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Fish and Invertebrate Species Composition in Estuarine Areas of Bago-Pulupandan, Negros Occidental, Philippines

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ABSTRACT

Estuaries are known as nursery grounds of many fishes and invertebrates. Their connectivity with other adjacent ecosystems is vital to their nursery role. Anthropogenic activities can potentially interfere with this function. Yet information on species inhabiting Philippine estuaries is little, and their distribution is not well-established. This study provides baseline data on fish and invertebrate composition of the coastal and estuarine areas of Bago and Pulupandan that were newly established marine protected area (MPA) and proposed MPA sites, respectively, for the conservation of Irrawaddy dolphin habitats. Fish distribution is included to show connectivity of estuaries with other adjacent ecosystems. Gill nets were used to collect fish bimonthly. Majority of the catch was economically important food fishes dominated by marine demersal species. These species were associated with two to three other habitats particularly the estuary, implying connectivity of coastal ecosystems. However, anthropogenic activities exert increasing pressure in estuarine areas, potentially threatening their existence and the fisheries they support.

Keywords: connectivity, anthropogenic activities

INTRODUCTION

Estuaries and coastal ecosystems are recognized as one of the most productive ecosystems worldwide. Being located in river mouths, marine and freshwater have combined influence on the estuaries' characteristics and its inhabitants (Elliott & Whitfield, 2011). River outflow transports autochthonous and allochthonous organic matter to combine with nutrients from tidal inputs that sink as abundant food sources in estuaries sustaining a detrital food chain (Whitfield, 1999). The estuaries' capacity as nutrient and detrital sink promotes high levels of primary and secondary productivity (Abrantes & Sheaves, 2010; Beck et al., 2001; Heck, 2008; Sheaves et al., 2014; Whitfield, 2016) that are transported to adjacent marine areas (Heck, 2008) or redistributed by tidal action (Elliott & Whitfield, 2011). Hydrodynamics has a strong influence on the transport of nutrients as well as larvae in estuaries (Elliot & Whitfield, 2011). Distribution of estuaries follows mangroves in the tropical region (Blaber, 2002). In some areas like Australia, estuaries comprise seagrasses, mangroves, and nearshore shallow-water areas because of their combined occurrence (Meynecke et al., 2007). Vegetation in estuaries provides heterogeneous habitats for fishes and invertebrates that influence fish species assemblage and abundance (Bloomfield & Gillanders, 2005). Estuaries are also characterized by highly fluctuating environmental conditions. Biological and physicochemical conditions are variable, constantly changing with tides and seasons. Thus, a limited number of species can tolerate the harsh environmental state; often only the more resilient ones remain (Elliott & Quintino, 2007).

Coastal areas form a region where several ecosystems sustaining artisanal fishery are interconnected. It covers the open coasts as well as the embayment and estuaries, which in the Philippines are defined by a distance of 1 km inland from the high tide mark and seaward up to 200 isobath (Department of Natural Resources, Bureau of Fisheries and Aquatic Resources of the Department of Agriculture, and Department of the Interior and Local Government, 2001). These areas are associated with several ecosystems such as coral reefs, seagrasses, wetland areas, estuaries, and extensive mangrove forests. Due to the proximity of these ecosystems to each other, their productivity is transferred to adjacent ecosystems by water currents. For example, litter obtained from seagrasses of Bais Bay could be as much as 0.282 gdw$m^{-2}d^{-1}$ from *Thalassia hemprichii* and 0.028 gdw$m^{-2}d^{-1}$ from *Enhalus acoroides*, of which 28% and 86% of their production, respectively, were exported to the mangroves (Pacalioga, 1993).

Coastal and estuarine ecosystems are well-known as nurseries for fishes and invertebrates (Baran & Hambrey, 1998; Seitz, 2014; Sheaves, 2014), including species of great importance ecologically, economically, and culturally (Beck et al., 2001). Other species utilize the estuaries as spawning area, breeding and feeding areas, and migration route (Seitz, 2014). Estuaries support ontogenetic migrations essential to the life histories of numerous organisms (Blaber, 2000; Nagelkerken et al., 2014). Euryhaline marine species immigrate to estuaries in large numbers early in their life (0 to 1 year old; Potter et al., 1990). As nursery grounds, estuaries become crucial areas for survival of juveniles that contribute to recruitment offshore (Sheaves et al., 2014) often associated with fisheries production (Blaber, 2000; Potter, 2015; Primavera, 1998).

The ability to successfully perform this nursery function relies on the complex ecological interactions within and the connectivity among these ecosystems (Gillson, 2011; Meynecke et al., 2007; Sheaves et al., 2014). Connectivity involves migration of organisms in different habitats as part of ontogenetic habitat shifts (Elliott et al., 2007), as well as the provision of materials and physicochemical conditions that facilitate essential ecological functions (Nagelkerken et al., 2014). Movements of organisms involve varied activities for growth and survival, for example, foraging, feeding, and taking shelter in transit or seeking protection from predators (Abrantes et al., 2015; Adams et al., 2006; Heck, 2008; Sheaves, 2014). Likewise, such migrations distribute nutrients to neighboring ecosystems as organisms release waste or become prey to predators.

Bago River drains one of the major river systems of Negros Island. It opens into the Guimaras Strait, which connects to the Visayan Sea, one of the Philippines' major fishing grounds. Along with Sibud Creek in Bago, the river's wide mouth can pour a large volume of freshwater and contribute organic matter as well as pollutants that can influence the physicochemical condition of the estuary and the functioning of its inhabitants. Bago River's estuarine areas are important fishing grounds, supporting the artisanal fishery of Bago's coastal barangays and the neighboring town of Pulupandan. It is also the habitat and feeding ground of the critically endangered Irrawaddy dolphin, *Orcaela brevirostris* (Dolar et al., 2018). The local government of Bago City established a marine protected area (MPA), while Pulupandan proposed to establish the same; all these efforts were concerted to protect the Irrawaddy dolphins and manage their fishery resources. Baseline data on fishery species composition are essential for evaluation of the protection efforts to be implemented in the area. Likewise, there are limited published data on the fish and invertebrate species collected in estuarine habitats of the Philippines. This rings some concern as estuaries are now threatened due to their favorable location for development. Its inhabitants are further endangered by increasing anthropogenic activities that result to urban, industrial, and agricultural pollution; overfishing; and poaching (Blaber, 2013; Sheaves, 2016). Due to limited information on these habitats, they are poorly appreciated and become most threatened despite their contribution to fisheries (Blaber, 2000; 2002). Information showing the estuary's importance particularly its nursery function and connectivity to other coastal ecosystems that sustain fishery production will be essential in promoting conservation of this poorly understood ecosystem.

To address this lack of information on estuarine ecosystems in the Philippines and to provide baseline data for the newly established protected areas, this study aimed to identify the fish and invertebrate species caught in estuarine areas within Bago and Pulupandan's MPA and adjacent non-MPA sites. Similarity of species composition among MPA and non-MPA sites was determined to show species resemblance of comparable habitat conditions. In addition, species distribution based on the species' occupied habitat was used to exhibit connectivity of the estuary with adjacent habitats such as river, marine/coastal, and reef or reef-associated areas.

MATERIALS AND METHODS

Study Sites

The study sites were established in the estuarine waters of Bago and Pulupandan. These estuaries are classified as partially mixed, coastal plain/drowned river valley based on estuary origin (Valle-Levinson, 2011). The MPA of Bago was established under City Ordinance 17-2 in February 23, 2017 (CO17-02, 2017), while that in Pulupandan was only a proposed site. The study was conducted in March 2018 to April 2019, one year after the establishment of Bago's MPA. Randomly selected points within the MPA were identified as MPA-Bago (10°34'0.419" N, 122°49'48.266" E) and proposed MPA-Pulupandan (10°32'4.002" N, 122°47'55.727" E) sites. Both sites were situated in relatively deeper areas (approximately 15–30 m deep) with sandy-muddy substrate and with riverine plumes during wet season. Likewise, two sites in shallow nearshore areas (<5 m deep) outside the MPA were designated as NonMPA-Bago (10°33'16.945" N, 122°50'30.57" E) and NonMPA-Pulupandan (10°32'48.602" N, 122°32'48.602" E), respectively. All sites receive freshwater outflow; Bago River for MPA-Bago, Bago and Sibud rivers for NonMPA-Bago, and Canjusa Creek for MPA-Pulupandan and NonMPA-Pulupandan sites. Due to slow water currents nearshore (Carmona, 2019), the NonMPA sites accumulate fine sediments forming generally muddy substrates. Figure 1 shows the location of these sites.

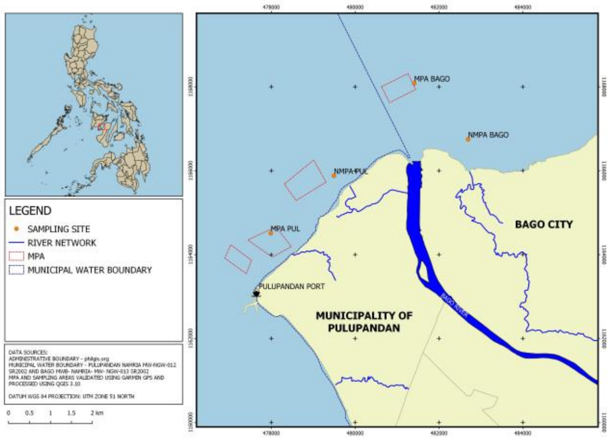

Figure 1. Map showing the location of MPAs and NonMPAs for Bago and Pulupandan.

Data Collection

Three replicate gill nets, each with 100-m length × 2-m width (area of 200 m^2) and mesh size of 5 cm, were dropped in each site and soaked for one hour to collect fishes and invertebrates. For consistency of tidal patterns, sampling was done during the first and last quarters of the lunar cycle beginning April 2018 to March 2019. Monthly collection was done for the first four months and was increased bimonthly from the fifth sampling onwards, covering 13 months. Since fishing activities in the area occurred only during the day, sampling was limited to daytime. After hauling the nets, these were brought ashore to collect the fishes and invertebrates. Fresh samples were photographed and identified. In addition, samples of each representative species were placed in glass jars containing 70% alcohol and sent to Silliman University for taxonomic identification/verification.

Data Processing and Analysis

A list of fish and invertebrate species collected from MPA and NonMPA sites was made. Habitats of each species were categorized using information from FishBase, SeaLife, and other web sources to determine species distribution. The types of habitats were coral reef and reef-associated areas, marine/coastal area, estuary, and river.

In addition, similarity of species composition was quantified using Sorensen's coefficient of community index (CC) with the following formula:

$$CC = \frac{2c}{2c+a+b}$$

where c is the number of common species in both communities and a and b are the number of species found only in Community A and Community B, respectively. Perfect similarity has a 1.0 value.

RESULTS AND DISCUSSION

Species Composition

A total of 74 species comprising 50 fishes, 2 rays, 18 crustaceans, 3 mollusks, and 1 echinoderm were collected from the MPA and NonMPA sites of Bago and Pulupandan. An earlier survey of the fishes and macroinvertebrates of Bago River found 55 fishes, 16 crustaceans, and 5 mollusks (Pacalioga et al., 2010). Data on landed catch from Bago-Pulupandan coastal waters had more species with 99 fishes, 8 crustaceans, and 1 mollusk (Pacalioga et al., 2017).

Bago and Pulupandan's MPA and NonMPA sites share 48 species, while 17 species were collected only in Bago and 9 species in Pulupandan. Table 1 presents the list of species with the type of habitats they inhabit.

Composition of total catch in the MPA and NonMPA sites consisted of 89.19% economically important food fishes and invertebrates. Fishes were among the most abundant species caught in Bago, dominated by the sciaenid or croaker *Johnius borneensis*, the threadfin *Eleutheronema tetradactylum*, and the catfish *Plotosus canius*. In Pulupandan, the catch was dominated by three species of crabs, namely, the flower crab *Matuta victor* and two portunid crabs, *Portunus pe lagicus* and *P. sanguinolentus*. In addition, there were three species that are considered major species for aquaculture in the Philippines (Aypa, 1995), namely, the milkfish *Chanos chanos,* the tiger prawn *Penaeus monodon*, and the mud crab *Scylla serrata*. Other species collected were among the major artisanal fisheries of the country such as the Indian mackerel *Rastrelliger kanagurta*, slipmouth *Leiognathus equulus*, blue swimmer crab *Portunus pelagicus*, siganid *Sillago sihama*, and the catfish *Plotosus canius* (Philippine Statistics Authority, 2018). Likewise, there were large-sized commercially important fish species such as threadfins *Eleutheronema tetradactylum* and *Filimanus sealei*; Spanish mackerel *Scomberoides commersonnianus;* groupers *Aethaloperca rogaa*, *Epinephelus bleekeri*, and *E. corallicola*; snapper *Lutjanus johnii;* and blue trevally *Carangoides ferdau*. These and other commercially important species were encountered as juveniles or subadults, which indicated the estuarine area's nursery function. Estuaries in Bago and Pulupandan were comparable with other tropical estuaries shown to provide important habitats for economically important larvae and juveniles (Djumanto et al., 2019; Morioka et al., 2020; Shervette et al., 2007); that may contribute to recruitment of offshore fisheries (Meynecke et al., 2007; Sheaves et al., 2014; Whitfield, 1999). Since the area is recognized locally as an artisanal fishing ground, the sustainability of its fishery resources will be beneficial to the coastal community and its economy.

Similarity of Species Composition

Similarity in species composition between Bago and Pulupandan MPA and NonMPA sites was compared using Sorensen's coefficient test, shown in Table 2. Results show that the two MPA sites overlapped by 70.45%, along with the Pulupandan MPA and NonMPA sites, which overlapped 64.10%. On the other hand, the Bago NonMPA site had the lowest similarity with other sites, particularly the Bago MPA (similarity index = 0.4819).

Higher similarity of species composition may reflect comparable environmental conditions among communities being compared. This was noted for the MPA sites of Bago and Pulupandan, both having sandy-muddy substrates and relatively deeper waters. Likewise, the two NonMPA sites with muddy substrates and low wave exposure in shallow nearshore coasts had high similarity index ($S = 0.5974$). The high species similarity of the Pulupandan MPA and NonMPA sites could also be explained by their proximity and the direction of water currents moving across the two sites. Description of coastal winds and currents along Bago-Pulupandan coasts show all sites to experience slow-moving currents during the Southwest monsoon or *habagat* that flowed across Pulupandan MPA, Pulupandan NonMPA, and Bago MPA (Carmona, 2019). As monsoon winds shifted during the Northeast monsoon or *amihan*, it was reinforced by local winds that caused water north of the Bago River to move southward, exposing the same sites to fast surface water currents. This strong influence of monsoon winds on Bago-Pulupandan's coastal water currents was significantly reflected in fish catch abundance and diversity (Pacalioga et al., 2017). It is more likely that egg dispersal and movements of larvae and juveniles in the estuaries and coasts also follow a monsoonal direction (Franzen et al., 2019; Galaiduk et al., 2018). On the other hand, the

Bago NonMPA site remain sheltered from these winds by the embayment and received only weak currents reaching nearshore (Carmona, 2019).

Table 1. List of species composition collected in Bago and Pulupandan MPA and NonMPA sites

Family	Species	Local and Common Names	Types of Habitats				
			Reef	Sandy-Muddy	Marine or Coastal	Estuary	River
a. FISH							
Apogonidae	*Ostorhinchus pleuron*	Munday-munday/rib-bar cardinal fish	/		/		
Carangidae	*Alepes kleinii*	Talang-talang/razor-belly scad	/		/		
	Carangoides ferdau	Lison/blue trevally	/		/	/	
	Carangoides praeustus	Tap-ingan/brownback trevally		/	/		
	Scomberoides commersonnianus	Lali/Talang queenfish	/		/	/	
	Scomberoides tala	Lapis/barred queen-fish	/		/		
Chanidae	*Chanos chanos*	Bangus/milkfish			/	/	/
Clupeidae	*Escualosa thoracata*	Nipis/white sardine			/	/	/
Cyanoglossidae	*Cynoglossus bilineatus*	Palad/fourlined tonguesole		/	/	/	
Drepaneidae	*Drepane longimana*	Bayang/concertina fish	/		/	/	
Engraulidae	*Stolephorus waitei*	Gurayan/spotty-face anchovy			/	/	/
Gerreidae	*Gerres filamentosus*	Latab/whipfin silver-biddy		/	/	/	/
Haemullidae	*Diagramma punctatum*	Alatan/painted sweetlips	/		/	/	
	Pomadasys argenteus	Tabal/silver grunt		/	/	/	/
	Pomadasys maculatus	Giring-giring/saddle grunt	/		/	/	
Leiognathidae	*Eubleekeria splendens*	Sapsap/splendid pony-fish		/	/	/	
	Leiognathus equulus	Lawayan/common po-nyfish			/	/	/
	Photolateralis stercorarius	Tabilos/oblong slip-mouth					
	Karalla daura	Sapsap/goldstripe po-nyfish		/	/		
Lutjanidae	*Lutjanus johnii*	Gingaw/John's snap-per	/		/	/	
Megalopidae	*Megalops cyprinoides*	Bulan-bulan/Indo-Pa-cific tarpon fish			/	/	/
Menidae	*Mene maculata*	Bilong-bilong/moon-fish	/		/	/	
Mugilidae	*Planiliza macrolepis*	Balanak/largescale mullet			/	/	/
	Planiliza subviridis	Gusaw/greenback mullet			/	/	/
	Ellochelon vaigiensis	Ugapang/squaretail mullet	/		/	/	/
	Osteomugil perusii	Tungkan			/	/	
Mullidae	*Upeneus sulphureus*	Salmonete white/sul-phur goatfish			/	/	
Paralichthyidae	*Pseudorhombus oligodon*	Palad untuhan/floun-der		/	/		
Platycephalidae	*Inegocia japonica*	Sunog/Japanese flat-head		/	/		
Plotosidae	*Plotosus canius*	Hito/eeltail catfish			/	/	/
Polynemidae	*Eleutheronema tetradactylum*	Kugaw (big), lanit (small)/threadfin			/	/	/
	Filimanus sealei	Kamugtok/threadfin		/	/		
Sciaenidae	*Johnius amblycephalus*	Abo itum/bearded croaker			/	/	/

	Johnius borneensis	Abo puti/sharpnose hammer croaker			/	/	/
	Nibea semifasciata	Abo pula/buktot		/	/		
	Dendrophysa russelii	Abo bugor/goatee croaker			/	/	/
Scombridae	*Rastrelliger kanagurta*	Bulaw/Indian mackerel			/		
Serranidae	*Aethaloperca rogaa*	Inid Pulahan/red-mouth grouper	/		/		
	Epinephelus bleekeri	Lapu-lapu/duskytail grouper	/		/		
	Epinephelus corallicola	Inid Kambang	/		/	/	
	Epinephelus malabaricus	Pugaro/Malabar grouper	/	/	/	/	
Sillaginidae	*Sillago sihama*	Aso-os/silver sillago			/	/	
Sphyraenidae	*Sphyraena jello*	Dubla-dubla, batog/pickhandle barracuda			/	/	
Synancelidae	*Choridactylus multibarbus*	Ugok		/	/		
Terapontidae	*Terapon theraps*	Lambiyaw/largescaled terapon			/	/	/
	Terapon jarbua	Buga-ong/jarbua terapon			/	/	/
Tetraodontidae	*Lagocephalus lunaris*	Butete/lunartail Puffer	/	/	/	/	
Triacanthidae	*Tripodichthys blochii*	Sulay-bagyo/long-tail tripodfish		/	/		
Trichiuridae	*Trichiurus lepturus*	Liwit/large hairtail fish		/	/	/	
b. RAY							
Dasyatidae	*Neotrygon orientalis*	Blue spotted maskray	/	/	/		
	Taeniura lymma	Ribbontail stingray	/	/	/		
c. CRUSTACEA							
Calappidae	*Calappa lophos*	Ku-om/common box crab	/	/	/		
Epialtidae	*Doclea* sp.1	Spider crab		/	/		
	Doclea sp.2	Damang-damang/spider crab		/	/		
Galenidae	*Galene bispinosa*			/	/		
Lysiosquillidae	*Lysiosquilla tredecimpunctata*	Kamantaha			/		
Matutidae	*Matuta victor*	Kumong/flower moon crab		/	/		
Penaeidae	*Penaeus indicus*	Putian			/	/	
	Penaeus monodon	Lukon/giant tiger prawn			/	/	
	Metapenaeus endeavori	Bulit		/	/		
Portunidae	*Charybdis feriatus*	Krusan/crucifix crab		/	/		
	Charybdis natator	Kalintugas			/		
	Podophthalmus vigil	Long-eyed swimming crab/sentinel crab		/	/		
	Portunus sanguinolentus	Pintukan			/		
	Portunus pelagicus	Kasag/blue swimming crab		/	/		
	Scylla serrata	Alimango/mud crab			/	/	/
	Thranita crenata	Mangrove swimming crab			/	/	
Squillidae	*Miyakella nepa*	Pitik-pitik/Smalleyed mantis shrimp		/	/		
Xanthidae	*Leptodius affinis*	Kubaw		/	/		
d. OTHER INVERTEBRATES							
Holothuridae	*Holothuria atra*	Balat		/	/		
Loliginidae	*Heterololigo* sp.	Lukos		/	/		
Muricidae	*Murex* xp.				/		
Pinnidae	*Pinna* sp.	Tarab		/	/		

Table 2. Matrix of community similarity determined by Sorensen's similarity index (S) using presence/absence data (perfect similarity is 1.0)

SITES	Bago MPA	Pulupandan MPA	Bago NonMPA	Pulupandan Non-MPA
Bago MPA	1.000	0.7045	0.4819	0.5934
Pulupandan MPA	0.7045	1.000	0.5238	0.6410
Bago NonMPA	0.4819	0.5238	1.000	0.5974
Pulupandan Non-MPA	0.5934	0.6410	0.5974	1.000

Furthermore, composition of fishes and invertebrates is influenced by the physicochemical conditions, for example, salinity and temperature that change with seasons and tidal cycles (Molina et al., 2020). Their distribution is dictated by their physiological tolerance (Able, 2005; Djumanto et al., 2019; Molina et al., 2020; Mourão et al., 2015), the abundance of food resources, as well as protection from predators (Elliott & Quintino, 2007; Ferreira et al., 2019; Whitfield, 1999). Since the rivers draining into Bago and Pulupandan had variable lengths and sizes, these created gradients in salinity, nutrient levels, and sediments that influenced the composition of fish assemblages, as described in other estuaries (Engman et al., 2019; Molina et al., 2020).

Species Distribution and Connectivity

Majority of the captured fish and invertebrate species were described in literatures to occupy several habitats (Table 1). An attempt to show the distribution of species based on occupied habitat is presented in Figure 2 using a multiple correspondence analysis (MCA), with its two dimensions explaining 68.5% of the variance. Most species inhabit the marine/coastal waters (68 of 74 species, 91.89% of all species collected), with 24 species occupying mainly marine areas, which can extend from intertidal areas of the coast to the continental shelf. This explains the position of marine/coastal habitat being closest to the origin of the MCA axes. Occupants of estuarine areas were relatively abundant as well (37 species of 74 species, 50%), although only 5 species were true estuarine species. Twenty-one species inhabit reef/reef-associated habitats, 8 species of which also inhabit the estuary. Likewise, 8 species that inhabit the river are also encountered in the estuary. Since many of the species occupying the reef and river also inhabit the estuary and the marine/coastal areas, MCA presents these habitats relatively close to each other. Likewise, more species were in closer proximity to these habitats.

Among the noteworthy species encountered as migrating juveniles were the groupers *Epinephelus corallicola*, *E. malabaricus*, and lutjanid *Lutjanus johnii* that inhabit coral reefs but were encountered in the estuarine areas. The narrow barred Spanish mackerel *Scomberoides commersonnianus* that occupy the reefs were also collected in the coastal areas. The few species entering rivers were *Chanos chanos* ("bangus"), *Escualosa thoracata* ("nipis"), and *Eleutheronema tetradactylum* ("kugaw" or "lanit"). *C. chanos* is collected in the river mouth as fingerlings to supply bangus aquaculture in the locality. *E. thoracata* was the most dominant landed fish species in Purok Mailum, a coastal area of Bago City (Pacalioga et al., 2017).

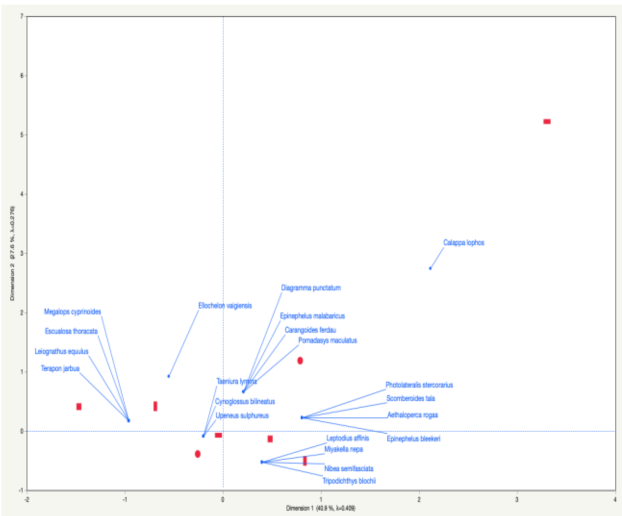

Figure 2. Distribution of fish and invertebrates based on occupied habitats.

Other species move into offshore areas to reduce osmoregulatory cost of lower salinity due to freshwater outflow that could have expanded the estuarine area as a result of dilution (Harrison & Whitfield, 2004). Barletta et al. (2003) observed the correlation of increased fish abundance with rainfall as nonestuarine species migrate to the lower estuary. In Bago and Pulupandan, local fishermen associated heavy downpour with abundant catch, coinciding with lower salinity levels of coastal waters during the rainy months of "habagat" (Pandan & Jonco, 2021).

Data showing majority of captured species occupying two to three habitats shown in Figure 2 reflect connectivity of estuaries and coastal areas within Bago and Pulupandan's MPA and NonMPA sites. These movements of organisms to feed or seek refuge and use various habitats within the seascape (Nagelkerken et al., 2014) illustrate the importance of connectivity in supporting nursery function (Vasconcelos et al., 2011). Fishes migrate to their adult habitats in stages; short movements between adjacent habitats increase their chances of survival (Mumby et al., 2004). Some species may utilize a predominant juvenile habitat, for example, seagrass, mangrove, estuary, but migrate to alternative habitats depending on its life stage or season, indicating subtle to major flexibility in ontogenetic habitat use (Kimirei et al., 2011). Availability of nursery habitats was shown to significantly influence adult stock sizes of coastal fishes (Sundblad et al., 2013), with potential implication on the sustainability of fisheries.

Threats to Estuarine Areas

Tropical estuaries are faced with unprecedented stress due to anthropogenic activities resulting to urban, industrial, and agricultural pollution; overfishing; and poaching (Barletta & Lima, 2019; Blaber, 2013). Being at the river mouth makes them main sites for development and are likely threatened by increase in human impacts (Sheaves, 2016).

One of the major threats to estuaries in Bago-Pulupandan is the clearing of old growth mangroves for aquaculture or infrastructure development. Construction of aquaculture dikes and walls of the boulevard that involve clearing of mangrove forests prevent tidal inundation. This process is essential to maintain physicochemical conditions for mangrove growth and survival, along with its associated fauna. Despite efforts of the local government towards mangrove reforestation, there remains a considerable area of idle aquaculture ponds and continued conversion of mangroves into roads and boulevards. Loss of the mangroves' structural diversity reduces species diversity of fish assemblages and threatens its capacity to perform nursery function (Blaber, 2007; Shervette et al., 2007; Wu et al., 2018).

Another threat to the estuary is pollution from surface runoff of agricultural lands, sewage from domestic sources and swine farms, and industrial wastes. These pollutants are transported by river outflow to drain into estuaries or flowed directly through sewer pipes. Data of Pandan and Jonco (2021) taken from MPA and Non-MPA sites of Bago and Pulupandan showed significantly high levels of phosphates, nitrates, as well as fecal and total coliform content in rivers and with nitrates even reaching offshore coastal waters. These pollutants enhance the potential for eutrophication in coastal areas (Todd, 2010), resulting to seasonal hypoxia that was shown to disrupt reproductive activities in fishes (Thomas, 2007). In addition, pesticides transported by surface runoff contain heavy metals that can reach lethal levels for living organisms resulting to decreased fish species richness and abundance (O'Mara, 2016).

Sand quarrying (Figure 3) intensifies erosion, creates deep depressions on the riverbed, and has made the Bago River's mouth noticeably shallow due to accumulated sediments. This can disrupt the freshwater and tidal water interchange and modify estuarine characteristics, including its fish assemblages. Furthermore, frequent and intense storms increase volume of river outflow and its transported sediments, reflected as significantly higher total suspended solids (TSS) in rivers and coastal areas (Pandan & Jonco, 2021) that could smother epi- and infauna of estuarine areas. These organisms are important links of detrital system to predatory species that make up the artisanal fisheries.

Figure 3. Quarrying activities in Bago River.

CONCLUSION

The MPA and NonMPA sites of Bago and Pulupandan are estuarine areas that support the artisanal fishery. Majority of samples collected were economically important food species. Fish and invertebrate species occupy marine habitats but some species migrate into the river, estuary, reef, and reef-associated areas. A considerable number of species occupy two to three habitats, showing connectivity of the estuary with several adjacent ecosystems.

The estuarine areas of Bago and Pulupandan are threatened by anthropogenic activities that concentrate pollution and sedimentation along river mouths and coasts. Clearing of mangroves that are closely associated with the estuary is a major threat that can result to elimination of its nursery function for fishes and invertebrates. Furthermore, pollution from all sources is hazardous to estuarine and marine life, which could lead to reduced productivity and biodiversity with corresponding impact on artisanal fishery.

RECOMMENDATIONS

There is a need to increase awareness of estuaries and its connectivity with adjacent coastal ecosystems to perform nursery function. The newly established MPAs must be properly implemented and managed for the conservation of the coastal and estuarine ecosystems and their resources. Priority must be given to policies that promote reduction of anthropogenic activities along river banks and coastal areas, particularly those resulting to habitat loss and pollution. More importantly, local government units must seek the effective implementation of these policies and find sustainable alternatives to the practices of its constituents contributing to the degradation of estuarine habitats.

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