DIVERSITY AND DISTRIBUTION OF ICHTHYOFAUNA AND MACRO-INVERTEBRATES IN INARIHAN RIVER, CALABANGA, CAMARINES SUR

Imee Franz N. Siares[1] and Sandy Rey B. Bradecina[2]

[1]Central Bicol State University of Agriculture Pili Campus
San Jose Pili, Camarines Sur

[2]Central Bicol State University of Agriculture Calabanga Campus
Sta. Cruz, Calabanga, Camarines Sur

*Corresponding author: imeefranz.siares@cbsua.edu.ph
sandyrey.bradecina@cbsua.edu.ph

Abstract — Rapid bioassessment was carried out to examine the ecological condition of an aquatic ecosystem of the three major rivers of Calabanga. The site was analyzed using indicators such as fish and significant invertebrate populations. Fish profiling and invertebrate composition, abundance, diversity, and distribution were analyzed. Fish samples were collected using a fine mesh net, trowel method, and traps for mollusk and crustacean samples. Nonparametric multivariate statistical analyses were used to analyze the data. Fifteen (15) mollusk genera were observed and identified in the study, followed by fish with ten (10) genera and crustaceans (shrimp and crabs) with eight (8) genera. Tigman River showed the highest number of species 32 identified on site, followed by the Hinagyanan River and Inarihan river with 25 and 21 species, respectively. Using the Shannon Weiner Index of Diversity, Tigman river showed a high value of diversity index of 3.00 while Hinagyanan and Inarihan with 2.40 and 2.31, respectively. Water quality was analyzed and exhibited direct and indirect impacts on the species composition. The downstream part of Tigman River also observed a highly diverse area, specifically in fish and mollusk species while species composition and diversity of the Hinagyanan and Inarihan rivers were similar values. This observed trend was affected by several anthropogenic impacts than environmental stress. Anthropogenic activities in the area can explain the existence of introduced species in the river. For instance, in *O. niloticus*, some local residences in Inarihan river (Tawang station) have tilapia aquaculture near the river. Once their population has been established, invasive species are difficult to eliminate. Moreover, introduced fish species are more likely to occur in anthropogenically impacted environments.

Keywords — **Abundance and distribution, diversity, ecological status, rapid bioassessment, and species composition**

INTRODUCTION

The Philippines is an archipelago located in the Indo-West Pacific Region, recognized for its high marine biodiversity and inland resources specifically rivers. The State of the Philippine Environment, IBON Foundation. Inc., Databank and Research Center, (2000) enumerates eighteen central river basins in the Philippines and these rivers are considered the primary source of aquatic/terrestrial organisms and livelihood for people (Addy et al., 2014). For instance, natural resources from rivers are the primary source of livelihoods for poor rural people. These include food, drinking water, irrigation, transportation, and others. However, the human population is increasing at the same time as the need for natural resources, leading to an increase in the conflict between flora and fauna and social conditions. Later on, the exploitation of rivers leads to the widespread degradation of natural resources resulting in a loss of habitat, biodiversity, and ecosystem. These effects on rivers will also result in diffuse pollution, water abstraction, invasive plants and animal species, and physical modification.

One of the vital rivers in Southern Luzon is located in the Bicol Region and ranks as the eighth largest river in terms of drainage area (TSPEIFDRC, 2000). It has a total land area of 317,103 hectares. Bicol River Basin is drained by two major rivers – Bicol River and Libmanan River, emptying into San Miguel Bay and one of the most productive marine ecosystems in the Bicol Region since the Calabanga Rivers and tributaries are connected in the Bay. In the early 1980s, (THIRIS) Tigman-Hinagyanan-Inarihan River Irrigation System, formerly known as the Naga-Calabanga Irrigation Project, under the National Irrigation Administration Bicol River Basin Irrigation Development Project (NIA-BRBIDP), constructed dams in three respective rivers from 1989-2012 for irrigation purposes. It served as the main accomplishment of the NIA - Region 5 project which contributed to the municipality of Calabanga and other municipalities. Further, the Bureau of Soils and Water Management (BSWM) of the Department of Agriculture (DA) conducted a study on Soil and Land Resources in Calabanga, Camarines Sur, in 2000, focusing on the agricultural topography of the municipality. Surprisingly, there is no documentation and information available regarding the monitoring and evaluating the ichthyofauna and aquatic invertebrates in the Calabanga Rivers. It is also worthy to note that the major rivers are composed of artificial dams and irrigations for agricultural purposes, which can affect the distribution, diversity, and structure of the faunal organism in the rivers. It is also essential to monitor the aquatic organism such as freshwater fishes and invertebrates in the major rivers to distinguish their current status.

Macroinvertebrates communities are broadly utilized as markers of stream biological system wellbeing status since they incorporate a wide extend of species, each with generally well-known affectability or resilience to waterway conditions. Bio-monitoring considers and the utilize of macro-invertebrates to rate the quality of water bodies of both lotic and lentic sorts have been broadly checked on somewhere else (Andem, A.B.,I.K. Esenowo, and D.O. Bassey, 2015).

MATERIALS AND METHODS

The Memorandum Circular No. 97-17 of the DENR – Biodiversity Management Bureau was adapted for this project.

Data Collection

The process that was administered on the data collection are the following; field-based assessment, characterization and profiling of study sites and collection of Ichthyofauna and Benthic Invertebrates.

Field-based Assessment. Field investigation was made to cross-check the river through field/site visits for a strategic plan for data collection. Consultation and coordination with the LGU was prioritized before the site visit. The researchers also requested a local official or person in the area as guide during sample collection for security and navigational purposes.

Characterization and Profiling of Study Sites. Three (3) sampling sites (Barangay Siba-o, Barangay Fabrica and Barangay Sugod) at Inarihan River were subjected for the assessment. Each sampling site undergo inventory and profiling using the following survey. (1) The wetland/ river site name was accomplished with the help of the LGU and key informants. Local names, alternative names, and historical names were also noted. (2) The river's location/ administrative coverage- the name of the municipalities, purok, sitio, barangay, and the nearest city was also noted. (3) Centroid- the geographical location of the sampling sites was noted by collecting the coordinates using GPS. (4) Areas and measurement- the area and measurements of the river were noted using satellite images or the available data in LGU.

Collection of Ichthyofauna and Benthic Invertebrates. After the inventory and survey of the sampling sites, an assessment of Ichthyofauna and benthic invertebrates was performed. Each sampling site was divided into three (3) significant streams, Upper Stream, Middle Stream, and Down Stream. Each stream was also sub-divided into three replicates with 50-meter distance intervals.

1. Parameters

Physico-chemical parameters such as DO, water temperature, pH, conductivity, and other parameters were collected using a handheld multiparameter device. River depth, size, and water velocity were noted using a meter stick or long rope (with measurement), transect line, and ping pong ball. The substrate (sandy, muddy, rocky, etc.) was also characterized using a substrate sieve.

2. Ichthyofauna

A Seine net or hand net (dimension 8.0m x 1.0, mesh size) was used as a trap to collect the fish sample and placed on a clean white slate board with a ruler (scale) for documentation, identification, and morphometric & meristic analysis using Image J software. Unidentified samples were placed in a clean ziplock with 10% formaldehyde or methyl alcohol to preserve for further investigation. After counting the collected samples, the remaining live fish were released back into the river. Specimens were identified using several fish identification materials by Herr (1924, 1927, 1953), Conlu (1986), Vidthayanon (2007), Froese and Pauly (2012), Fish-based website (2020). Further, the collected fish samples were categorized by their Family, Scientific name, English name, Common/ Local name, and occurrence.

3. Invertebrate

Shovels and sieves were used for the sampling collection. The substrate was collected and placed into the sieve to examine the macro-invertebrate present in the river. The collected soil sample was placed in a clean ziplock for further investigation. The collected microinvertebrates were examined under a digital microscope and identified at the laboratory's lowest possible taxon while macroinvertebrates were collected using picking and gleaning strategy in the littoral zone of the river. Fish-based website and other freshwater invertebrate books and materials were used to identify the sample and the collected benthic invertebrate samples were categorized by their Family, Scientific name, English name, Common/ Local name, and occurrence.

Data Analyses

a. Richness and Diversity

Species richness was determined by analyzing the number of species present in a community. The relative abundance for each species was calculated as follows;

Relative abundance = (a_i / A) x 100%

Where a_i is the number of individuals collected, and ***A*** is the total number of species collected. The diversity index was computed using the Shannon-Weiner diversity index (H') (Shannon & Weaver 1949).

$$H = -\Sigma (Pi) \ln Pi;$$

Where: ***Pi*** is the proportional abundance of the i-th species (ni/N); ***Σ*** is the sum symbol, and ***ln*** is the natural logarithm. Evenness (J') was computed following Shannon's Diversity:

$$J' = \frac{H'}{lnS}$$

Where: ***H*** is the Diversity Index, In is the natural logarithm, and ***S*** is the number of species. Species dominance was computed using Simpson's index formula:

$$\lambda = \sum_{i=1}^{S} \frac{ni\ (ni-1)}{N\ (N-1)}$$

Where: ***S*** is the total number of species. n_i is the number of individuals in the i-th species, and ***N*** is the total number of individuals. Species densities (number of individuals collected in one species /10m²) and relative abundances (number of individuals collected in one species / the total number of species collected) were computed for each sampling area. Abundance data were $\log_{10}$ (x+1) transformed to linearize the relationship. Descriptive statistics of environmental variables were also calculated.

RESULTS AND DISCUSSION

Characterization of Physical Habitat of Inarihan River

Inarihan River is located in the North-East portion of Camarines Sur (13°42'45.07"N; 123°14'9.03"E), approximately 25 km distance from Naga City and has a length of 19.59 km from upstream (sampling area) to the coastal area, and it is surrounded by tall trees, rice fields, cornfields, and other crops. This river serves as the source of irrigation in Calabanga and other nearby municipalities such as Bombon, Magarao, and Canaman.

Community Structure of Biological Data

Sixteen (16) species of freshwater fishes were observed in the Inarihan River. Five (5) species were observed in the upstream area, while six (6) and five (5) species were observed in midstream and downstream, respectively. These samples were collected during the dry season. Table 1 shows the species composition of the collected fish samples in Inarihan with its respective stream.

Table 1. Species composition of freshwater fishes in Inarihan River (Dry Season).

Freshwater Fishes	UPS	MDS	DNS
Zenarchopterus dispar	/	/	/
Leiognathus equulus	*	*	/
Dermogenys pusilla	/	/	*
Glossogobius celebrius	/	/	*
Poecilia sp.	/	/	*
Rhynchoramphus georgi	*	*	*
Sillago sp.	*	*	/
Mugil cephalus	*	*	/
Cyprinus carpio	*	*	*

Doryichthys boaja	*	*	/
Clarias batrachus	*	*	*
Scatophagus argus	*	*	*
Awaous grammepomus	/	/	*
Gobiopterus lacustris	*	/	*
N. niloticos	*	*	*
Other Gobby	*	*	*

Legend: * - Exist; **/** - Does NOT exist
UPS-Upstream Station
MDS-Midstream Station
DNS-Downstream Station

A total of Fifteen (15) species of fish were identified during wet season sampling. Only three (3) species were collected and identified in the upstream station, while four (4) and seven (7) species of fish were collected and identified in the midstream and downstream, respectively. Table 2 represents the species composition of freshwater fishes collected in Inarihan during wet season sampling.

Table 2. Species composition of freshwater fishes in Inarihan River (Wet Season).

Freshwater Fishes	UPS	MDS	DNS
Zenarchopterus dispar	*	*	/
Leiognathus equulus	*	*	*
Dermogenys pusilla	*	*	*
Glossogobius celebrius	*	*	*
Poecilia sp.	/	*	*
Rhynchoramphus georgi	*	/	*
Sillago sp.	*	*	/
mugil cephalus	*	*	/
Cyprinus carpio	*	*	/
Doryichthys boaja	*	*	/
Clarias batrachus	*	*	/
Scatophagus argus	*	/	*
Awaous grammepomus	/	*	*
Gobiopterus lacustris	/	/	*
N. Niloticos	*	/	/

Legend: * - Exist; **/** - Does NOT exist
UPS-Upstream Station
MDS-Midstream Station
DNS-Downstream Station

Table 3 indicated that Forty-one (41) species of macroinvertebrates were identified during the sampling collection in the wet season. Thirty-eight (38) species of macroinvertebrates were identified in the upstream station, while forty-one (41) and eighteen (18) species were identified in midstream and downstream, respectively. Among the sampling station, the midstream showed a high number of species wherein all macroinvertebrates were collected.

Table 3. Species composition of macro-invertebrates in Inarihan River (Wet Season).

Macroinvertebrates	UPS	MDS	DNS
Nerita sp.	/	/	*
Melaniodes turriculus	/	/	*
Melanoides filocarinata	/	/	*
Jagora asperata	/	/	*
Terebralia palustris	/	/	*
Littoraria sp	/	/	/
Volema myristica	/	/	/
Cerithidea sp.	/	/	/
Pomacea canaliculata	/	/	/
Terebralia sulcata	/	/	/
Polymesoda sp.	/	/	*
Azorinus coarctatus	/	/	/
Glauconome virens	/	/	/
Isognomon ephippium	/	/	*
Gafrarium tumidum	/	/	*
Pitar citrinus	/	/	/
Alpheus sp	/	/	/
Caridina sp.	/	/	*
Atyidae	/	/	*
Varuna litterata-	/	/	*
Perisesarma sp	/	/	*

Potamidae	/	/	*
Gecarcinucidae	/	/	*
Episesarma sp	*	/	*
Pagurus bernhardus	*	/	*
Scylla serrata	*	/	/
Ephemeroptera	/	/	*
Plecoptera	/	/	*
Tricoptera	/	/	*
Psephenidae	/	/	*
Chironomidae (non-biting midge)	/	/	/
Pleuroceridae	/	/	*
Physidae	/	/	*
Hydrachnidae	/	/	*
Ants	/	/	/
Gyrinidae	/	/	/
Corbiculidae	/	/	/
Oligochaeta	/	/	/
Odonata	/	/	/
Coleoptera	/	/	/
Hemiptera	/	/	/

Legend: * - Exist; **/** - Does NOT exist
UPS-Upstream Station
MDS-Midstream Station
DNS-Downstream Station

Inventory during dry season shown in Table 4 indicated Forty-one (41) species of macro-invertebrates were collected and identified in this station. Twenty-two (22) species were identified upstream, while twenty-one (21) species and eighteen (18) species were in midstream and downstream stations. Most species were dominated by aquatic insects and benthic organisms, especially upstream and midstream. Among sampling stations, species such as *Gyrinidae, Corbiculidae, Oligochaeta, Odonata, Coleoptera*, and *Hemiptera* were observed.

Table 4. Species composition of macro-invertebrates (Dry season).

Macroinvertebrates	UPS	MDS	DNS
Nerita sp.	/	*	*
Melaniodes turriculus	/	/	*
Melanoides filocarinata	/	/	*
Jagora asperata	/	/	*
Terebralia palustris	*	*	*
Littoraria sp	*	*	/
Volema myristica	*	*	/
Cerithidea sp.	*	*	/
Pomacea canaliculata	*	*	/
Terebralia sulcata	*	*	/
Polymesoda sp.	*	*	/
Azorinus coarctatus	*	*	/
Glauconome virens	*	*	/
Isognomon ephippium	*	*	*
Gafrarium tumidum	*	*	*
Pitar citrinus	*	*	/
Alpheus sp	*	*	/
Caridina sp.	/	/	*
Atyidae	/	/	*
Varuna litterata-	/	/	*
Perisesarma sp	*	*	*
Potamidae	*	*	*
Gecarcinucidae	*	*	*
Episesarma sp	*	*	*
Pagurus bernhardus	*	*	*
Scylla serrata	*	*	/
Ephemeroptera	/	/	*
Plecoptera	/	/	*
Tricoptera	/	/	*
Psephenidae	/	/	*
Chironomidae	/	/	/

Pleuroceridae	/	/	*
Physidae	/	/	*
Hydrachnidae	/	/	*
Ants	/	/	/
Gyrinidae	/	/	/
Corbiculidae	/	/	*
Oligochaeta	/	/	/
Odonata	/	/	/
Coleoptera	/	/	/
Hemiptera	/	/	/

Legend: * - Exist; **/** - Does NOT exist
UPS-Upstream Station
MDS-Midstream Station
DNS-Downstream Station

Abundance, Distribution, and Diversity (Fish)

The midstream station observed the high number of taxa and individuals collected with six (6) total taxa with twenty-two (22) total individuals while upstream and downstream stations acquired a similar total number of taxa and individual counts with five (5) taxa and ten (10) individual counts in Table 5. Moreover, the midstream station showed the highest diversity index with a 1.59 value, followed by the downstream and upstream stations with 1.51 and 1.47 "H," respectively. The species richness also observed the highest value of 5.59 compared to the 4.8 value of upstream and downstream stations. Species such as *Poecilla sp.*, *D. pusilla*, *A. grammepomus*, and *G. celebrius* are much more observed in upstream stations.

Table 5. Alpha diversity indices of the fish community (Wet season).

	UPS	MDS	DNS
Taxa_S	5	6	5
Individuals	10	22	10
Shannon_H	1.471	1.591	1.505
Evenness_ e^H/S	0.8706	0.8181	0.9006

Legend: UPS-Upstream Station; **MIDS**-Midstream Station; **DNS**-Downstream Station

Species such as *Poecilla sp., D. pusilla, A. grammepomus,* and *G. celebrius* are much more observed in upstream stations. *Gobiopterus lacustris* and *Dermogenys pusilla* were observed dominantly in the midstream station, while species such as *Mugil cephalus, Sillago sp.*, and *Zenarchopterus dispar* were observed dominantly in the downstream station of the Inarihan river.

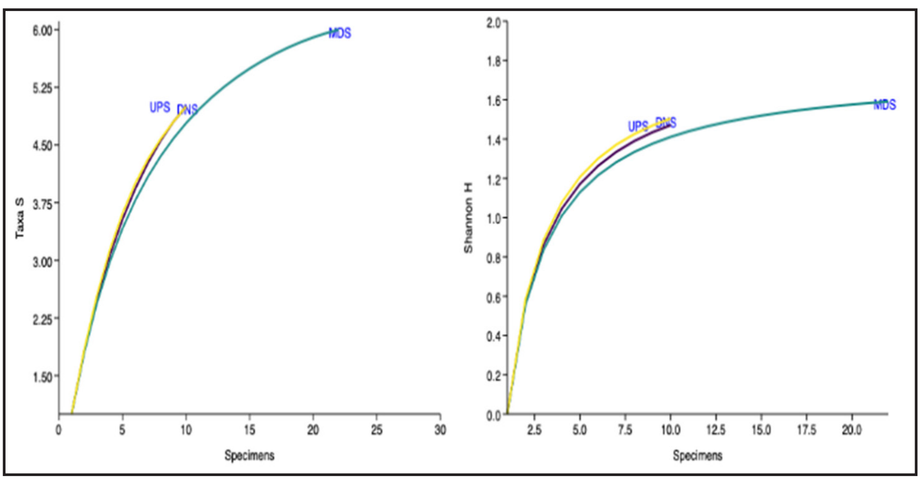

Figure 1. Graph of species richness and diversity index of fish samples (wet season); (a) Species Richness; (b) Shannon Diversity Index.

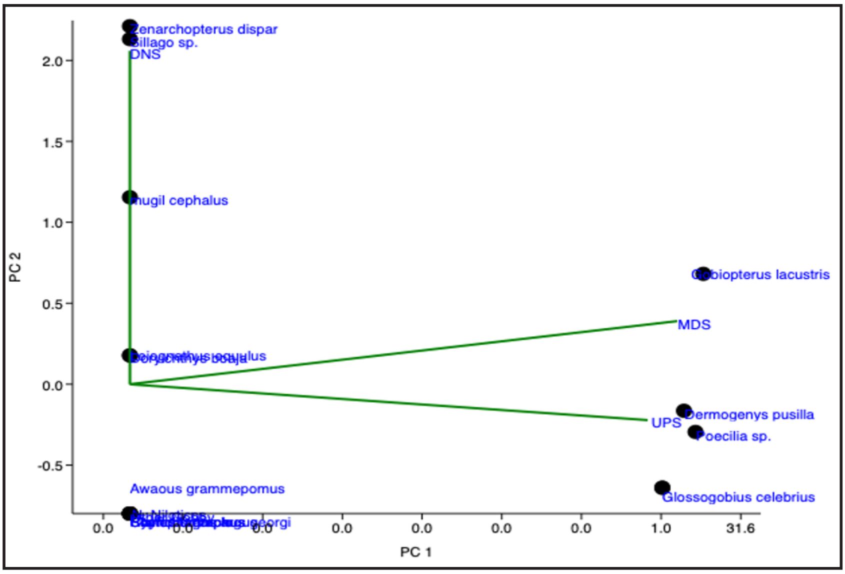

Figure 2. Distribution of collected fish samples between streams (wet season).

Downstream station observed the highest taxa collected and identified among sampling stations. A total of seven (7) taxa were noted in the station, while midstream and upstream obtained four (4) and three (3) taxa, respectively (see Table 6). Further, the downstream station obtained the highest diversity values with 1.53 'H,' followed by the midstream station with 1.14 H and the upstream station with 0.91 diversity values.

Furthermore, species richness was higher in the downstream area with 6.89 values against 3.97 and 2.99 values in midstream and upstream. The midstream station acquired the highest individual count with 38 individuals, while upstream and downstream acquired a similar individual count with twenty-seven (27) individuals. The upstream showed a high evenness value of 0.83, followed by midstream and downstream with 0.78 and 0.66 evenness values.

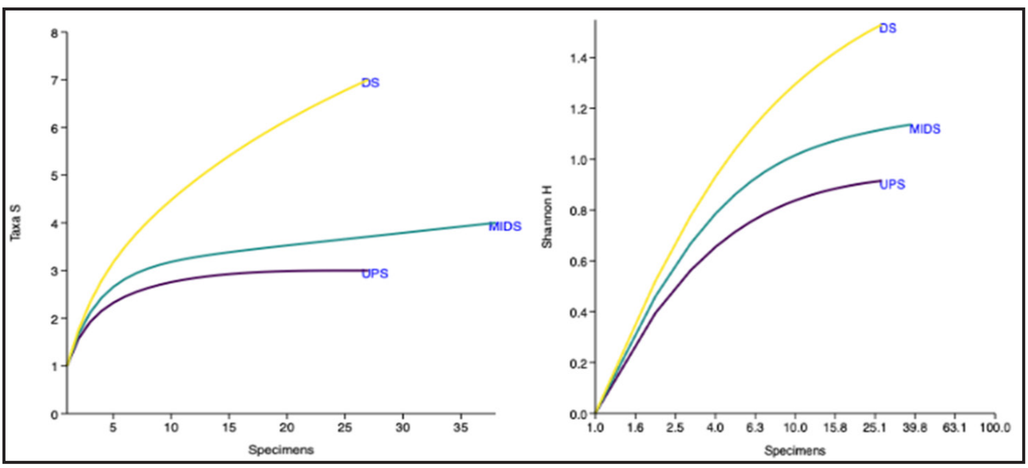

Figure 3. Graph of species richness and diversity index of fish samples (dry season); (a) Species Richness; (b) Shannon Diversity Index.

Table 6. Alpha diversity indices of the fish community in Inarihan river. (Dry season).

	UPS	MIDS	DS
Taxa_S	3	4	7
Individuals	27	38	27
Shannon_H	0.9146	1.137	1.529
Evenness_ e^H/S	0.8319	0.779	0.6593

Legend: UPS-Upstream Station; **MIDS**-Midstream Station; **DNS**-Downstream Station

Species such as *A. grammepomus* and *Poecilia sp.* were observed most dominant in the upstream station. *R. georgi*, *C. carpio*, and *O. niloticos* were observed to be more dominant in the midstream station. At the same time, *Zenarchopterus dispar, Sillago sp.*, and *Mugil cephalus* were highly dominant in the downstream station. *Clarias batracus* was also observed both midstream and downstream.

Table 7 shows midstream station obtained the highest collected and identified samples and values between stations, taxa, individuals, diversity index, and evenness and species richness values. Forty-one (41) taxa were observed against thirty-eight (38) and eighteen (18) identified taxa observed upstream and downstream, respectively. The number of individuals also showed higher numbers in midstream with 215 against 206, and 101 total individuals observed upstream and downstream, respectively. Furthermore, the highest species richness value was observed in midstream with 40.96 against 37.94 and 17.98 upstream and downstream.

Table 7. Alpha diversity indices of macro-invertebrate community in Inarihan river (Wet season).

	UPS	MIDS	DS
Taxa_S	38	41	18
Individuals	206	215	101
Shannon_H	3.102	3.312	2.43
Evenness_ e^H/S	0.5852	0.6692	0.6313

Legend: UPS-Upstream Station; **MIDS**-Midstream Station; **DNS**-Downstream Station

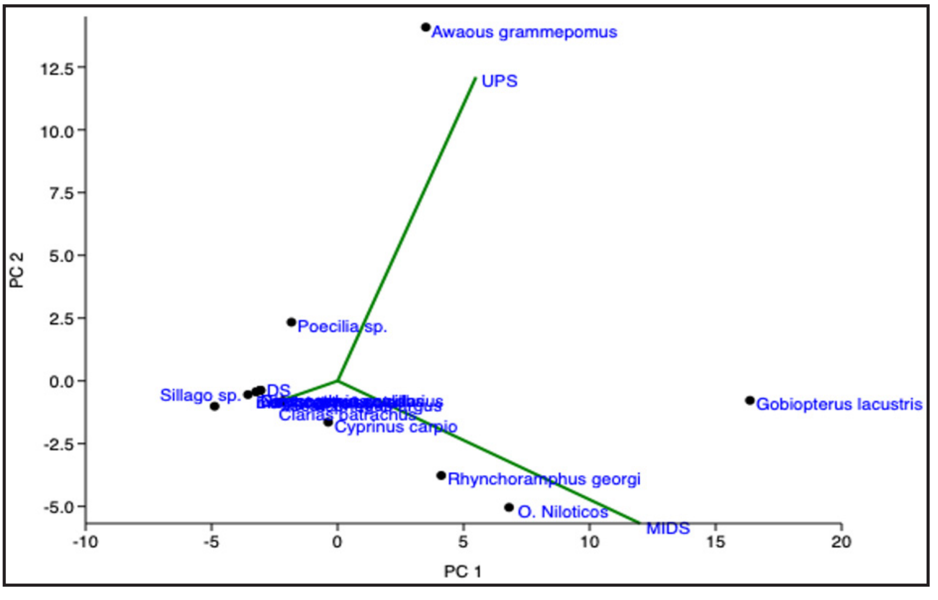

Figure 4. Distribution of collected fish samples between streams (dry season) macro-invertebrates.

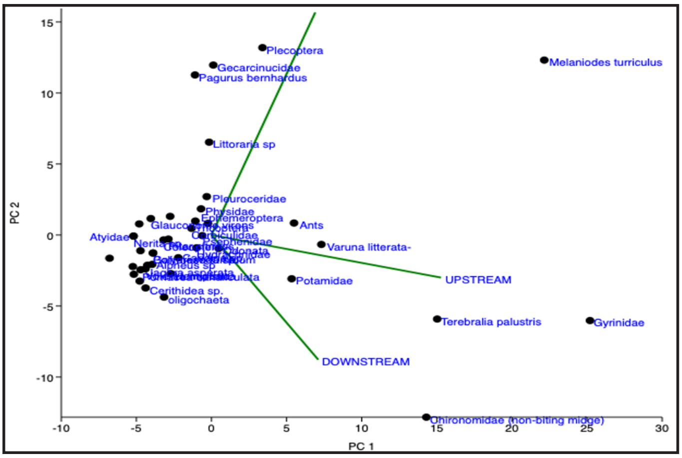

Figure 5. Graph of species richness and diversity index of macro-invertebrates samples (wet season); (a) Species Richness; (b) Shannon Diversity Index.

Species such as *Terebralia palustris, Gyrinidae, Potamidae, Varuna litterata,* and *Chironomidae,* were observed abundantly in the upstream station. Midstream stations were highly dominated by *Plecoptera, Gecarcinucidae, Pagurus bernhardus, Littorarian sp, Pleuroceridae,* and *Physidae,* while *Scylla serrata, Gyrinidae, Corbiculidae,* and *Oligochaeta* were highly observed in the downstream area. Moreover, *Gyrinidae, Chironomidae, Odonata, Coleoptera, Hemiptera, Littoraria sp.,* and *Corbiculidae* were highly observed among sampling station/streams. *Melaniodes turriculus,* was observed to be most dominant both upstream and midstream.

Table 8. Alpha diversity indices of macro-invertebrate community in Inarihan river (Dry season).

	UPS	MIDS	DS
Taxa_S	23	21	17
Individuals	142	135	95
Shannon_H	2.887	2.832	2.36
Evenness_ e^H/S	0.7802	0.8082	0.623

Legend: UPS-Upstream Station; **MIDS**-Midstream Station; **DNS**-Downstream Station

Table 8 shows upstream station having the high value of collected taxa with twenty-three (23) taxa against twenty-one (21) and seventeen (17) total taxa observed in midstream and downstream, respectively.

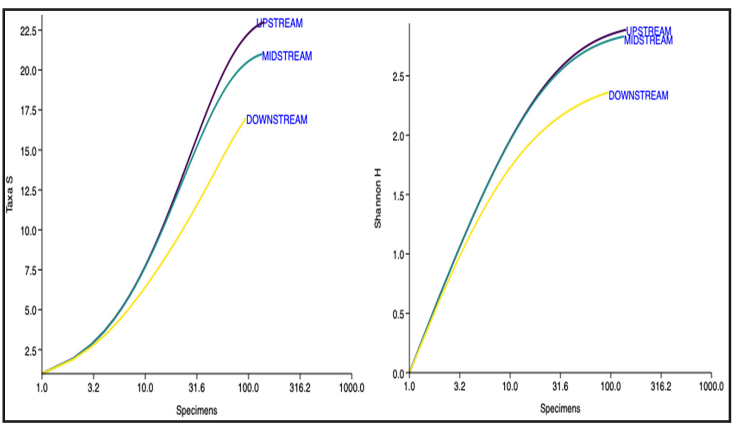

Figure 6. Distribution of collected macro-invertebrates samples between streams (wet season).

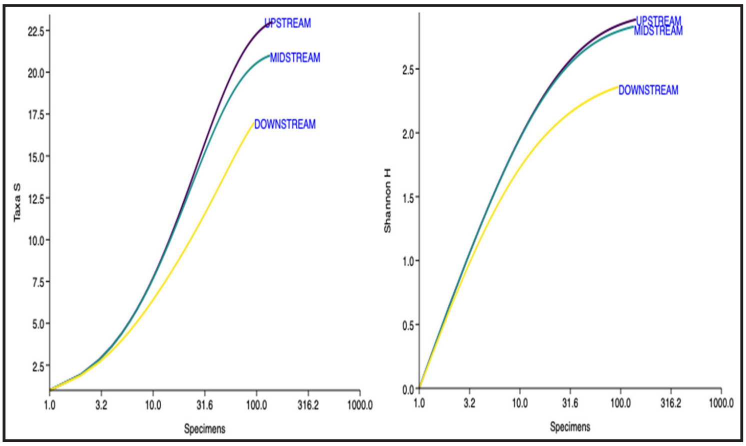

Figure 7. Graph of species richness and diversity index of macro-invertebrates samples (dry season); (a) Species Richness; (b) Shannon Diversity Index.

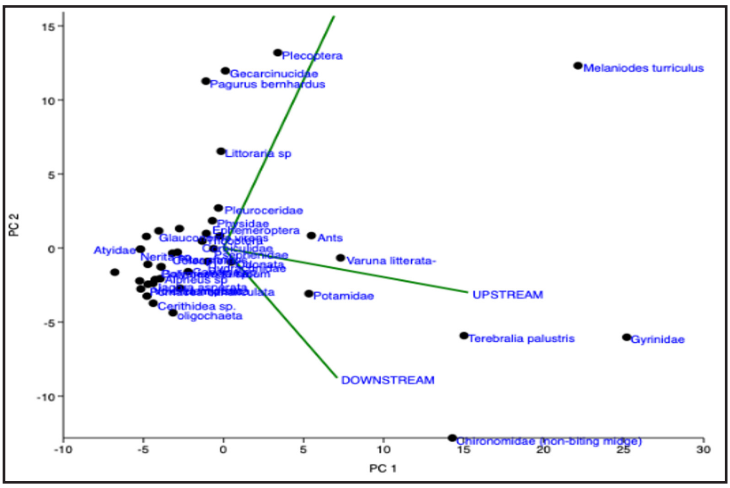

Figure 8. Distribution of collected macro-invertebrates samples between streams (Dry season).

Further, upstream obtained the highest individual counts with 142 individuals against 135 and 95 individual counts from midstream and downstream. Upstream holds the highest diversity index value of 2.89 'H', followed by midstream station with 2.83 and downstream with 2.36. Meanwhile, species evenness observed a high value in midstream with 0.808, followed by the upstream and downstream with 0.78 and 0.623. In terms of richness, the upstream station obtained the highest species richness value with 22.99 against 20.9 and 16.95 for midstream and downstream stations, respectively.

The upstream station was dominated by several taxa such as *Melaniodes turriculus, Nerita sp., Caridina sp., Atyidae, Odonata, Gyrinidae,* and *Chironomidae. Jagora asperata, Atyidae, Varuna litterata, Plecoptera, Pleuroceridae, Physidae, Odonata. Corbiculidae,* and *Coleoptera* were highly observed and distributed in midstream. *Terebralia sulcata, Littoraria sp, Cerithidea sp., Pitar citrinus, Alpheus sp., Gyrinidae,* and *Odonata* were distributed in the downstream station.

DISCUSSION

Calabanga, Camarines Sur is endowed with abundant natural water resources such as the Isarog and San Miguel Bay and changes in physical habitat of the rivers directly affect by high precipitation resulting in the occurrence of large quantities of surface water. In this study, three habitat types are observed; the upstream station of Inarihan river – a forested area composed of lush trees and vegetation, the midstream portion – an agricultural area, and the downstream – an estuary area. Riverine and estuarine provide a home for different fish species and a primary source of food, protection from a current, and refuge from predators, and breeding ground (Angermeier & Karr, 1984). Data analysis revealed that areas with a high abundance of trees observed the lowest water temperature. Forested sites with abundant trees and vegetation can contribute to the canopy cover providing shades (Studinski et al., 2021). It was highly observed upstream and in the midstream portion of Inarihan River. The main cause of warmer temperature in respected streams was the decrease of vegetation in the riparian zone. Agricultural activity also contributed to nutrient loading due to fertilizer, resulting in increased conductivity and total dissolved solids (Al-Shami et al., 2011; Piggott et al., 2012).

Distribution and abundance of Freshwater Fish

In this riverine system, *Zenarchopterus* were observed to be highly abundant in all streams of Inarihan River. According to Paller et al. (2011), freshwater fish families usually dominate the riverine ecosystem. Other native fish collected in all rivers are the *G. celebius, R. georgii and D. pusilla,* and these species are highly noticed in both dry and wet collections. Further, these native species are mostly prepared in the upstream and midstream areas since they are well adopted in pristine, vegetated, fast-flowing, cool headwater reaches.

Anthropogenic activities in the area can explain the existence of introduced species in the river such as *O. niloticus*. Some local residents in Tawang station have tilapia aquaculture near the river. Thus, there is a high probability that it would be distributed through contamination or accidentally releasing eggs and juveniles into the river. Paller et al. (2011) insisted that introduced species are often attributed to the deliberated introduction by the fisherfolks and escaping from nearby rice paddies. *C. carpio* and *M. batracus*, were also noted in Inarihan River, and are considered invasive species. The reproductive success of introduced species may be due to their higher adaptability to environmental stress and are habitat generalists (Guerrero, 2005; Cagauan, 2006). These species are more likely to occur in anthropogenically impacted environments (Kennard et al., 2005; Vescovi et al., 2009). The presence of introduced and invasive species can cause the decline of native species in TINAH Rivers, resulting in the decline of river health (Kennard et al., 2005). In a riverine system, fish species richness normally follows an increasing pattern from upstream to downstream (Welcomme, 1985; Bayley & Li, 1994). These statements are the actual findings of this study. Downstream stations of the respective rivers observed high species richness with six (6) total taxa identified. *Mugillidae, Zenarchopteridae, Sillago, Scatophagidae*, and *Syngnathidae* were noted as brackish water species because of their reproduction and life cycle requirements. Brackish water is the nursery area for various fish species, including *Mugilidae, Crustaceans*, and *gastropods* (Ruselle et al., 2003).

Higher diversity and equitability of fish were observed during the wet season. Freshwater fishes most prefer high water depth and frequent precipitation. Vescovi et al. (2009), stated that rainy season provides a sufficient volume of water for improved D.O. to replenish and refill the river. Griffin

& Ojeda (1992) also explained that the fish population increases during rainy seasons (spawning season) due to environmental stimuli triggered by seasonal changes. The ecological stimuli affect the endocrine response and regulate the metabolism and reproduction of the fish (Redding & Patinio, 1993). Different scenarios were also observed during the dry season. Water depth along the rivers was observed lower, reducing habitat availability, production of food, and water quality (Brandford & Heinonen, 2008). During summer, warmer water temperature causes low dissolved oxygen (Bradecina & Cabrera, 2020), leading to the river's decline in fish abundance (Uy, 2008).

Distribution and abundance of macro-invertebrates

Current is one of the essential factors that structure riverine communities. Fast-flowing water was observed upstream and midstream with cobble and pebble substrate and low water temperature levels. *Ephemeroptera* was noted as one of the dominated macroinvertebrates in the sampling area (Buffagni et al., 2010). Family *Corbiculidae* is classified as collectors that filter delicate particulate organic matter which is essential to the nutrition of the said group (Lampert et al., 2007). Mollusks have gills that allow them to thrive in such conditions and are filter-feeders and usually predominate downstream since they can effectively utilize the decreased size of organic particles (Lampert et al., 2007).

The changes in macrobenthic invertebrate communities are determined by the differences in the ability of resident genera to tolerate the environment around them despite the environment choosing the kind of food available (Matthaei et al., 2000 as cited by Aura et al., 2011). *Chironomidae* is pollution-tolerant and present in all streams. *Ephemeroptera* is dominant upstream and in midstream, and *Thiaridae* is the most dominant taxa in midstream but present in low abundance upstream and classified as somewhat pollution sensitive. These are *Ptilodactylidae, Corbiculidae, Trichoptera, Thiaridae* and *Ephemeroptera*. *Ptilodactylidae* was present upstream but absent downstream due to their preference for fast-moving waters. *Corbiculidae* and *Thiaridae* were present on both sites and are somewhat pollution tolerant. *Trichoptera* was present only downstream. However, we could not assume that the downstream site is clean because of a notable disturbance. The intolerant group is composed mainly of *Ephemeroptera* (all stations), *Plecoptera* (upstream), and *Trichoptera* (downstream). These groups are pollution sensitive, which requires high dissolved oxygen and neutral pH and feed on naturally available food sources such as decaying leaves. *Ephemeroptera* is considered sensitive to environmental stress, and their presence signified relatively clean conditions (Merritt and Cummins, 1978) and found in highest upstream. Aquatic worms (e.g., *Oligochaeta*) are pollution tolerant and can tolerate low oxygen, low or high pH, and warmer water and get oxygen from the air, not depend upon D.O. in the water and perform ecological functions and roles with potentially important repercussions for human health issues. These ecological values of *Oligochaeta* include their importance in aquatic food chains; their impact on sediment structure and water-sediment exchanges; their long history of use in pollution monitoring and assessment; their potential to reduce sludge volumes in sewage treatment systems; and their role as an intermediate host for several myxozoan parasites of fishes, including commercially exploited species (Martinez-Ansemil et al., 2007).

The presence, distribution, and abundance of freshwater mollusks depend on the salt content, vegetation, and nature of the bottom that plays such a crucial role in the sedimentation and purification processes. They are part of many freshwater fish's diets and are excellent ecological indicators. The poorer water quality downstream than upstream could be attributable to several man-induced activities such as urban off-to-surface river water. The main taxa of aquatic insects considered in this study are *Gerridae* and *Veliidae*. These two taxa of water striders are categorized under the infraorder *Gerromorpha* of the order *Hemiptera*: semiaquatic insects that live on or near the water. These predatory macroinvertebrates feed on terrestrial insects and crustaceans that fall on the water, which they recognize by the ripples they create on the surface (Resh & Carde, 2003). Members of infraorder *Gerromorpha* have several morphological adaptations to their unique habitat. Gerrids have greatly extended middle and hind legs, while Veliids have fan-like claws on their middle legs and both groups have subapical claws. These adaptations allow them to float and move on water surface films (Bush et al., 2008). Fish were found to feed on water striders only sporadically, which probably suggests that these invertebrates secrete unpleasant chemicals as defense mechanisms (Resh & Carde, 2003). In the upstream region, both taxa are almost of equal population size. In the midstream section, gerrids were highly dominant. In all sampling sites, gerrids and veliids were highest and cohabited the same pool area. The release of organic substances and surfactants to water bodies, reduces water tension on the surface film and affects populations of semiaquatic insects by incapacitating their water-floating ability (Bush et al., 2008).

CONCLUSIONS

The variability in the distribution and diverse composition of ecologically important fishes and macro-invertebrates in the river was explained by various vegetation types such as weather conditions, anthropogenic activities, and physicochemical parameters. Frequent assessment of macroinvertebrates, river habitat, riparian zone, and other aquatic organisms in the river is needed to save the Calabanga River from deterioration.

REFERENCES

Andem, A. B., Esenowo, I.K., and Bassey, D. O. 2015. "Application of biotic indices and pollution tolerance index in assessing macroinvertebrate assemblage of Ediba River, cross river state, Nigeria." Journal of Environmental & Analytical Toxicology S7. DOI: 10.4172/2161-0525.S7-007.

Aura, C. M., Raburu, P.O., and Herrmann, J. 2011. Macroinvertebrates' community structure in Rivers Kipkaren and Sosiani, River Nzoia basin, Kenya. Journal of Ecology and the Natural Environment Vol. 3(2), pp. 39-46. Retrieved from: http://www.ephemeroptera-galactica.com/pubs/pub_a/pubaurac2011\p39.pdf.

Buffagni A., Erba, S., & Armanini, D. G. 2010. The lentic–lotic character of Mediterranean rivers and its importance to aquatic invertebrate communities. Aquat. Sci. 72:45–60. DOI:10.1007/s00027-009-0112-4.

Bush, J.W.M., Hu, D.L., and Prakash, M. 2008. The integument of water-walking arthropods: form and function. Advances in insect physiology. Vol. 34 pp. 117-192. Retrieved from: https://doi.org/10.1016/S0065-2806(07)34003-4.

Griffith, M.B., Hill, B.H., Mccormick, F.H., Kaufmann, P.R., Herlihy, A.T., and Selle, A.R. 2004. Comparative application of indices of biotic integrity based on periphyton, macroinvertebrates, and fish to southern Rocky Mountain streams. Ecological Indicators 5 (2005) 117-136. Retrieved from: https://doi.org/10.1016/j.ecolind.2004.11.001.

Lampert, W. & U. Sommer. 2007. 2nd ed. Limnoecology: The Ecology of Lakes and Streams. NY: Oxford University Press. Retrieved from: https://jcsites.juniata.edu/faculty/merovich/limnology_files/Limnoecology.pdf.

Martin, P., Martinez-Ansemil, E., Pinder, A., Timm, T., Wetzel, M.J. 2007. Global diversity of *oligochaetous clitellates* (*"Oligochaeta"; Clitellata*) in freshwater. In: Balian, E.V., Lévêque, C., Segers, H., Martens, K. (eds) Freshwater Animal Diversity Assessment. Developments in Hydrobiology, vol 198. Springer, Dordrecht. Retrieved from: https://doi.org/10.1007/978-1-4020-8259-7_14.

Matthaei C.D., Arbuckle C.J., Townsend C. R. 2000. Stable surface as refugia for invertebrates during disturbance in a New Zealand stream. Journal of the North American Benthological Society, 19: 82-93. Retrieved from: https://doi.org/10.2307/1468283.

Paller, M.H., Reichert, M.J.M., Dean, J.M., and Siegle J.C. 1999. Use of fish community data to evaluate restoration success of a riparian stream. Ecological Engineering 15 (2000) S171- S187. Retrieved from: https://www.osti.gov/servlets/purl/1000070.

Resh, V. H. and R. T. Carde. Ed. 2003. Encyclopedia of Insects. USA: Elsevier Science. Retrieved from: https://doi.org/10.1016/B978-0-12-374144-8.X0001-X.