Review of Socio-Economic Research and Development Studies 2018
Volume 2 No. 1, 81-94

ROLE OF MACROINVERTEBRATES AS BIOINDICATORS AND RESIDENTS' PERCEPTION ON WATER QUALITY IN BILAR RIVER, BOHOL, PHILIPPINES

Eunice Kenee L. Seriño[1], Rumila C. Bullecer[2], Maria Felomina P. Talagsa[2] and Maridel Jan C. Madrona[2]

[1]*Department of Biological Sciences, Visayas State University, Visca, Baybay City, Leyte*
[2]*Department of Forestry and Environmental Science, Bohol Island State University, Bilar Campus, Zamora, Bilar, Bohol*

This study investigates the diversity and use of macroinvertebrates as bioindicators of water quality in three selected sites of Bilar River. River usage, management issues and people's perception on water quality were also assessed. Kick and sweep sampling methods were used to collect macroinvertebrate samples and physico-chemical parameters of the river were measured. Ecological parameters using standard indices were employed to describe macroinvertebrate diversity. A total of 12 macroinvertebrate species belonging to seven orders under four classes (Bivalvia, Gastropoda, Malacostraca and Insecta) were encountered. Results revealed that the two most abundant macroinvertebrate groups were found to be tolerant and very tolerant, suggesting that the water quality is considered "degraded to poor" based on tolerance ranking. Results show that Site 2 (Brgy. Poblacion) had the highest diversity, evenness, and richness index values, but lowest in dominance among the sites. Mean water pH was slightly acidic with low water temperature while water depth, flow and velocity were influenced by the presence of man-made dams and land bridges in the sites that hamper natural water flow. Bilar River plays an important role in the local community as irrigation and food sources but poor solid waste management in the area threatens its quality. Respondents believed that the river's water quality is deteriorating and will continue to deteriorate through the years, thus, conservation measures should be done to protect its health.

Keywords: bioindicators, diversity, macroinvertebrates, water quality

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[1] Corresponding author: Ms. Eunice Kenee L. Seriño, Department of Biological Sciences, Visayas State University, Visca, Baybay City, Leyte 6521-A Philippines. Email: eklserino@vsu.edu.ph

1. INTRODUCTION

Rivers are important part of the environment since it supports life and it is the source of natural, social, and economic goods especially to humans. Nowadays, water pollution is one of the most alarming forms of environmental degradation because of its direct effects to human health and socio-economic system components (Withanachchi et al., 2018). The condition of a river system is a direct reflection of land use activities and pollution made by humans.

In conservation studies, biological monitoring has been a valuable method used to protect and preserve the biological integrity of natural ecosystems (Kumari et al., 2007). Biological methods based on aquatic macroinvertebrates have been widely used to assess general water quality in rivers (Coimbra et al., 1996). These organisms are bottom-dwelling, with no backbones and can be seen with the naked eye (Readel, 2002). Riverine macroinvertebrates play different trophic roles in the processing of forest litter (Merritt & Lawson, 1992). Together with other microorganisms, they transform these food materials into utilizable nutrients that are in turn consumed by primary producers in aquatic habitats such as phytoplankton and periphyton. Macroinvertebrates are also good bioindicators of water health because of their sensitivity and tolerance to certain pollutants (Tampus et al., 2012).

According to Bonnet (2015), people's concerns towards clean water are considered as an essential part of water resource management. The perception of local residents towards water quality could reflect to the status of the environmental and social conditions in a given area. Safeguarding freshwater ecosystems is therefore essential to the protection of ecological processes and economic prosperity, which, in turn, are essential to the welfare and well-being of future generations. It is important that water quality and river systems are monitored so that water resources can be managed fairly; contaminants and their effects can be detected and controlled; and environmental protection policies and programs can be assessed.

This study looked into some of the biological, physical, and chemical characteristics of the midstream section of Bilar River. The data generated from this research will provide a substantial amount of information needed in putting up a river monitoring system, most ideally a community-based one to be sustainable.

The study investigates the role of macroinvertebrates as bioindicators of water quality in Bilar River, particularly in barangays Riverside, Poblacion and

Roxas. Specifically, this paper aims to determine some physico-chemical parameters in the river; identify the taxonomic composition of macroinvertebrates in the three selected areas; determine the occurrence and most abundant macroinvertebrate groups; assess the water quality of the river with the use of tolerance ranking of macroinvertebrates; determine the diversity, richness, evenness and dominance of macroinvertebrates; investigate how the people living near the river utilize the water resource and how they use local knowledge in determining water quality.

2. METHODOLOGY

Establishment of the Sampling Sites

Bilar River runs on an almost east-west direction for about 25 km from barangay Villasuerte passing down through barangays Rizal, Owac, Yanaya, Riverside, Poblacion, Zamora, Roxas and Dagohoy. It continues to flow to Sevilla where it eventually empties into bigger Loboc River while some tributaries go to Brgy. Rizal in Batuan and Brgy. La Victoria in Carmen (Figure 1). Its headwaters are believed to be in Anislag Spring in Omjon, Valencia. The river is one of the important tributaries to Loboc River and therefore a significant integral part of the whole Loboc Watershed.

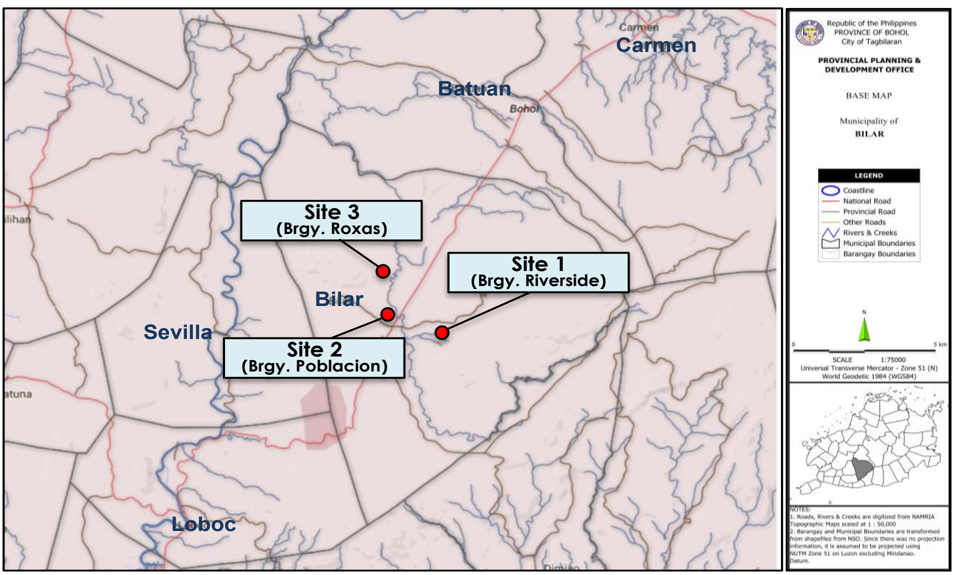

Figure 1. Map of Bilar showing the location of the sampling sites (source: Bohol Provincial Planning and Development Office, 2015)

Three sampling sites, with three sub-sites each, were strategically established. Site 1 was located below the bridge near the Army Camp in Brgy. Riverside. Water sampling in this section captured the dam, irrigation canal, boating site, small patch of a forested riparian zone, rice fields and grasslands. Site 2 was just after the highway bridge going downstream in Brgy. Poblacion, about 700 meters from Site 1. The impact stretch included rice fields, a dam, houses and piggeries along the riverbanks. Site 3 was in Brgy. Roxas, about 800 meters downstream from Site 2. The subject stretch has a dam, a prominent river bend, rice fields flanking it in a small stretch, a forested stretch, a short land bridge with culverts, and a right angle bend.

Physico-Chemical Parameters

Water temperature (°C) was measured using a field thermometer. The tip of the instrument was submerged to a depth of about five inches from the surface for a few minutes and three readings were recorded. The stream flow (m^3/sec) was computed by multiplying the cross-sectional area (m^2) of the river and its velocity (m/sec). Cross-sectional area was determined by measuring the width and depth of the waterway in small sections and multiplying these measurements together to work out the cross-sectional area. Velocity was taken using the float method, wherein a tennis ball was timed as it floats on a predetermined 10m-distance parallel to the waterway. Velocity was computed by getting the average time it took the ball to travel per second. The water pH was measured by using pH indicator paper strips. One strip was dipped into the water sample for a few seconds until it is wet. The color change of the strip was then compared to the colors on the side of the kit to match it with the corresponding pH value.

Sample Collection

Two sampling methods were applied in collecting the macroinvertebrate samples, namely, the kick and sweep sampling methods. These methods were adapted from Waterwatch Victoria Community Monitoring Manual (1996). Collection was replicated three times for each sampling method in each selected site.

For kick sampling, a kick net was placed at the downstream edge of the riffle so that the current can flow through it. To collect the samples, the streambed was disturbed for a distance of one meter upstream of the net by vigorously kicking the mud and stones for three minutes. The water current sweeps the invertebrates into the net. A forward scooping motion was used to lift the net from the water to avoid the collected animals to escape. For sweep method, the sampling net was swept vigorously around the water banks of the stream, sweeping around and through the vegetation for an approximate distance of 10 m. The net was handled carefully to ensure that no animals would move out from it.

The contents of the net were gently emptied into a bucket. The net was checked for any stuck animals and rinsed before taking another sample. Samples were placed in properly labeled plastic bottles and 75% ethanol was added to preserve the samples for identification.

Data Collection and Identification

Collected macroinvertebrate samples were placed in a petri dish and examined under the stereomicroscope. Individuals were counted and listed according to kind. Photos were taken to aid further identification and documentation by using a digital camera. Identification of samples was limited up to order level with the help of the Waterwatch macroinvertebrate practical guides.

Data Analysis

After identifying the samples, the number of individuals was recorded on the macroinvertebrate result sheet or the Tolerance Ranking Table. The number of macroinvertebrates for each group (very sensitive, sensitive, tolerant and very tolerant) was summed up. The two groups having the most number of macroinvertebrates were determined and these were used for the Water Quality Indicator Table. This analysis was adapted from Waterwatch Victoria (1996).

Data were further analyzed by some ecological parameters such as occurrence, relative abundance, Shannon-Wiener diversity index, Shannon's equitability index, Menhinick's index for species richness and Simpson's index of dominance (Magurran, 1984).

Social Survey

A questionnaire was formulated to capture the necessary information on demographic profile, water usage and perception on water quality in Bilar River. Residents living near the river were chosen as respondents. A total of 30 randomly selected respondents were interviewed from the three barangays.

3. RESULTS AND DISCUSSION

Physico-Chemical Parameters

Table 1 shows the physico-chemical parameters in the three sampling sites. The river had many shallow areas although the average depth was 1.83 meters. Average stream flow was 2.43 m3/sec with a mean velocity of 0.13 m/sec. Water depth, flow and velocity were influenced by the presence of dams and land bridges in the sites, which hampered the natural flow of the river. According to Madrona (2005), pH in Bilar River was 6.8-7 but in the present study, water pH level ranged from 6-6.33, which indicates a slightly acidic condition. This can be attributed to the effluents coming from the rice fields, built-up areas and pigpens present near the river. The average water temperature was 22.47°C, which is relatively low due to rainy weather.

Table 1. Physico-Chemical Characteristics of the Sampling Sites in Bilar River

Physico-chemical parameter	Site 1	Site 2	Site 3	Average
Depth (m)	1.56	1.95	1.97	1.83
Flow (m^3/sec)	1.62	2.53	3.15	2.43
pH	6	6	6.33	6.11
Water Temperature (°C)	22.1	22.89	22.43	22.47
Velocity (m/sec)	0.12	0.11	0.15	0.13

Species Composition and Occurence

Table 2 shows the species composition and occurrence of macroinvertebrates in the three selected sites. A total of 12 macroinvertebrate species belonging to seven orders under four classes were encountered. Class Insecta was the most represented group with four orders, which include Coleoptera (beetles), Hemiptera (bugs), Megaloptera (alderflies) and Odonata (damselflies and dragonflies).

For occurrence, Site 3 had the most number of macroinvertebrates observed (10 species) in the river, followed by Site 1 (8 species) and Site 2 had the least (6 species). The macroinvertebrates common in the three sites include damselfly nymph, freshwater mussel, freshwater shrimp, freshwater snail, and water strider. Some species were only encountered in specific sites. Alderfly, needle bug, water boatman, and whirligig beetle larva were only encountered in Site 3 while freshwater crab was only observed in Site 1.

Table 2. Species Composition and Occurrence of Macroinvertebrates in Bilar River

Taxonomic Group		Macroinvertebrates	Site 1	Site 2	Site 3
Class	**Order**				
Bivalvia	undetermined	freshwater mussel	1	1	1
Gastropoda	undetermined	freshwater snail	1	1	1
Malacostraca	Decapoda	freshwater crab	1	0	0
		freshwater shrimp	1	1	1
Insecta	Coleoptera	whirligig beetle larva	0	0	1
	Hemiptera	needle bug	0	0	1
		water boatman	0	0	1
		water scorpion	1	0	1
		water strider	1	1	1
	Megaloptera	alderfly	0	0	1
	Odonata	damselfly nymph	1	1	1
		dragonfly nymph	1	1	0
		Total	**8**	**6**	**10**

Note : 1=present; 0=absent

Tolerance Ranking of Macroinvertebrates

Table 3 shows the tolerance ranking results of macroinvertebrate groups. Very sensitive animals are only likely to be found in streams with good water quality. Sensitive animals are only found in streams with good or medium water quality. Tolerant animals can be found across a range of water quality in streams, but can live in poor-quality water. Very tolerant animals can be found in water of poor to good water quality, but are usually the most abundant group in streams with poor water quality.

The results showed that the two highest groups in terms of abundance were the tolerant (588 individuals) and very tolerant (7 individuals) groups. The third in rank went to the sensitive group (1 individual) and no individual under the very sensitive group was observed.

Table 3. Tolerance ranking results of macroinvertebrates in Bilar River

Macroinvertebrate Group	Sampling Method (no. of bugs found)		Total for each group	Rank each group from 1-4 1 - group with most no. of bugs 4 - least number of bugs
	Kick	Sweep		
VERY SENSITIVE			**0**	**4th**
stonefly	0	0		
mayfly	0	0		
SENSITIVE			**1**	**3rd**
alderfly larvae	0	1		
dobsonfly larvae	0	0		
cased caddisfly larvae	0	0		
water mite	0	0		
TOLERANT			**588**	**1st**
beetle larvae	0	3		
dragonfly nymph	0	7		
pond skater/water strider	0	130		
freshwater prawns/shrimps	0	280		
freshwater crabs	0	1		
damselfly nymph	0	112		
fly larvae	0	0		
molluscs	44	9		
water bugs	0	2		
caseless cadissfly larvae	0	0		
VERY TOLERANT			**7**	**2th**
freshwater hoglouse	0	0		
water beetles	0	0		
greater water boatman	0	0		
lesser water boatman	0	7		
leeches	0	0		
flatworms	0	0		
worms	0	0		

These results were further analyzed using the Water Quality Indicator Table that takes the two highest macroinvertebrate groups after the tolerance ranking. To finally determine the water quality, the two groups (tolerant and very tolerant) were fitted against each other (Table 4). The intersecting point between the two groups gives the final reading. The result indicates that the water quality is considered to be "degraded to poor". This result is similar to the study of Madrona (2005) but differ in terms of composition. It is good to note that mayflies under the very sensitive group were observed in 2005 but no longer encountered in the present study.

Table 4. Water quality indicator based on tolerance ranking

	Very Tolerant	Tolerant	Sensitive	Very Sensitive
Very Tolerant	Degraded	Degraded to Poor	Medium	Good to Medium
Tolerant	Degraded to Poor	Poor	Medium to Good	Good
Sensitive	Medium	Medium to Good	Good	Excellent

Relative Abundance

Figure 2 shows the relative abundance of the top five macroinvertebrates encountered in Bilar River. Freshwater shrimp had the highest relative abundance (47%) followed by water strider (22%), damselfly nymph (19%), freshwater snail (7%) and freshwater mussel (3%). These five most abundant macroinvertebrates belong to the tolerant group. Tolerant animals can be found across a range of water quality in streams, but can live in poor-quality water. In the study of Madrona (2005), freshwater mollusks, prawns and crabs were the abundant macroinvertebrates in the river.

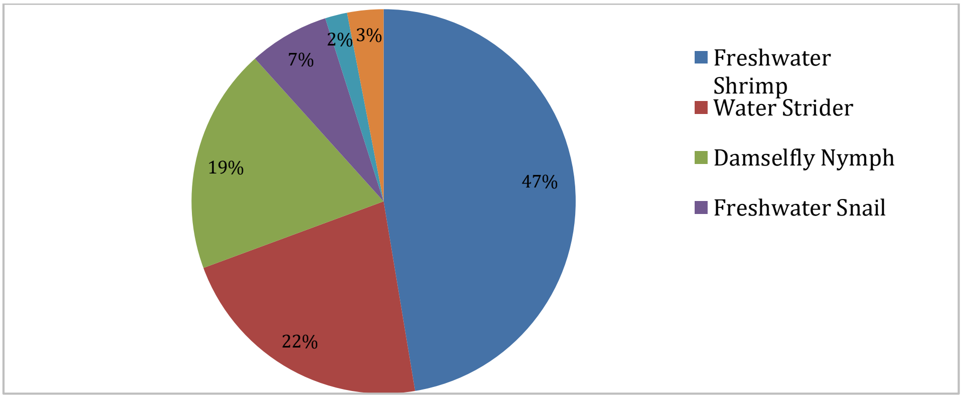

Figure 2. Bar graph showing the relative abundance of macroinvertebrates in Bilar River

Species Diversity, Evenness, Richness and Dominance of Macroinvertebrates

Figure 3 shows the diversity, species evenness, species richness, and dominance index values of macroinvertebrates in the three sites. Site 2 had the highest diversity (1.50), evenness (0.84), and richness (0.62) index values, but lowest in dominance (0.26) among the sites. These results suggest that the site supports a greater number of successful macroinvertebrate species and there is also a more even distribution of these organisms.

Site 1 had the lowest diversity (1.12) but it has the highest dominance value (0.46). This implies that there are high numbers of few individuals causing uneven distribution among the macroinvertebrates in the site, thus, affecting species diversity.

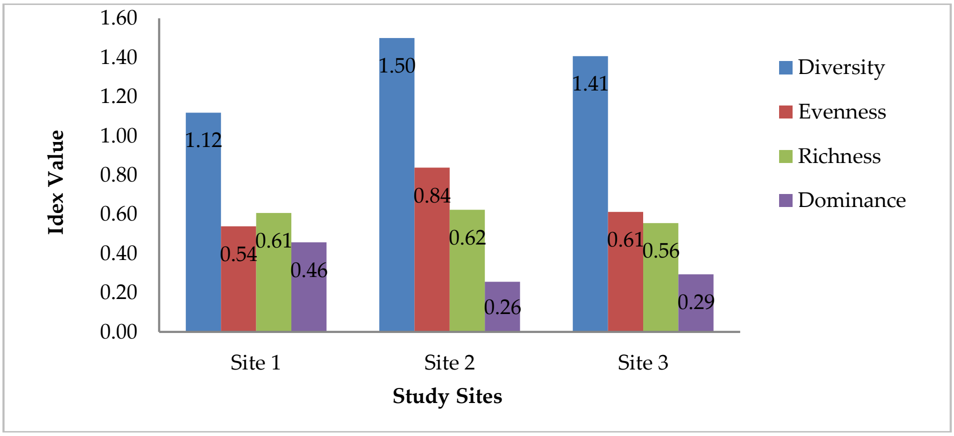

Figure 3. Diversity, evenness, species richness and dominance index values of macro-invertebrates in Bilar River

Uses of the River, Issues and People's Perception on Water Quality

Table 5 shows the socio-demographic profile of the respondents. A total of 30 randomly selected respondents living near the Bilar River were interviewed. Half of the respondents were females and half were males. Most of the respondents have an age ranging from 25-35 (37%) and 36-45 years old (37%). Forty-three percent (43%) were from Brgy. Riverside, 40% from Brgy. Poblacion and only 17% from Brgy. Roxas, Bilar. Most of the respondents were housewives (50%) and farmers (47%).

Bilar river is an integral part of the daily lives of the people residing close to the river bank. Aside from its ecological importance, the river plays an important role in the daily chores of the respondents including agricultural activities. Most of them used the river for irrigation (77%) considering that rice farming is one of the major livelihoods in the municipality of Bilar. Some answered that they also do fishing (40%) in the river while others use the river for laundry (7%) and bathing (7%) purposes.

Table 5. Socio-demographic profile of the respondents

Gender	Total	Percentage (%)
Female	15	50
Male	15	50
Total	30	100
Age		
66-below	2	7
56-65	1	3
46-55	5	17
36-45	11	37
25-35	11	37
Total	30	100
Address		
Poblacion	12	40
Riverside	13	43
Roxas	5	17
Total	30	100
Occupation		
Farmer	14	47%
Housewife	15	50%
Helper	1	3%
Total	30	100

In terms of river problems, more than 90% of the respondents said that throwing garbage is the major problem in the river. More than 70% said that it was caused by pigpens near the river and 47% said that it was caused by dumping of wastes directly into the river such as animal and human wastes. Moreover, 63% said that they have monthly river clean-up in their community while 37% said that they do not know any mitigating measure done by the government to conserve the water quality of the river.

Fifty-seven percent (57%) of the respondents said that water quality refers to the cleanliness of the water but 43% said that they do not know what water quality is all about. This suggests that the community needs to be educated so that people will have awareness on the importance of water quality and how to conserve it.

Figure 4 shows the perception of the respondents based on the river's water quality through time. Majority of the respondents (70%) said that five years ago, the river was clean while others stated that it was very clean (30%). For the present condition of the river, 50% of them said that the river is polluted while 20% of them emphasized that it is very polluted. But some respondents still considered that the river is clean (30%) at present but almost 90% of the respondents believed that it would be very polluted five years from now.

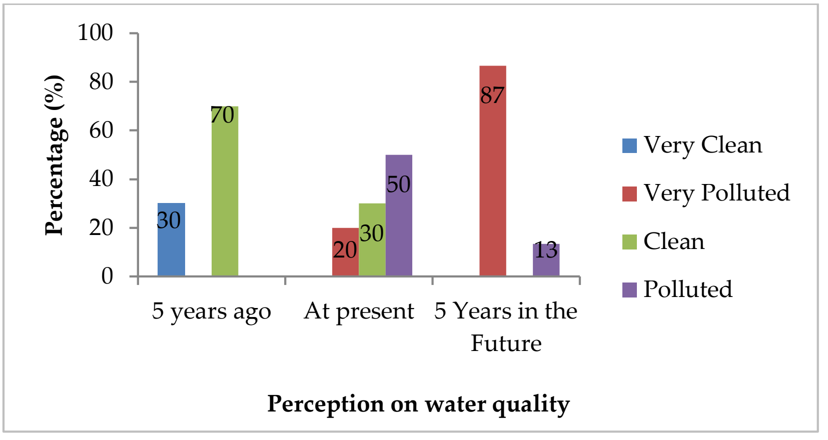

Figure 10. Peoples' perception on water quality

4. CONCLUSIONS

Bilar River serves as a habitat for a variety of macroinvertebrates. The study revealed that tolerant and very tolerant macroinvertebrate groups dominated the river ecosystem, which indicates that it has a "degraded to poor" water quality and this condition could suggest substantial organic pollution in the river due to various agricultural and other anthropogenic activities present in the area. Results of the diversity indices were influenced by the presence of few macroinvertebrate species under the tolerant group with great number of individuals. The presence of dams and land bridges in the area hampered natural water flow, thus affecting its depth, flow and velocity. Rainy weather influenced the water temperature and slightly acidic pH could be associated with the effluents coming from rice fields, built-up areas and pigpens near the river channel. The river system and its resources play a vital role in the local economy in terms of irrigation and food sources but poor solid waste management in the area threatens it. Most of the respondents believed that the water quality of Bilar River is deteriorating and will continue to deteriorate through the years if no significant actions will be done to protect and conserve it.

5. RECOMMENDATIONS

It is highly recommended that LGU officials of Bilar and the community should be educated more on freshwater resource management and water quality so that people will understand and appreciate the importance of rivers and this could inspire them to participate on conservation programs of river ecosystems. Existing laws and ordinances regulating the establishment of the built-up areas and projects like piggeries close to the river should be imposed and also with the regulations on proper solid waste management. A community-based, LGU-led waterway health monitoring should be put in place in order to keep track of the waterway health, improve management and sustainability of the water resources in Bilar. Similar studies should be made in other barangays situated in the upper and lower portions of the entire Bilar River to have a full picture for environmental monitoring.

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