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Fish Species Abundance and Species Richness in a Diverted Channel in Ilog, Negros Occidental, Philippines

Jessica Oñate-Pacalioga[1]* and Aimee Peralta[2]
[1]Department of Natural Sciences, University of St. La Salle, Bacolod City, Philippines, 6100
[2]Carlos Hilado Memorial State College-Binalbagan Campus, Philippines

Corresponding Author: jopacalioga@usls.edu.ph; jpacalioga@gmail.com

ABSTRACT

The effect of channel diversion in Ilog, Negros Occidental, was studied by comparing fish species abundance and species richness in the two river mouths, namely, Bungol Channel in Andulauan and Bocana in Lower Ilog River of the Ilog-Hilabangan River System. Data were collected for six months, from March to May 2011 for the dry season and from July to September 2011 for the wet season. Samples were collected using cast net and other indigenous gears in the locality. About 56 fish species belonging to 49 families were noted, and only three of these were introduced species. Fish species abundance was significantly different (t-test, p = 0.04), only in Bocana during the dry season. Nevertheless, fish species richness varied with season, as evidenced by the higher values observed in different river mouths. Tidal flow can significantly contribute to fish abundance and species richness, particularly during the dry season. Channel diversion with accompanying change in river discharge affected fish species abundance and species richness. These were modified further due to anthropogenic activities.

Keywords: channel diversion, fish species abundance, species richness, river flow, tidal flow

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1. INTRODUCTION

River systems are significant ecosystems supporting high biodiversity. This biodiversity stems from the complex interactions of the area's physical and chemical features, modified by the conditions created by living organisms, which are themselves continually affected by the area they inhabit. The river systems originate from usually forested hinterlands and receive inputs of organic materials to be recycled along its course. The organic materials are consequently deposited in certain sections of the river, contribute to the river's energy budget, and support its high biodiversity and productivity (Giller and Malmqvist, 1997), as food sources, primarily for fishes (Vannote et al., 1980). The Riparian sections of the rivers provide a variety of ecological services and functions complementing those of the river that they are often considered important buffer zones for wildlife (Freitag et al., 2011; DeCecco & Brittingham, 2011).

The flow and sediment transport disturbances along environmental gradients influence the form and biodiversity of river systems. These are reinforced by the presence of vegetation growth, which creates dynamic mosaics of habitat patches along the environment gradients of the natural river landscapes (Gurnell, Lee, and Souch, 2007). The riparian vegetation stabilizes the stream banks and act as final filter for the slope run-off, preventing its direct entry into the streams. It has been found to increase bed and bank due to the vegetation roots that reinforce~~s~~ the soil as it grows (Andrews, 1984).

Freshwater ecosystems are one of the most productive and diverse ecosystems (Nelson, 1994)—yet it remains poorly studied particularly in Asia (Kottelat & Whitten, 1996). Earlier researches on Philippine freshwater fishes (Herre, 1923, 1924, 1927, 1953; Roxas & Ablan, 1940) were mainly on taxonomy. Studies on limnology, biodiversity, and characterization of rivers (Carumbana, 2006; Davies, 1999; Pagulayan, 2003; Menes, 2010) are more recent.

Fish abundance and species richness in streams and rivers are maintained by a hierarchical set of processes that originate from biogeographical factors with varying processes. These determine landscape characteristics creating local habitat features related to stream geomorphology (i.e., depth, gradient, water velocity, and substrate composition), which determine abundance of particular species (Pusey et al., 2008). Larger streams tend to have higher species richness because species richness is noted to be correlated with habitat width (Smith, 1981) and volume (Angermeier & Schlosser, 1989). Similarly, large islands have greater species richness compared to smaller islands, particularly when accompanied by habitat complexity introduced by presence of more streams (Donaldson & Myers, 2002). In addition, the type of lotic habitat is also correlated with species richness. Running water was found to be most suitable for many freshwater fishes compared to riffles and pools (Jayaratne & Surasinghe, 2010), although endemic freshwater species of tropical Australia predominantly occupy riffles (Pusey et al., 2008). Substrate type providing heterogeneous habitats, e.g., rock and gravel, promote higher species richness in Choiseul Island (Boseto et al., 2007). In addition, proximity to the estuary or coast where migrant marine species breed may contribute to higher species richness (Jowell et al., 1996).

Seasonal temperature changes were found to increase abundance and species richness during the warm season. It also determined temporal changes in species composition of the fish community (Koutrakis et al., 2000). In Canada, climate warming due to climate change was found to affect the distribution of some cold-temperature species by promoting the expansion of its range from North to South

(Chu et al., 2005). Regular river discharge is influenced by the predictable rainfall patterns of the seasonal wet and dry conditions. River discharge was found to be strongly correlated with species richness, such that Australian rivers with higher discharges are likely to support more species (Pusey et al., 2008).

Landscape alterations are occurring almost everywhere in the world, modified mostly for human use. Rivers provide water resources for agriculture, commerce, and industry, such that human development has been closely linked with rivers and streams. More evident transformations of landscapes occur in the urban areas that make them progressively deficient of areas with significant ecological value (Baschak & Brown, 1995). Rivers, in particular, being the center for trade and commerce, have been modified as most major cities are built around rivers for transportation and for industrial functions. As a result, anthropogenic activities have contributed to the degradation of many rivers in the Philippines, with 50 of the 421 rivers declared biologically dead (Mesina, 1996).

Channel modifications of the Ilog River was initiated by the local government of Ilog in 1970 to address the problem of flooding. This resulted to changes in water discharge and accompanying topography and geomorphology of the river, which affected the activities and livelihood of communities along the riverbanks. This study covers a brief discussion of the river's hydrology and a comparison of fish species abundance and species richness of the two river outlets, in Bocana of Lower Ilog River and in Andulauan of Bungol Diversion Channel. Anthropogenic activities that directly or indirectly affect the river water quantity and quality are also discussed. The study highlights the need to integrate knowledge in hydrology and ecology in choosing strategies and formulating policies for resource management.

2. MATERIALS AND METHODS

Site Description and Sampling Method

Descriptions of the Ilog-Hilabangan River System were taken from Teruel et al. (2012). Ilog-Hilabangan River is geographically located within latitudes of 9°30'19" to 10°4'2" North and longitudes of 122°31'42" to 123°7'3" East. It drains an estimated catchment area of 210,947 hectares in the southern part of Negros Island (Figure 1). It covers around 17 % of the total area of the island, making it the largest basin in the Island of Negros and the 11th largest hydrologic unit in the country. The basin covers parts of Himamaylan, Kabankalan, Ilog, Candoni, and Cauayan in the Province of Negros Occidental and Jimalalud, Tayasan, Ayungon, Bindoy, Mabinay, Bais, Tanjay, and Bayawan of the Province of Negros Oriental.

Ilog River is the primary drainage path of the Ilog-Hilabangan River System, having a total length of about 123 km from its original outlet in Lower Ilog River at the Municipality of Ilog to the upstream end in Tablas River at the Municipality of Candoni. With tributaries emanating from the western side of the basin and from the south and southeastern side of the basin, Ilog River drains both the Occidental and the Oriental parts of Negros until the coastal areas of Municipality of Ilog, which empties to Guimaras Strait. It has a total of 45 contributing rivers and streams, with Hilabangan River as its second largest tributary. Due to its diversion, two outlets of the river exist in different barangays, namely, Barangay Bocana, Ilog, and the diverted outlet in Barangay Andulauan, Ilog.

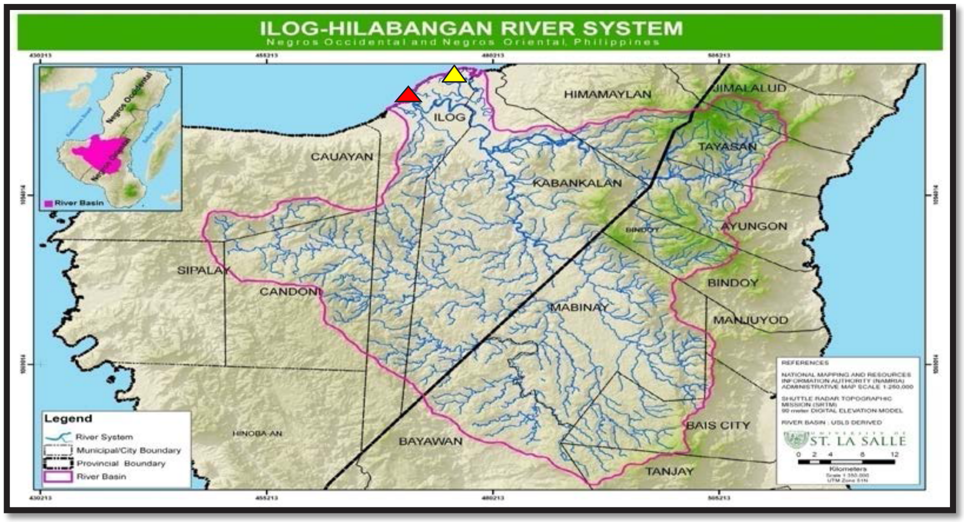

Figure 1. Map of Ilog-Hilabangan River System. (Red triangle is Bocana and yellow triangle is Andulauan.)

Two study sites were established, one in each river outlet. Fishes were sampled once per month for three successive months for the dry (March, April, and May) and the wet (July, August, and September) seasons. Cast net (3-m diameter, 5-cm mesh size) was the main gear used for sampling. The use of indigenous gears described by Carumbana (2006) and Gomez-Roxas *et al*. (2005), particularly those encountered in each locality, was adapted to enhance capture of representative fish species in the area. This included spear gun, dip net called “tikpaw,” a modified scoop basket called “sikop,” a handheld hook called “kawit” or “pakarus”, a push net called “suwayang”, and a barrier net called “puna” or “tapak”. Photographs of freshly caught fishes were taken to reduce the need for voucher specimen. Identification of fishes made use of the following references: Allen (1991), Herre (1953 and 1958), Rau and Rau (1980), and Smith and Heemstra (1986).

Habitat Description

Each of the study sites is located in separate river outlets found in two different barangays of Ilog, namely, Barangay Bocana and Barangay Andulauan. A brief description of the geomorphology and vegetation cover taken from Teruel et al. (2012) was included to highlight the environment—human interactions in each site.

a. **Bocana.** This is part of the original waterway of Ilog–Hilabangan River System, referred to as the Lower Ilog River. It has a length of 6.3m. The riverbed is sand and mud. There are no floodplains because the banks are covered in vegetation composed of mostly grasses/shrubs and nipa plantation towards the coastal area. Despite the vegetation, riverbanks are easily eroded due to the muddy substrate of the banks. The upstream portion of this river segment was rechanneled as part of the flood-control program. The river mouth is shallow resulting from the accumulation of sediments promoted by the presence of oyster beds and extensive nipa plantation.

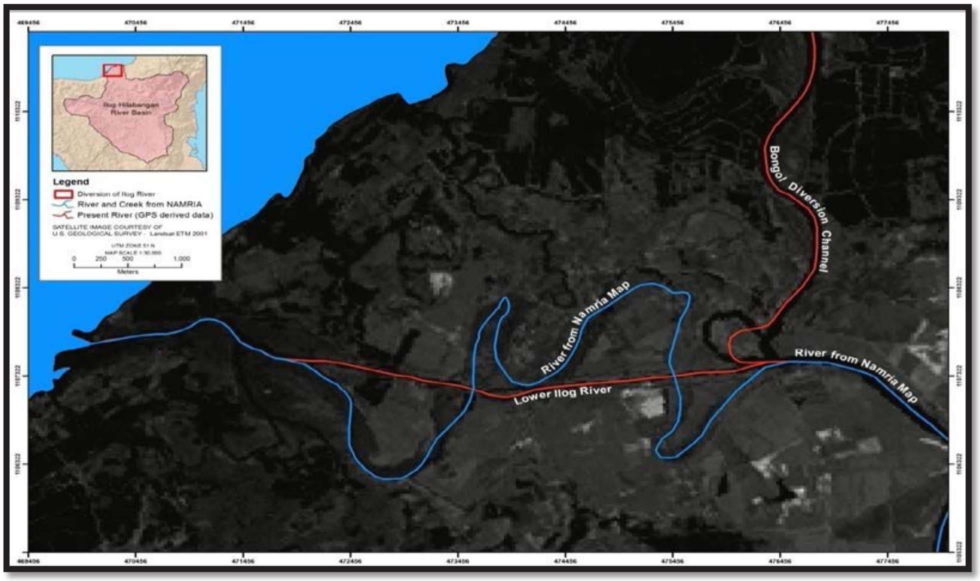

Figure 2. Diversion and re-channelization of the downstream area of Ilog-Hilabangan River.

b. Andulauan. This is also known as Bungol Diversion Channel. It was originally a tidal stream, with a 1.5-m width and a length of 6.8m. Over the years, it widened and formed extensive mudflats covered in 0.5- to 1-m thick mud on both sides of the channel. It was planted with mangroves, as part of the Department of Environment and Natural Resources, (DENR) reforestation project, but some portions were overgrown with grasses. The mudflat at the river mouth was inhabited by fiddler crabs that form mats, along with some gastropods. Numerous water birds flock to the mudflat to feed.

Historical records obtained from Kabankalan City's City Land Use Plan (CLUP) (2000–2010) showed numerous typhoons battering Kabankalan and Ilog. Among the worst typhoons was Typhoon Rena (November 1949), which damaged crops and properties and lost 500 lives. The more recent ones were Typhoon Ruping (November 1990), Typhoon Nitang (November 2001) and Typhoon Ursula (2003). The destruction of Malabong Bridge in 1964, which isolated the town from the rest of the province impelled the local government to divert Ilog River into Bungol Channel. The project was started in late 1970s to redirect some portion of flood waters to relieve the town of Ilog from annual flooding.

The nationally funded project included the dredging and rechannelization of Bungol Channel, which connected it to the lower Ilog River and straightened the meandering path of the lower Ilog River (Figure 2). This project succeeded in providing maximal conveyance for flood water in the river basin, increasing the water's velocity.

The river's geomorphology promotes flooding in the lower portion of the basin to include Kabankalan and Ilog. The catchment area is huge, covering 210,947 hectares, with mountainous and hilly areas on the eastern side and extensive alluvial and coastal plains on the western side and a clay-sandy loam soil type. With the proximity of Hilabangan River, a major tributary, to the river mouth and the large volume of tidal water entering the mouth to reach approximately up to 13 km, a heavy downpour would likely cause flood in Kabankalan and Ilog areas.

Data Analysis

Data on fish abundance and species richness were used for comparison between sites and seasons. Two-way analysis of variance (two-way ANOVA) tested for significant differences in sites, seasons, and the interaction between stations and seasons. *t*-Tests were also applied to show differences between stations within each season.

In addition, community similarity that compared diversity of the river outlets was determined using Sorensen coefficient, which gives more weight to similar species present in two communities being compared.

Sorensen Coefficient C = 2a/ (2a + b + c)

where a = no. of species common to both sites; b = no. of species in B, but not in A; c = no. of species in A, but not in B.

3. RESULTS

Species Composition

There were 56 fish species belonging to 32 families that were collected in both river outs. A total of 538 and 1,249 individuals were caught in the dry and wet seasons, respectively. A list of fish species collected in Andulauan and Bocana river outlets is presented in Table 1.

Table 1. List of Fish Species Collected in Andulauan and Bocana river outlets of Ilog River in 2010.

Family	Species	Local Name	IUCN Classification	Dry		Wet	
				Andolauan	Bocana	Andolauan	Bocana
NATIVE SPECIES							
1. Ambassidae	*Ambassis interrupta*	Parangan	Native	35	14	8	
	Ambassis miops	Parangan	Native		1	8	
	Ambassis uraethenia	Parangan	Native	5	31		26
	Parambassis sp.		Native	1			
2. Antennariidae	*Antennarius biocellatus*	lapat-lapat	Native		2		
3. Apogonidae	*Apogon hyalosoma*	Mu-ong	Native	4	7		
4. Carangidae	*Carangoides ferdau*	Lison-lison	Native	3	4		
	Caranx sp.		Native	2	29	7	15
5. Chanidae	*Chanos chanos*	bangus	Native		2		
6. Eleotridae	*Butis amboinensis*	Palo/Tuko-tuko	Threatened	25	12	20	
	Eleotris fusca	Bagtis (black)	Native	1			
	Eleotrimus tridactylus	Kugaw	Native	1			
	Ophiocara porocephala	Bagtis	Native	3			
	Oxyeleotris gyrsinoides	Ubog/Ilabu	Native		3		

Table 1 continued...

7. Elopidae	*Elops machnata*	Awa	Native		2	2	1
8. Engraulidae	*Anchoviella sp.*	Guno/nipis	Native	1	2	1	
9. Gerridae	*Gerres filamentosus*	Latab	Native	9	15	3	16
10. Gobiidae	*Carragobius urolepis*		Native		1		
	Favonigobius reichei	Tuko	Native		1		
	Glossogobius aureus	Bagtis/Wasay	Native	53	11	80	20
	Glossogobius giuris	Bagtis	Native		1	4	
	Glossogobius sp.1	Bagtis	Native		26	5	
	Gobiodes sp.	worm gobi	Native	4			
	Opheocara porocephala	Bagtis	Native	3			
	Periophthalmus kalolo	Tambasakan	Native	1	3		
	Stenogobius opthalmoporous		Native	4		9	
	Taenioides anguillaris	worm gobi	Native			3	12
	Taenioides cirratus	Bearded worm gobi	Native	1			
11. Hemiramphidae	*Zenarchopterus dispar*	Sigwil (halfbeaks)	Near Threatened			1	
12. Kuhlidae	*Kuhlia marginata*	Damagan	Native				1
13. Leiognathidae	*Leiognathus equulus*	Sap-sap	Native	33	8	32	17
14. Lutjanidae	*Lutjanus argentimaculatus*	Pulahan/ Managat	Native		6		1
15. Mugilidae	*Liza subviridis*	gusaw/Balanak/ Tungkan	Native	24	32	59	87
	Mugil cephalus	gusaw	Native	28	23	380	130
16. Mullidae	*Uphenoides sulphoreus*	Salmonete	Native		2	1	
17. Platycephalidae	*Flathead fish sp.1*	Sunob	Native			5	
18. Plotosidae	*Plotosus canius*	Alimusan	Native			13	2
19. Pomacanthidae	*Butterfly fish*	Humoy-humoy	Native		1		
20. Scatophagidae	*Scatophagus argus*	Kikiro	Native	5	6	3	4
21. Sciaenidae	*Nibea soldado*	Abo	Native				2
22. Siganidae	*Siganus guttatus*	Danggit	Native		2		
23. Sillagonidae	*Sillago sihama*	Aso-os	Native	2	4	48	18
24. Synancelidae	*Choridactylus multibarbus*	Ugok/ scorpionfish	Native		9		
25. Syngnathidae	*Microphis sp.2*	pipefish	Native		1		
26. Terapontidae	*Terapon jarbua*	Bugaong	Native	1	3		12
27. Tetraodontidae	*Arothron manillensis*	Butete	Native		6	1	
	Arothron sp.1	snake skin butete	Native		4		

Table 1 continued...

EELS							
1. Anguillidae	*Strophidon sathete*	Sili-sili	Native	5		55	105
	Moringua raetaburrhua	"red eel"	Native		2		
2. Ophichthidae	*Bascanichthys*	Sili-sili	Native	1		1	
	Cirrhimuraena chinensis		Native	1			
	Cirrhimuraena kaupi		Native	1			
	Cirrhimuraena sp.		Native			6	23
INTRODUCED SPECIES							
1. Belontiidae	*Trichopterus trichogaster*	Gurami	Introduced species		1		
2. Cichlidae	*Oreochromis niloticus*	Tilapia	Introduced species	1			1
3. Clariidae	*Clarias batrachus*	"Taiwan"	Introduced species			1	
			TOTAL ABUNDANCE	**258**	**277**	**756**	**493**

Seasonal Influence on Channel Diversion

Two-way ANOVA results show a significant difference in fish species abundance with season ($p = 0.044$). This is reflected in Figure 3, where more fishes were caught during the wet season compared to the dry season. Comparing the two sites for each season separately, the *t*-test did not show any significant difference between Andulauan and Bocana (dry season $p = 0.809$; wet season $p = 0.400$). Fish abundance in Andulauan was not significantly different as well (*t*-test $p = 0.159$), despite the apparent increase in the amount of fishes caught during wet season. However, the significant difference was noted in Bocana where more fishes were caught during the wet season (*t*-test $p = 0.040$).

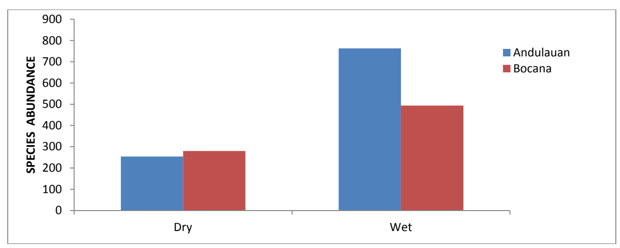

Figure 3. Comparison of fish species abundance to show effect of channel diversion in Andulauan.

Fish species richness in each site was shown to be affected by season, with a significant difference in the season-site interaction (Two-way ANOVA $p = 0.014$), as shown in Figure 4. The *t*-test results did not show any significant difference between sites (*t*-test $p = 0.188$) during wet season, nor was there a significant difference in fish species richness of Andulauan in both seasons (*t*-test $p = 0.350$). Nevertheless, Bocana yielded significantly more species of fish compared to Andulauan (*t*-test $p = 0.022$), during dry season (*t*-test $p = 0.010$).

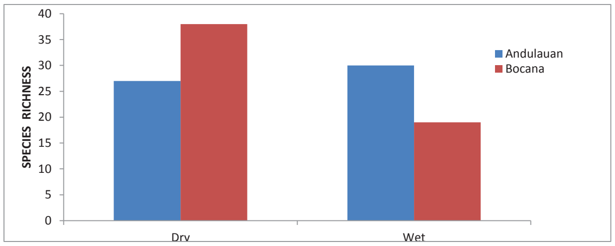

Figure 4. Comparison of fish species richness showing effect of channel diversion in Andulauan.

Species composition of the two river outlets were shown to be relatively the same, with similarity coefficient values of only $C = 0.5$ (dry season) and $C = 0.58$ (wet season), respectively.

4. DISCUSSION

Channel diversion in Ilog River resulted to differences in species abundance and species richness of its two river outlets, Andulauan and Bocana. Seasonal influence on the river flow, with greater volume during high precipitation in wet season and reduced flow in dry season, was shown to affect the amount and variety of fishes caught in the two river outlets, despite the relatively rainy dry season at the time of sampling.

Species abundance in Andulauan and Bocana was not significantly different in both seasons, although more fishes were captured in Andulauan during the wet season. No direct measurements of river width were made in the two river outlets, but the Andulauan outlet was approximately 30% wider compared to Bocana, based on ocular estimates. Furthermore, nipa plantation which were grown extensively towards the river in Bocana contributed to making the river narrower. This would possibly explain the higher species abundance obtained in Andulauan; as river width and volume were observed to correlate with fish species abundance (Smith, 1981), and was also noted in downstream areas of Patos Lagoon during high precipitation (Garcia et al., 2003).

Results of the hydrology study (Teruel et al., 2012) show that Ilog-Hilabangan River System discharges between 13 m^3/s to over 478 m^3/s of river water. The straightening of river in Bocana and the diversion in Bungol Channel facilitated the river's flood discharge and modified the streamflow, which increased water velocity and enhanced erosion of the riverbanks (Figure 5). Despite being a tidal stream with an original width of 1.5m, the Bungol Diversion Channel has widened and is now estimated to drain approximately 75-80% of river water compared to Bocana's 15-20%. Since river volume was positively correlated with water current, Andulauan would drain a larger volume of water with a stronger water current compared to Bocana, particularly during the wet season. This strong water current would counter the entering tidal flow and resist its entry into the channel, which may explain the absence of any significant difference in species abundance and species diversity between Andulauan and Bocana.

Figure 5. Erosion at the channel diversion, (a) channel leading to Andulauan, (b) Malabong at the point of re-channelization. (Photos by J.P. Gabriel).

In the dry season, entry of tidal waters brought in more fish species in Bocana but not in Andulauan. The large volume of river water draining from Andulauan created a strong river current that could have prevented migrating fishes carried by tidal waters to counter its flow. As tidal water was entering Bocana at the start of high tide, Andulauan was observed to continue draining (Carmona, personal communication). On the other hand, the smaller volume of water draining from Bocana, particularly in the dry season, permitted the entry of tidal waters to influence species richness and replenishment of nutrient supply, which enhances the river's diversity and productivity.

Thus, only Bocana showed significant seasonal differences in species abundance and species richness, particularly in the dry season. With reduced river discharge, the influence of tidal flow becomes significant, causing the increase in species abundance and species richness. Additional information to support this observation is based on results of the Pearson correlation test on the data from the downstream station of Lower Ilog River, which indicated a high positive relationship between fish species richness and temperature, salinity, and total dissolved solids (Teruel et al., 2012), factors that were all associated with high tide conditions in the dry season.

Species abundance for fishes was not shown to be strongly influenced by selected physico-chemical variables. However, species richness increased with warmer water temperature, salinity, and total dissolved solids, which could be the result of the significant volume of tidal waters entering the river during dry season. High salinity and total dissolved solids during dry season were brought about by tidal waters, as higher values of these parameters occurred when sampling was done at high tide. The entry of tidal water replenishes the nutrient supply and also facilitates migration of fishes into the river, which enhances the river's diversity and productivity.

Impacts of Anthropogenic Activities

Introduced Species

A number of species have been introduced through aquaculture, pet trade, and mosquito control. Of the eight introduced species recorded in Ilog–Hilabangan, two species were intentionally introduced to address existing concerns. *Gambusia affinis* was introduced for mosquito, control and *Cyprinus carpio* was added to enhance river fish supply, which was perceived to decrease in 1986. *G. affinis* is most abundant in Hilabangan River, while *C. carpio* was never encountered throughout the sampling period, although anecdotal reports of fishermen affirmed its presence in the midstream station.

The presence of *Gambusia affinis* in large numbers at the upstream station is a potential environmental threat. It is reported to have adverse ecological impact in seven countries (Casal et al., 2007). Like most places in the country, it was introduced in rivers to control the rapidly growing mosquito population. *G. affinis* appeared to be well adapted and have become established in the area, as it was reported to exhibit 89% potential to become established (Casal et al., 2007). Its size ranged from 2.1–6.8 cm, which is 2–3 times bigger than those obtained in Bago River (Pacalioga et al., 2010). Of the 15 samples dissected (Appendix N), all were found gravid at varying stages of maturity (Peralta, personal communication). Since *G. affinis* are live bearers, all of its larvae can live independently upon release. When its population is left unchecked, it may likely replace the existing native species. In fact, in the lower section of Isi River (Upstream station), where the river widened and became slow moving, *G. affinis* was the predominant species.

The presence of the janitor fish *Pterygoplichthys disjunctivus* and the carp *Cyprinus carpio* also poses potential threats to the native species. These species are known to compete with native species for habitat use and for food. Since both species are considered voracious feeders; eggs or larvae of native species can become potential food for these species.

Pollution

The river serves as a receptacle for varied forms of pollution, ranging from domestic, agricultural, to industrial sources. Domestic pollution in the form of sewage and garbage were observed from the upstream, midstream, till the downstream sections of the river. Portions of the midstream riverbank were used as dumping site for garbage. Solid wastes, e.g., plastic bags, diapers, styroform, along with fallen bamboo poles from upstream, are carried by flood waters into the river, which can be transported elsewhere or collected in riverbends. This made fishing with the use of gill nets very difficult, as they could be ripped by submerged bamboo poles.

In addition, sewage coming from households as well as backyard swine farms was also thrown in the river. In the upstream station, the river is utilized as bathing and cooling ponds for farm animals, e.g., carabaos, horses. Mounds of animal wastes were a common sight along river banks.

Run-off coming from agricultural lands that contain fertilizers and pesticides also contributes to the pollution. Erosion of riverbanks and upland areas was intensified by heavy downpour that occurred in both dry and wet seasons. This resulted to a muddy riverbed in the midstream and downstream stations.

Industrial effluents were also periodically released into the river. Anecdotal information from the community along the river's midstream show that these wastes resulted to reduced fish catch and sometimes fish kills, particularly in the main Ilog River leading to Bocana. During the March 2011 sampling, fishing activity was called off when gel-like materials called "sapwa" were seen floating in the river. The fishermen narrated that this material adhered and coated the gill nets and cast nets so that no fishes were caught despite repeated efforts to collect samples. This gel-like substance remained suspended in the water for the 2-day sampling and reduced the water's visibility. Fish kill was observed during the May 2011 sampling when dead fishes were seen floating or were scattered along river banks and also increased catch of decapods.

Nipa Plantation

Extensive nipa plantation exists in the downstream station, particularly in Vista Alegre and Bocana. Nipa grows naturally in river mouths as an associated mangrove species of the forest. It promotes land accretion and stabilizes river banks. It contributes livelihood for the community. In fact, many of the local fishermen shifted to nipa plantation when fishing in the area became unprofitable. However, nipa plantation has been gradually expanding towards the river; such that the Bocana river mouth is notably made narrow and shallow as more sediments are accumulated with each flood. The increasing frequency of floods due to climate change would potentially make river draining in Bocana ineffective.

5. CONCLUSION AND RECOMMENDATIONS

The Ilog–Hilabangan River System exhibits high species diversity that is strongly influenced by the river's topography, hydrology, substrate type, and the climate. In particular, channel diversion resulting to the huge volume of river discharge during periods of high precipitation affected the species abundance and species richness of the estuarine areas downstream. Tidal waters also contribute to species diversity and becomes pronounced during dry season. Nevertheless, the presence of barriers, natural and man-made, may limit the exchange of materials, food sources, and replenishment of nutrients only to the river mouth. The presence of an extensive nipa plantation in the downstream station can become a barrier and impede the important link between the river and sea. Vegetation in the periphery of river streams must be regulated to ensure the free exchange of materials between two ecosystems.

Presence of introduced species upstream can potentially penetrate the estuarine areas through flooding during periods of high precipitation, which facilitate their movement downstream and threaten the existence of resident native species. *Gambusia affinis*, *Pterygoplichthys disjunctivus,* and the carp *Cyprinus carpio* are invasive exotic species that can compete and potentially displace the native species. Their abundance in the upstream sections of the river is an important concern that needs to be addressed.

Effect of pollution can be expanded to distant locations due to flooding. All types of pollutants, e.g., agricultural, domestic, and industrial are potential threats to the health of the river. Disposal of these pollutants must be regulated and the waste released into the river must be required to undergo processing or treatment to make it tolerable for most aquatic organisms.

Flooding can worsen due to climate change. Due to changing water velocity and volume of outflow brought about by river channelization, biodiversity loss may intensify; livelihood activities may change.

6. ACKNOWLEDGEMENT

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