Upper Mekong: Current assessment of the fish community, threats and conservation. Rev Fish Biol Fish 19 (4): 465-480. DOI: 10.1007/s11160-009-9114-5.

Kottelat M, Whitten AJ, Kartikasari SN, Wirjoatmodjo S. 1993. Freshwater Fishes of Western Indonesia and Sulawesi. Perilus Editions. Hongkong.

Laffaille P, Acou A, Guillouet J, Legult A, Lafortune H, Gallimard X. 2016. Assessing the impacts of fish passes. Ecol Ind 61: 391-402. DOI: 10.1016/j.ecolind.2015.09.015.

Mallari NAD, Tabaranza BR, Jr., Crosby MJ. 2001. Key Conservation Sites in the Philippines: A Haribon Foundation and BirdLife International Directory of Important Bird Areas. Bookmark, Inc., Makati City, Philippines.

Manacop PR. 1953. The life history and habits of the goby, Sicyopterus extraneus Herre (Anga) Gobiidae, with an account of the goby-fry fishery of Cagayan River, Oriental Misamis Province, Mindanao, Philippines. Philippine J Fish 2: 1-60.

Martinez FB, Galera IC. 2011. Monitoring and evaluation of the water quality of Taal Lake, Talisay, Batangas, Philippines. Acad Res Intl 1 (1): 239-256.

Myers NS. 1986. The endemic fish fauna of Lake Lanao, and the evolution of higher taxonomic categories. Evolution (4): 332-333. DOI: 10.7828/ajob.v6i1.697.

Ng PKL, Tan HH, Lim KKP, Kottelat M. 1998. Peat swamp fishes of Southeast Asia: Diversity under threat. Raffles Museum of Biodiversity Research, Department of Biological Sciences, The National University of Singapore. http://rmbr.nus.edu.sg/articles/dbv/peat.html. [18-9-2021]

Olaya AA. 2013. Assessment of physicochemical parameters of waters in Ilae Local Government Area of Ondo State, Nigeria. Intl J Fish Aquat Stud 1 (5): 84-92.

Ong PS, Afuang LE, Rossell-Amball RG (eds) 2002. Philippine Biodiversity Conservation Priorities, a 2nd iteration of the national biodiversity strategy and action plan: final report. Department of Environment and Natural Resources, Conservation International Philippines, Biodiversity Conservation Program, U.P. Center for Integrative and Development Studies, Quezon City.

Paller VGU, Labatos BV, Lontoc BM, Matalog OE, Ocampo PP. 2011. Freshwater fish fauna in watersheds of Mt. Makiling Forest reserve, Laguna, Philippines. Philipp J Sci 140 (2): 195-206.

Quimpong VT, Oproso EM, Cudal MC, Coquilla KL, Buot GA, Forten DF, Bruno AGE, Amoroso VB. 2015. Assessment and monitoring of fish species in mountain streams and lakes of Mindanao LTER sites. Asian J Biodivers 6 (1): 100-121. DOI: 10.7828/ajob.v6i1.697.
Quimpang VT, Opiso EM, Salolog MC, Tubongbanua RM Jr., Amoroso VB. 2016. Fish species composition, distribution and diversity in two selected rivers of Mt. Hamiguitan Range Wildlife Sanctuary (HRWS), San Isidro, Davao Oriental, Mindanao, Philippines. Asian J Biodivers 7 (1): 96-111. DOI: 10.7828/ajob.v7i1.869.

Quimpang VT, Cudal MC, Opiso EM, Tubongbanua RM Jr. 2020. Fish abundance and physico-chemical properties of Matingao River and Marbel River, Mt. Apo Natural Park, Mindanao, Philippines. CMU J Sci 23 (2): 14-20.

Quimpang VT, Cudal MG, Leaño EP, Opiso EM, Calunsag VLB, Amoroso VB. 2018. Physicochemical characteristics and fish fauna composition of Lake Duminagat, Mt. Malindang Range Natural Park, Philippines. DOI: 10.7828/jmds.v7i2.1222.

Sarkar UK, Pathak AK, Lakra WS. 2008. Conservation of freshwater fish resources of India: New approaches, assessment and challenges. Biodivers Conserv 17 (10): 2495-2511. DOI: 10.1007/s10531-008-9396-2.

Tumanda M, Roa EC, Gorospé JG, Daitia M, Dejarme S, Gaid R. 2003. Limnological and water quality assessment of Lake Mainit, Mindanao State University at Naawan.

Uy WH, De Guzman AB, Acuña RE, Roa RL. 2015. Aquatic biodiversity of Lake Mainit, Southern Philippines. DOI: 10.48031/msunjear.2015.03.01

Vallejo AN JR. 1986. Fishes of Laguna de Bay. Nat App Sci Bull 37 (4): 285-346. DOI: 10.1088/0031-9112/37/7/015.

Vannote RL, Minshall GW, Cummins KW, Sedell JR, Cushing CE. 1980. The river continuum concept. DOI: 10.1139/f80-017

Vedra SA, Ocampo PP, de Lara AV, Rebancos CM. 2013. Indigenous Goby population in Mandulog river system and its conservation by communities in Iligan City, Philippines. J Environ Sci Manag 16 (2): 11-18. DOI: 10.47125/jesam/

Vedra SA, Ocampo PP. 2014. The fishery potential of freshwater gobies in Mandulog River, Northern Mindanao, Philippines. Asian J Agri Dev 11: 1. DOI: 10.22004/ag.econ.200295.

Vidthayanon C. 2007. Overview on freshwater fishes of the Philippines. Unpublished Paper presented during the National Training Course on Freshwater Fish Identification, 18 October 2007. UPLB Limnological Research Station, Zonal Center 2, PCAMRD, IBS-UPLB, PIBCFI, Chester Zoo and WorldFish Philippine Center, SEARCA, Los Baños.