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Ichthyofaunal Diversity and Water Quality Parameters in Talisay and Bagac River Systems, Bataan, Luzon Island, Philippines

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ABSTRACT The fishery resources and hydrological data in the major river systems in Bataan (Philippines) are poorly studied. A preliminary study was conducted to assess the fish assemblages and water quality parameters along the three stream sections of Talisay and Bagac river systems (Luzon Island). The study collected 977 fish individuals from 50 species and 34 families; 28 fish species were observed in Talisay, whilst Bagac had 37 fish species. Forty-two fish species (84%) were categorized as native in the studied rivers. Family Gobiidae comprised the largest number of species in either river. Introduced or exotic fish species from the families Cichlidae and Cyprinidae comprised 16% of the total identified fish taxa. Among the cichlid family, the *Sarotherodon melanotheron* was the most abundant fish species (Talisay: $n = 118$; Bagac: $n = 134$). Shannon-Weiner's diversity index in Bagac ($H = 2.47$) was higher than in Talisay ($H = 1.91$). The similarity rate of stream sections was low (27.28%) based on fish assemblage characteristics. In the ten water quality parameters, the levels of biological oxygen demand, fecal coliform, and total suspended solids exceeded the normal range for a Class C water body classification (agri-fisheries purposes), particularly in the midstream and downstream sections of the studied rivers. The present study supplied ecological datasets that can be adopted as bases to enhance the river conservation management measures in the region.

KEY WORDS Balanga; conservation; fish diversity; Gobiidae; tilapia.

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INTRODUCTION

The peninsular province of Bataan (Central Luzon, Philippines) is abundant with aquatic habitats in the form of rivers, streams, creeks, and waterfalls. The volcanic terrain of the province resulted in the creation of more than 100 rivers radiating from the northern (Mt. Natib) and the southern (Mt. Mariveles) mountain groups. The province's river systems are characterized by a radial drainage pattern as they developed around a central elevated point and flow in all directions. Bagac and Talisay rivers are one of the major river systems in Bataan with headwaters in the Mariveles mountain group (including Mt. Samat) but flow in an opposite direction.

The river systems substantially contribute to the province's socioeconomic development and social integrity (PEMSEA, 2017). The river and its catchment basins are being used for irrigation, navigation, fishing, and drainage system, and are modified for agro-industrial purposes and human settlement areas (Roque et al., 2019; Corpuz and Espaldon, 2023). However, as the human population continues to grow, the threats of pollution, habitat degradation, and overexploitation of aquatic resources are proportionally increasing. Moreover, the poorly evaluated conservation status of the river systems is leading to imprudent utilization of the river resources and ineffective urban and environmental planning. River deterioration is an important issue in river basin management and adversely affects humans and aquatic organisms (Harris & Silveria, 1999). Data on fish assemblage and physicochemical parameters supply necessary information as a function of fisheries stability and ecological integrity of the river, which can be the basis for enhancing environmental policies and other regulatory mechanisms (Paller et al., 2017).

While the ecological profile of Bataan has been published, no information has been reported on the province's fish assemblages and fishery resources in various river systems (CLSU, 2022). To address this paucity of scholarly information on fish assemblages of Bataan, the present study was conducted to evaluate the composition, diversity, and abundance of freshwater fishes collected from the Talisay and Bagac rivers, with some notes on the water quality parameters.

MATERIAL AND METHODS

Study Area

The Talisay River (14°48'46"N - 120°33'19"E at the river mouth) is the largest river of Bataan and the main river of the Talisay Watershed (Pilar and Balanga City, Bataan) (Fig. 1). The headwaters commenced on the northeastern side of Mt. Mariveles in Liyang, Pilar extending to approximately 13 km before draining into Manila Bay, where the mouth of the river traverses the villages of Tortugas and Puerto Rivas of Balanga City. The upstream section is located in an open forest with few residential units. Midstream reach traverses agricultural land areas with perennial crops, weeds, and shrubs that are predominant in the riparian zone. The downstream portion runs in the urban land area of Pilar and Balanga City and is bounded by concretized river banks with patchy mangrove trees.

The Bagac River (14°35'27"N -120°23'22"E at the river mouth) is situated on the northwestern side of Mariveles, Bataan, where the water sources are fed by various mountain streams before emptying in the West Philippines Sea. The headwater is originated from Bisay and Saysayin Falls, with riparia surrounded by semi-pristine open forests. The midstream sections run in the agricultural land subbasin characterized by rice and coconut plantation land use. Few housing units in the grasslands are also observable in the sub-basin areas of the river. The downstream area drains into the town of Bagac with one side of the riverbank occupied by mangroves and perennial weeds, whilst the other side facing the town proper is concretized for flood control and river erosion mitigation.

Fish Collection

Nine stations that are distributed in longitudinal profiles in each stream were selected. Three stream sections (70 m in length) were sampled at each station. In the upstream, these stations were selected to cover the distinct habitat types present in every river section (riffle, run, and pool) (Corpuz et al., 2016). In all circumstances, the fish collection was done using a 12-V backpack electrofishing gear, which was interchangeably operated by two persons. Seine netting and cast netting were also used. Individual sampling run per section lasted about 1 h and was carried out during day time. Fish samplings were conducted from December 2020 until November 2021. Captured fish were immediately counted and identified at the lowest possible taxon. A number of native fish specimens were released into the river after identification. Specimens were either housed in the laboratory as live specimens or preserved in a 10% buffered formaldehyde solution for further documentation and identification.

Fish Diversity

Species richness was determined by the number of species present in a community. The relative abundance for each species, Shannon-Weiner diversity index (H'), Evenness (J'), and Simpson's Dominance Index (λ) were also calculated. Bray-Curtis

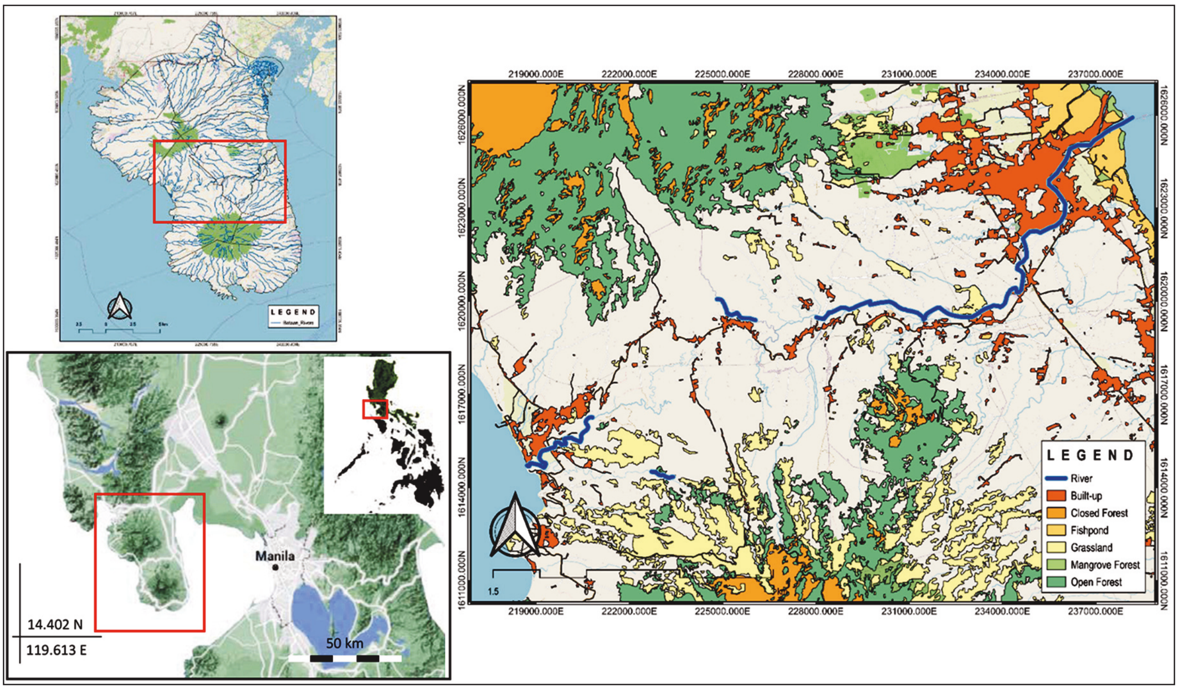

Figure 1. Map of Bataan, Luzon Island, Philippines displaying the Talisay River (blue line) in the east coast, and Bagac River (blue line) in the west coast of the province.

Index (Clarke, 1993) and Morisita Similarity Index were used for multi-group comparison among river sections in each stream using log (x+1) transmuted abundance data, and comparison of stream sections between rivers.

Water Quality Parameters

The water samples were collected from the three different sampling areas during the dry months (February–April 2021) and wet months (August–October 2021). The samples were aseptically obtained from the mid-surface part of the water column using sterile polyethylene containers. Primary water quality variables including Biological Oxygen Demand (BOD, mg L^{-1}), Chloride (mg L^{-1}), color (TCU), fecal coliform (MPN / 100 ml), Nitrate as NO_3-N (mg L^{-1}), Phosphates (mg L^{-1}), and Total Dissolved Solids (TSS, mg L^{-1}) were analyzed in the laboratory (Echem Environmental Testing Laboratory Corporation), whereas the dissolved oxygen (mg L^{-1}), temperature (°C), salinity (g L^{-1}) and pH levels were determined on-site using a hand-held device (YSI Digital Water Quality Meter).

RESULTS AND DISCUSSION

Fish assemblages

Ichthyofaunal assessment in Talisay and Bagac river systems recorded 50 species from 34 families (Table 1, Figure 2). We inventoried 22 fish families and 30 species in Talisay, whilst Bagac had 28 families and 38 fish species. There were 13 fish species that were observed to occur in both sampling rivers. These include *Ambassis miops*, *Apogon hyalosoma*, *Butis butis*, *Oreochromis niloticus, O hornorum, Sarotherodon melanotheron*, *Mayaheros urophthalmus*, *Clarias batrachus*, *Gerres filamentosus*, *Glossogobius giuris*, *Mugil cephalus, Eleutheronema tetradactylum, Scaptophagus argus*, *Elops saurus*, and *Terapon jarbua*. Forty-two fish species (84%) were categorized as naturally occurring (either native or endemic) in the studied rivers. Introduced species, which were mainly from the families Cichlidae and Cyprinidae comprised 16% of the total identified fish taxa. Family Gobiidae had the greatest number of species in both rivers. Migratory fish and euryhaline fishes frequented the river, particularly in the downstream areas; whereas the up-

Family	Scientific Name	Talisay	Bagac	Status
AMBASSIDAE	*Ambassis miops* (Günther, 1872)	+	+	Native
APOGONIDAE	*Jaydia poecilopterus* (Cuvier, 1828)	-	+	Native
APOGONIDAE	*Apogon hyalosoma* (Bleeker, 1852)	+	+	Native
ARIIDAE	*Arius manillensis* (Valenciennes, 1840)	+	-	Endemic
BUTIDAE	*Butis butis* (Hamilton, 1822)	+	+	Native
CARANGIDAE	*Carangoides hedlandensis* (Whiteley, 1934)	-	+	Native
CARANGIDAE	*Caranx hippos* (Linnaeus, 1766)	-	+	Native
CHANIDAE	*Chanos chanos* (Fabricius, 1775)	+	-	Native
CICHLIDAE	*Oreochromis niloticus* (Linnaeus, 1758)	+	+	Introduced
CICHLIDAE	*Coptodon zillii* (Gervais. 1848)	+	+	Introduced
CICHLIDAE	*Sarotherodon melanotheron* (Rüppell, 1852)	+	+	Introduced
CICHLIDAE	*Mayaheros urophthalmus* (Günther, 1862)	+	+	Introduced
CLARIIDAE	*Clarias batrachus* (Linnaeus, 1758)	+	+	Native
CLUPEIDAE	*Sardinella albella* (Valenciennes, 1847)	+	-	Native
CYNOGLOSSIDAE	*Cynoglossus bilineatus* (Lacepède, 1802)	-	+	Native
CYPRINIDAE	*Carassius carassius* (Linnaeus, 1758)	+	-	Introduced
CYPRINIDAE	*Cyprnius carpio* (Linnaeus, 1758)	+	-	Introduced
ELOPIDAE	*Elops saurus* (Linnaeus, 1766)	+	+	Native
GERREIDAE	*Gerres filamentosus* (Cuvier, 1829)	+	+	Native
GOBIIDAE	*Glossogobius giuris* (Hamilton, 1822)	+	+	Native
GOBIIDAE	*Glossogobius aureus* (Akihito et Meguro, 1975)	+	-	Native
GOBIIDAE	*Rhinogobius* sp.	-	+	Native
GOBIIDAE	*Platycephalus indicus* (Linnaeus, 1758)	+	-	Native
GOBIIDAE	*Sicyopus* sp.	-	+	Native or endemic
GOBIIDAE	*Stiphodon* sp.	-	+	
HAEMULIDAE	*Plectorhinchus gibbosus* (Lacepède, 1802)	-	+	Native
HAEMULIDAE	*Pomadasys argentus* (Forsskål, 1775)	-	+	Native
HAEMULIDAE	*Haemulon* sp.	+	-	Native
HEMIRAMPHIDAE	*Hemiramphus* sp.	+	-	Native
LEIOGNATHIDAE	*Leiognathus equula* (Forsskål, 1775)	+	+	Native
LEIOGNATHIDAE	*Gazza minuta* (Bloch, 1975)	-	+	Native
LUTJANIDAE	*Lutjanus rivulatus* (Cuvier, 1828)	-	+	Native
LUTJANIDAE	*Lutjanus* sp.	-	+	Native
MEGALOPIDAE	*Megalops cyprinoides* (Broussonet, 1782)	-	+	Native

MONODACTYLIDAE	*Monodactylus argenteus* (Linnaeus, 1758)	-	+	Native
MUGILLIDAE	*Mugil cephalus* (Linnaeus, 1758)	+	+	Native
MURAENESOCIDAE	*Muraenesox* sp.	-	+	Native
OSPHRONEMIDAE	*Trichopodus trichopterus* (Pallas, 1770)	+	-	Introduced
PEMPHERIDAE	*Pempheris japonica* (Döderlein, 1883)	-	+	Native
PLATYCEPHALIDAE	*Inegocia japonica* (Cuvier, 1829)	-	+	Native
POECILIIDAE	*Gambusia affinis* (Baird et Girard, 1853)	+	-	Introduced
POLYNEMIDAE	*Eleutheronema tetradactylum* (Shaw, 1804)	+	+	Native
POMACENTRIDAE	*Neoglyphidodon bonang* (Bleeker, 1852)	-	+	Native
SCATOPHAGIDAE	*Scatophagus argus* (Linnaeus, 1766)	+	+	Native
SCIAENIDAE	*Dendrophysa russelii* (Cuvier, 1829)	+	-	Native
SIGANIDAE	*Siganus vermiculatus* (Valenciennes, 1835)	-	+	Native
SILLAGINIDAE	*Sillago sihama* (Fabricius, 1775)	+	-	Native
TERAPONTIDAE	*Leiopotherapon plumbeus* (Kner, 1864)	+	-	Endemic
TERAPONTIDAE	*Terapon jarbua* (Fabricius, 1775)	+	+	Native
TRIACANTHIDAE	*Pseudotriacanthus strigilifer* (Cantor, 1849)	-	+	Native
ZANCLIDAE	*Zanclus cornutus* (Linnaeus, 1758)	-	+	Native
ZENARCHOPTERIDAE	*Zenarchopterus* sp.	-	+	Native

Table 1. Species composition of ichthyofaunas in the rivers of Talisay and Bagac, Bataan.

stream of Bagac served as a haven for cryptic neon goby such as *Sicyopus* sp. and *Stiphodon* sp. Such rare species were released in the river after on-site identification. Native freshwater fishes including gobies and halfbeaks are also thriving in the upstream section.

Table 2 shows the distribution of fish species along the different river sections of Talisay and Bagac. A total of 977 fish specimens were collected (472 samples from Talisay and 505 in Bagac) including 36 families and 50 species. In general, more species were collected in the downstream regions. Based on the species composition, Family Cichlidae dominated Talisay's fish catch, contributing around 34.75% to the total catch. This was followed by Ariidae (28.39%), Cyprinidae (9.53%), Mugilidae (8.05%), Gobiidae (5.08%), and Poecilidae (3.39%). Similarly, Family Cichlidae dominated the catch in Bagac garnering around 30.89% of the total catch. This was followed by Leiognathidae (9.90 %), Ambassidae (9.11%), Gobiidae (8.71%), Carangidae (5.94%), Elopidae (4.55%), and Polynemidae (4.55%). It is worth mentioning that the upstream of Talisay was already invaded by introduced fishes (cichlids and guppies). The family Cichlidae dominated the total catch occupying around 31% to 45%. Among the cichlid family, the *S. melanotheron* was the most abundant fish species (Talisay: n = 118; Bagac: n = 134). The *S. melanotheron*, also known as blackchin tilapia, is native to Africa and the brackish estuaries and lagoons of Senegal and Zaire (Trewavas, 1983). In the Philippines, it was first observed in Laguna de Bay in 2008, and it is reported as a "pest" that has invaded the brackishwater ponds of Central Luzon (Guerrero, 2014), and the waters of Manila Bay (Ordoñez et al., 2015). This species is described as nuisance fish competing for food and space during grow-out operations, threatening the biosecurity of fish farming in the eastern portion of the province (Flores et al., 2015).

Canonico et al. (2005) reported the effects of introduced cichlids on native biodiversity. According to the authors, tilapia species are highly invasive and exist under feral conditions in every nation in which they have been cultured or introduced. They particularly affect the trophic interaction of the receiving aquatic environment. Even though tilapias are generally considered detritivores or planktivores, they have been documented to consume the eggs and larvae of other fish species, and even small fishes (Arthington & Blühdorn, 1994). This particular feeding habit could greatly affect the native populations as the fish not only competes with food and space, but also directly consumes the progenies of other fishes. Further, in the present study, the observed great abundance of *S. melanotheron* on both rivers is a clear manifestation of the ability of the fish to thrive in environments with fluctuating habitat variables, and its capacity to dominate and proliferate in waters where the fish have been introduced. Another interesting finding in the study was the abundance of the endemic *A. manillensis* (n = 134) in Talisay. This siluriid species was mostly reported in Laguna de Bay and recently, there have been reports of a drastic reduction in its population sizes (Santos & Quilang, 2012). The fish was abundant in Talisay (east of Bataan), whereas no specimen was collected in Bagac (west of Bataan).

Diversity Indices

The present study revealed a significantly higher Shannon-Weiner's diversity index in Bagac (H = 2.47) than in Talisay (H = 1.91) (Diversity t = 6.75, $P < 0.05$). The high scores of Pielou's evenness index (Talisay = 0.64; Bagac = 0.73), and low Simpson's dominance (Talisay = 0.22; Bagac = 0.14) were calculated implying an equitable distribution of niche space for dominant and non-dominant fishes (Begon et al., 2006; Paller et al., 2013). The higher diversity observed in Bagac can be attributed to lesser anthropogenic pressure as compared to Talisay. The lesser taxa and diversity observed in the upstream can be explained by integrative ecological factors/ mechanisms regulating biodiversity (Grossman et al., 2010).

Similarity

A low spatial similarity (27.28%) was observed among the stream sections based on fish abundance and composition (Table 3, Fig. 3). The highest similarity percentage was apparent between the upstream and downstream of Talisay, with a 61% level of resemblance, whilst the lowest similarity was registered between the downstream and upstream of Bagac. The observed low similarities in fish assemblages can be linked to the radial channel pattern of the studied river systems which are draining in the opposite directions. While the distance between the two rivers is only a few kilometers, the habitat disconnection is evident due to geographical barriers and hydrological partitioning. The distribution of fish species is evident, particularly for stenohaline fishes that are adaptive to higher altitudes, and nil salinity conditions. The distribution and abundance of exotic fish in the river sections may not be the consequence of the aforementioned scenario, but rather the escapement from inland aquaculture or the intentional or unintentional stocking of farmed fish in the river systems.

Biodiversity Indices	Talisay			Bagac		
	D	M	U	D	M	U
Species Richness / Taxa	18	10	5	25	8	3
Shannon-Weiner diversity index (H')	1.83	1.50	0.96	2.36	0.52	1.04
Dominance index (λ)	0.25	0.32	0.43	0.15	0.79	0.35
Shannon Evenness Index (J')	0.64	0.65	0.87	0.73	0.29	0.95

Table 2. Biodiversity indices of the three sections of Talisay and Bagac river system, Bataan, Philippines.
D = downstream; M = midstream; U = upstream.

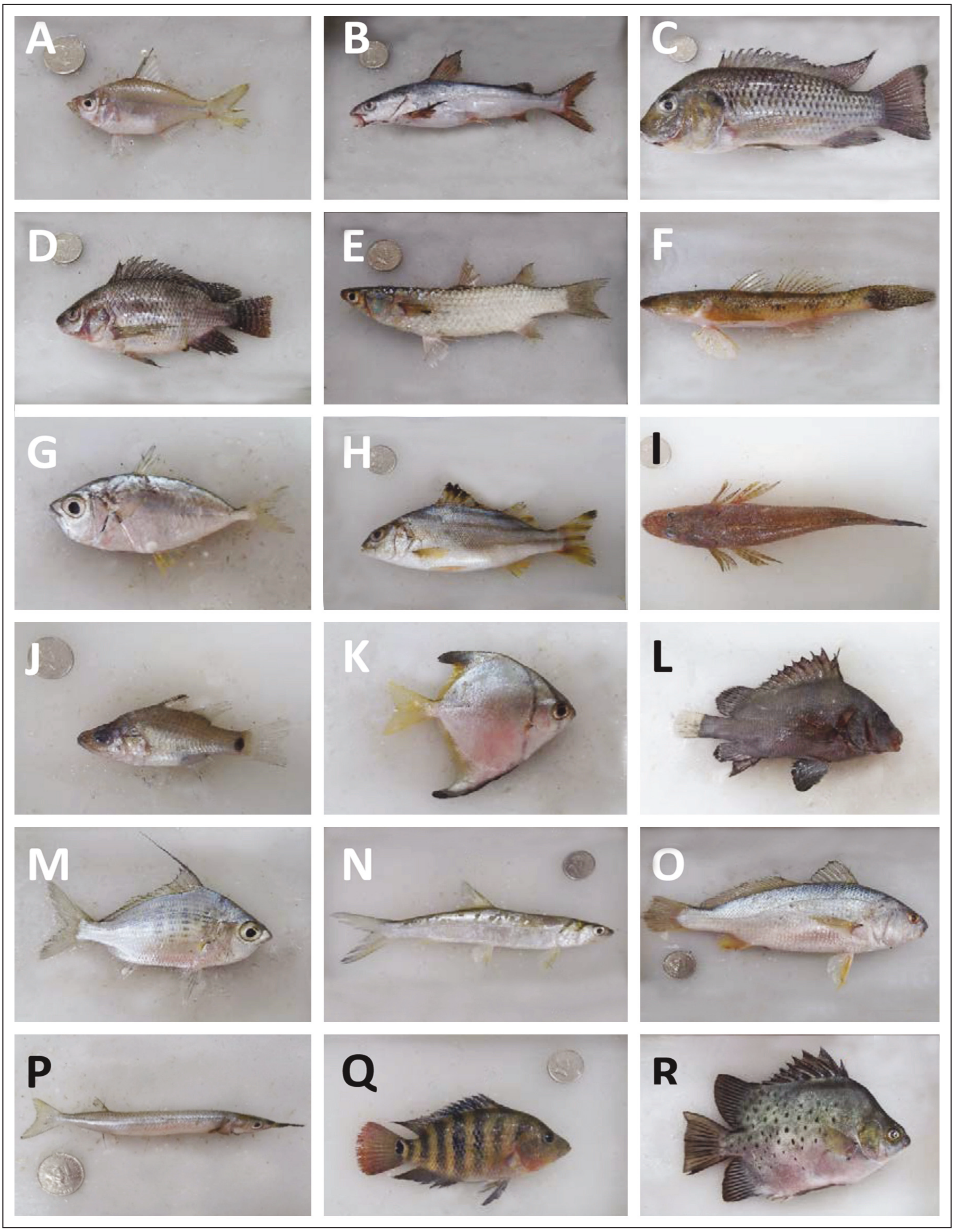

Figure 2. Representative fish species collected from Talisay and Bagac River systems: *Ambassis miops* (A), *Arius manillensis* (B), *Sarotherodon melanotheron* (C), *Oreochromis niloticus*, (D), *Mugil cephalus* (E), *Glossogobius giuris* (F), *Gazza minuta* (G), *Terapon jarbua* (H), *Butis butis* (I), *Apogon hyalosoma* (J), *Monodactylus argenteus* (K), *Plectorhinchus gibbosus* (L), *Gerres filamentosus* (M), *Elops saurus* (N), *Dendrophysa russelii* (O), *Zenarchopterus* sp. (P), *Mayaheros urophthalmus* (Q), and *Scaptophagus argus* (R).

Sampling Sites	UT	MT	DT	UB	MB	DB
UT		22.59	24.48	42.35	39.39	10.23
MT			61.15	3.36	35.57	29.96
DT				13.42	33.64	36.04
UB					26.85	4.02
MB						26.19
DB						

Table 3. Bray-Curtis similarity (%) of sampling sites based on log-transformed abundance data of fish assemblages from Talisay and Bagac river systems, Bataan, Philippines. Overall similarity = 27.28%. UT = upstream of Talisay; MT = midstream of Talisay; DT = downstream; UB = upstream of Bagac; MB = midstream of Bagac; UB = upstream of Bagac.

Water Quality Parameters	Talisay			Bagac		
	downstream	midstream	upstream	downstream	midstream	upstream
Biological Oxygen Demand, mg L^{-1}	13.67 ± 1.73	8.33 ± 0.58	2.67 ± 0.58	8.33 ± 1.73	6.16 ± 1.15	< 2.00
Chloride, mg L^{-1}	49.67 ± 4.79	20.31 ± 11.41	11.33 ± 0.96	44.67 ± 3.31	28.33 ± 2.36	10.00 ± 1.63
Color, TCU	5.00 ± 0.00	5.00 ± 0.00	5.00 ± 0.00	5.00 ± 0.00	5.00 ± 0.00	5.00 ± 0.00
Dissolved Oxygen, mg L^{-1}	5.57 ± 0.06	3.17 ± 0.92	4.96 ± 0.40	4.93 ± 0.29	3.73 ± 0.91	4.63 ± 0.51
Fecal Coliform, MPN / 100 mL	130,670 ± 34,063	91,670 ± 577.35	2,000 ± 346.41	48,000 ± 2,309	37,670 ± 2,886.75	1,670 ± 262.99
Nitrate as NO_3-N, mg L^{-1}	0.46 ± 0.02	0.31 ± 0.06	0.21 ± 0.02	0.48 ± 0.05	0.30 ± 0.04	0.13 ± 0.06
pH (range)	7.43 ± 0.12	7.24 ± 0.15	7.30 ± 0.26	7.17 ± 0.12	7.03 ± 0.15	7.4 ± 0.34
Phosphates, mg L^{-1}	0.13 ± 0.03	0.10 ± 0.001	0.05 ± 0.01	0.1 ± 0.001	0.07 ± 0.03	0.01 ± 0.001
Temperature, °C	32.03 ± 0.11	28.87 ± 0.81	27.23 ± 0.15	30.43 ± 0.35	28.73 ± 0.21	26.23 ± 0.81
Total Dissolved Solids, mg L^{-1}	99.00 ± 15.39	100 ± 13.23	19 ± 6.92	85.00 ± 4.35	82.33 ± 15.37	26.67 ± 16.07

Table 4. Water quality parameters (mean ± SD) in the stream sections of Talisay and Bagac Rivers, Bataan, Philippines.

Water Quality Parameters

The ten primary water quality parameters of the two river systems are summarized (mean ± SD) in Table 4. Based on BOD levels, the Talisay and Bagac rivers had moderately polluted waters (2–8 mg L^{-1}), with the downstream being severely polluted (≥ 8 mg L^{-1}) (Wilhem, 2009). In reference to DAO (2016), the downstream section of both rivers and the midstream of Bagac exceeded the Class C water body classification. The chloride levels in the sampling sites were in the ideal ranges (DAO, 2016; Hong et al., 2023). The color of the water was similar to all sampling sites (5 TCU) and did not exceed the normal limit specified by DAO (2016). Except for the DO records in the midstream, the subsurface DO levels in all sites were within the ideal value of 5 mg L^{-1} (Boyd, 1998). The fecal coliform counts exceeded the standard limit of 200 MPN / 100 ml for a Class C water body category (DAO, 2016). The present finding indicates fecal coliform bacterial contamination in the sampling areas, which may pose health risks to human populations. In all studied sites, the quantities of nitrate as NO_3-N, and phosphate in water samples did not surpass the standard limit of 7.0 mg L^{-1}, and 0.5 mg L^{-1}, respectively, whereas the pH and temperature readings were within the normal ranges (6.5–9.0 for pH and 26–31°C for temperature). The total suspended solid varied among river sections, albeit the midstream and downstream exceeded the limit level of 80 mg L^{-1} (DAO, 2016). The high TSS level indicates the high turbidity condition of the studied river sections as influenced by suspended organic and inorganic materials (> 2 μm in size) in the water column (FEI, 2014; DAO, 2016).

CONCLUSIONS

The conspicuous fish faunal characteristic of the studied rivers is the longitudinal gradient change of fish diversity and abundance along the stream sections of the studied rivers. While species richness is higher in native fish species; exotic fish species of known commercial importance had greater fish individuals. This preliminary study supplied vital information on the diversity and distribution of riverine fishes in Talisay and Bagac, which can provide future reference and impetus to enhance the river conservation program and native fish restoration projects by the LGUs of Bataan and nearby provinces. The updated inventory of fish, coupled with the condition of water quality parameters, served as evidence of the environmental concerns and challenges threatening the ecological integrity of the studied rivers. Periodic rapid fish-based bio-assessment and long-term water quality monitoring in Talisay and Bagac and other river systems are open for future investigations.

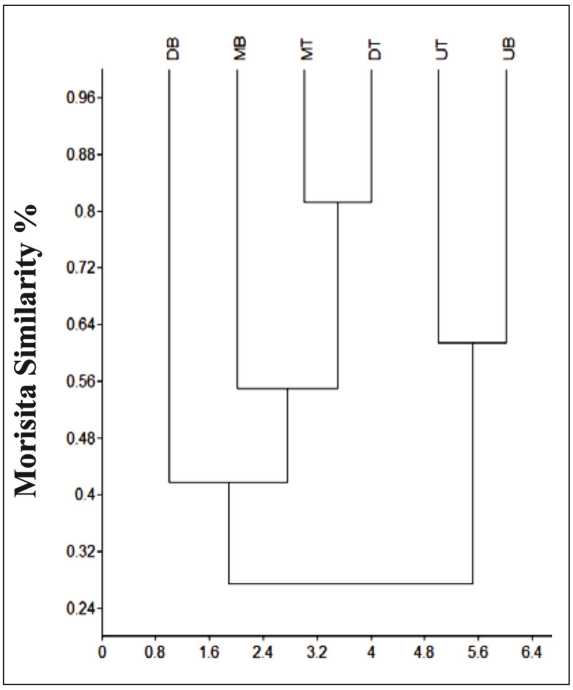

Figure 3. A dendrogram of unweight pair group average method showing the clustering of sampling sites derived from fish species composition and log-transformed abundance data.

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