A baseline survey of coral reef fishes within the marine protected area in Mapalad, Barangay Dalipuga, Iligan City, Philippines

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Abstract. An underwater fish visual census was conducted to establish baseline information on the community structure of coral reef fishes in the fringing reef inside the Marine Protected Area of Sitio Mapalad, Barangay Dalipuga, Iligan City, Philippines. The fish assemblage within the Marine Protected Area comprises 40 fish species, distributed among 13 families. Species diversity of target and indicator species is very poor, miscellaneous species is poor. Species density of target and indicator species is poor, and miscellaneous species are high. Biomass of target species is low; indicator and miscellaneous species are very high. Family Pomacentridae is the most abundant, with the relative abundance (RA) of 90.77%, followed by family Serranidae with 2.97%. All the remaining families have an RA of < 1%. Family Pomacentridae is the most abundant in the 0-5 cm and 6-10 cm size categories, while Family Acanthuridae is the most abundant in the > 10 cm size category.
Key Words: Fish biomass, abundance, fish community structure, photo-transect.

Introduction. Coral reefs function as breeding grounds for fishes, sea cucumbers, giant clams, squids, cuttlefishes and many other organisms and for their high primary productivity especially for fisheries (Latiff & Zakri 1998), and in providing food and shelter for reef-associated organisms (Sale et al 1984; Caley & St John 1996; Cole et al 2008; Simpson et al 2008; Wilson et al 2010). Reef fisheries are often vital to the survival of coastal communities in the tropics, as they provide employment and a high proportion of the dietary protein (Mohamad-Norizam & Ali 2000). Many factors can influence the abundance, spatial and geographic distribution of reef fishes, including biotic processes such as competition, predation and recruitment (Sale 1978; Warner & Chesson 1985; Munday et al 2001), abiotic factors including depth and exposure (Pinheiro et al 2013), and historical disturbance events such as hurricanes and tsunamis (Adjeroud et al 1998). Even though a large number of studies analyses reef fish community and biotic-abiotic factors such as wave exposure, sediment loads, water depth as well as topographical complexity of the coral reef substrate (Luckhurst & Luckhurst 1978), few of them correlated the importance level and interrelationship of these factors about reef fish abundance and species richness (Pereira et al 2014).

Reef fish status can be determined based on abundance (Nañola et al 2006). One way of measuring the abundance of reef fishes is by Underwater Fish Visual Census (UFVC). This method is the most effective for monitoring coral reef fishes, particularly in remote locations (Choat & Pears 2003) and provides rapid estimates of relative abundance, biomass, and length frequency distributions of reef fishes (Russ 1985; Kulbicki 1988). Based on the utilization function and ecological aspects, reef fishes can be grouped into target, indicator, and miscellaneous fish (major groups). Target species are important fish preferred by fishermen because they are economically important (English et al 1997); consumed and usually hunted by fishermen (Fadhilah & Harahap 2020); and used coral reefs as spawning and nursery ground (English et al 1997). Families that belong to this category are Siganidae, Serranidae, Acanthuridae, Lethrinidae, Lutjanidae, Nemipteridae, Caesionidae, Scaridae, and Haemulidae (Sala et al 2020). Indicator fishes are species of fish that have a very strong association with the coral habitat, indicating a healthy reef. The Chaetodontidae fish family is an indicator of coral health (Fadhilah & Harahap 2020). Miscellaneous fish species are a varied collection of fish that do not fall into commonly targeted or known categories. This category is labeled as "by-catch" or "trash fish" in fisheries management, indicating their incidental capture during targeted fishing activities or their perceived low commercial value compared to other commercially targeted species (Hong et al 1990). Families that belong to this category are Apogonidae, Pomacanthidae, Pomacentridae, Scorpaenidae, Synodontidae, and Tetraodontidae (English et al 1997).

This study was conducted from 2022-2023 in the fringing reef inside the Marine Protected Area of Sitio Mapalad, Barangay Dalipuga, Iligan City. This research primarily aims to characterize the community structure of coral reef fishes with emphasis on species composition, diversity, density, and biomass of target, indicator, and miscellaneous species.

Material and Method

Description of the study site. The study was conducted in July 2022- July 2023 in the fringing reef in the core zone of the fully protected, 45-hectare coastal area of Barangay Dalipuga, Iligan City, Philippines, with geographic coordinates 8°19’19.8” N and 124°14’47.6” E (Figure 1, see yellow triangle in the map). Dalipuga Marine Protected Area is one of the four MPAs in Iligan City as per City Ordinance 11-5763 and 06-5034. Its boundaries are the municipality of Lugait, Misamis Oriental, to the north and the south by the Barangay Kiwalan, Iligan City.

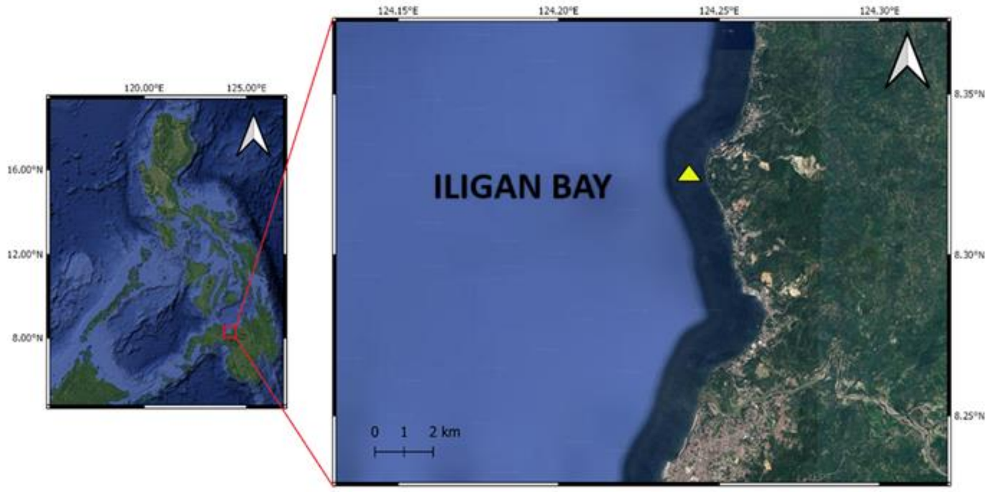

Figure 1. Location of the Marine Protected Area in the coastal barangay of Dalipuga, Iligan City, Philippines (yellow pyramid). (Source: QGIS, version 3.14.16).

Species composition and diversity. A 200-meter transect line represented the sampling area, laid parallel to the coastline at a constant depth of 8-10 meters. The basic unit of data collection was a 25 m^2 imaginary quadrat, and the total survey area was 500 m^2. UFVC was employed to conduct fish assessment in the coral reef area using SCUBA, following the standard procedure of English et al (1997). The researcher waited 5-10 minutes for the fish to return before starting the visual census every 10m of the transect line, starting at 0 m. All fish that entered the 5m x 5m imaginary quadrat were identified to the lowest taxa possible using ”Reef Fish Identification-Tropical Pacific (Allen 2003), and the number of fish individuals was counted and sizes estimated to the nearest cm for each individual of target, indicator, and miscellaneous species.

Relative abundance and fish density. RA is the total abundance of individual species relative to the total population of fish in the area (Odum 1971). Relative abundance: $pi = Ni/N$, where pi is the proportion of individuals of that species, Ni is the number of individuals of that species, and N is the total number of individuals of all species. Fish density refers to the total number of individuals in 1000 m^2.

Biomass. Fish biomass expressed in Mt Km^{-2} was computed using size estimates from the UFVC and length-weight conversions of the form $W = aL^b$, where W is the weight of the fish in grams, a as the multiplicative factor, L is estimated length in cm, and b as the exponent (b > 1) (Bohnsack & Harper 1988). The species-specific parameters a and b are constants and are available from various references (Kulbicki et al 1993). The fish total length estimates were conducted following the procedures of Mille & Van Tassell (1994) and Yulianto et al (2015) with slight modifications. In the calibration training, styrofoam models were used to represent fish sizes 1-5 cm, 6-10 cm, and >10cm. Fish models were tied to a string and sinker with the other end fixed to the boat above the water to simulate natural fish movements in the coral reef. The fish models were suspended 1.5 meters above the bottom, so the models were observable at eye level. At a distance of 1m from the models, the researcher began the successive left-to-right recording of length estimates in a dive slate. The calibration trainings were conducted until the diver reached a bias of < 5%. Species diversity and density were calculated and classified using the categories adapted by Corrales et al (2015), and fish biomass by Nañola et al (2006).

Physico-chemical parameters. Water samples were collected by the water displacement method at transect depth (7-8 meters) during high and low tide once weekly for three months for the determination of physico-chemical parameters. Dissolved oxygen and temperature were measured using the digital DO meter (JPB 70A Portable Digital Pen dissolved oxygen meter), salinity with a pre-calibrated refractometer (Atc HR 27-100), and pH using a pH meter (Finther pen-type digital pH meter). Total suspended solids (TSS) were analyzed using the gravimetric method. All parameters were measured in triplicate.

Results. A total of forty reef fish species distributed among thirteen families and twenty-three genera inside the Marine Protected Area of Barangay Dalipuga, Iligan City, were recorded (Table 1).

Table 1

Species composition, frequency, and relative abundance of reef fishes

Utilization function categories	Frequency	Relative abundance (%)
Target species		
Acanthuridae		
Acanthurus nigricans (Linnaeus, 1758)	2	0.16
A. nigrofuscus (Forsskål, 1775)	12	0.94
Zebrasoma scopas (Cuvier, 1829)	2	0.16
Scaridae		
Scarus niger (Forsskå,l 1775)	2	0.16
S. flavipectoralis (Schultz, 1958)	1	0.08
Lutjanidae		
Lutjanus decussatus (Cuvier, 1828)	1	0.08
Nemipteridae		
Scolopsis bilineata (Bloch, 1793)	1	0.08
Anthiadidae		
Pseudanthias huchtii (Bleeker, 1857)	38	2.97
Total	59	4.76
Indicator species		
Chaetodontidae		
Chaetodon baronessa (Cuvier, 1831)	8	0.63
C. citrinellus (Cuvier, 1831)	1	0.08

Heniochus chrysostomus (Cuvier, 1831)	4	0.31
H. varius (Cuvier, 1829)	8	0.63
Total	21	1.65
Miscellaneous species		
Pomacentridae		
Abudefduf vaigiensis (Quoy & Gaimard, 1825)	62	4.85
Amblyglyphidodon leucogaster (Bleeker, 1847)	9	0.7
A. curacao (Bloch, 1787*)*	4	0.31
A. ternatensis (Bleeker, 1853)	15	1.17
Amphiprion clarkii (Bennett, 1830)	2	0.16
A. ocellaris (Cuvier, 1830*)*	1	0.08
A. akindynos (Allen, 1972*)*	1	0.08
Pycnochromis caudalis (Randall, 1988)	25	1.96
P. retrofasciatus (Weber, 1913)	1	0.08
Chromis ternatensis (Bleeker, 1856)	135	10.56
Dascyllus reticulatus (Richardson, 1846)	30	2.35
D. trimaculatus (Rüppell, 1829)	35	2.74
Pomacentrus coelestis (Jordan & Starks, 1901)	143	11.19
P. moluccensis (Bleeker, 1853)	242	18.94
P. pavo (Bloch, 1787)	312	24.41
P. smithi (Fowler & Bean, 1928)	23	1.8
P. vaiuli (Jordan & Seale, 1906)	20	1.56
P. brachialis (Cuvier, 1830)	100	7.82
Pomacanthidae		
Centropyge vrolikii (Bleeker, 1853)	8	0.63
Apogonidae		
Cheilodipterus quinquelineatus (Cuvier, 1828)	2	0.16
Fistulariidae		
Fistularia commersonii (Rüppell, 1838)	1	0.08
Labridae		
Labroides dimidiatus (Valenciennes, 1839*)*	1	0.08
Thalassoma lunare (Linnaeus, 1758)	11	0.86
Bodianus mesothorax (Bloch & Schneider, 1801*)*	1	0.08
Halichoeres argus (Bloch & Schneider, 1801)	1	0.08
Mullidae		
Parupeneus barberinus (Lacepède, 1801)	1	0.08
P. crassilabris (Valenciennes, 1831)	1	0.08
Zanclidae		
Zanclus cornutus (Linnaeus, 1758)	11	0.86
Total	1,198	92.74
Grand total	1,278	100

Species diversity. Eight target species distributed among 5 families were identified, representing 20% of the total number of species, with *Acanthurus nigrofuscus* (surgeonfish) as the most abundant target species. Indicator species were represented by 4 species of Chaetodonts, which represent 10% of the total number of species. Miscellaneous species consisted of 8 species distributed among 7 families. Sixty-four percent of the miscellaneous species belong to the family Pomacentridae. Based on classification adapted by Corrales et al (2015) (very poor 0-26, poor 27-47, moderate 48-74, high 76-100, and very high > 100) diversity of target and indicator species was very poor, while miscellaneous species was poor.

Density and abundance. Target species density was 118 individuals in 1000 $m^{2,}$ representing an average of 4.77% of the overall mean fish abundance (Figure 2). Indicator species were represented by butterflyfish of Family Chaetodontidae with a mean Chaetodontid abundance of 42 individuals 1000 $m^{-2,}$ representing an average of 1.64% of the overall mean fish abundance. The density of miscellaneous species inside the MPA is 2,396 individuals 1000 $m^{-2,}$ representing an average of 92.74% of the overall mean fish abundance. Based on density classification adapted by Corrales et al (2015), the density of target and indicator species is poor, while miscellaneous species is high.

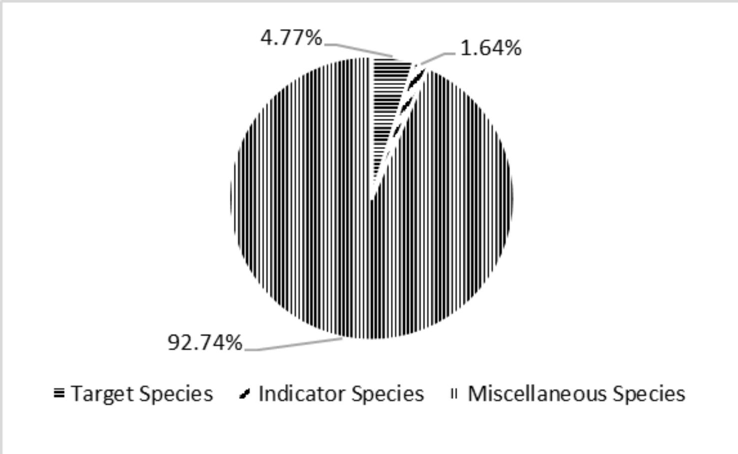

Figure 2. Overall mean abundance of the 3 fish function categories.

Relative abundance of fish families and genera. Pomacentridae has the highest relative abundance of 90.77%, followed by Anthiadidae with 2.97%. The remaining families were less abundant with RA < 1% (Figure 3).

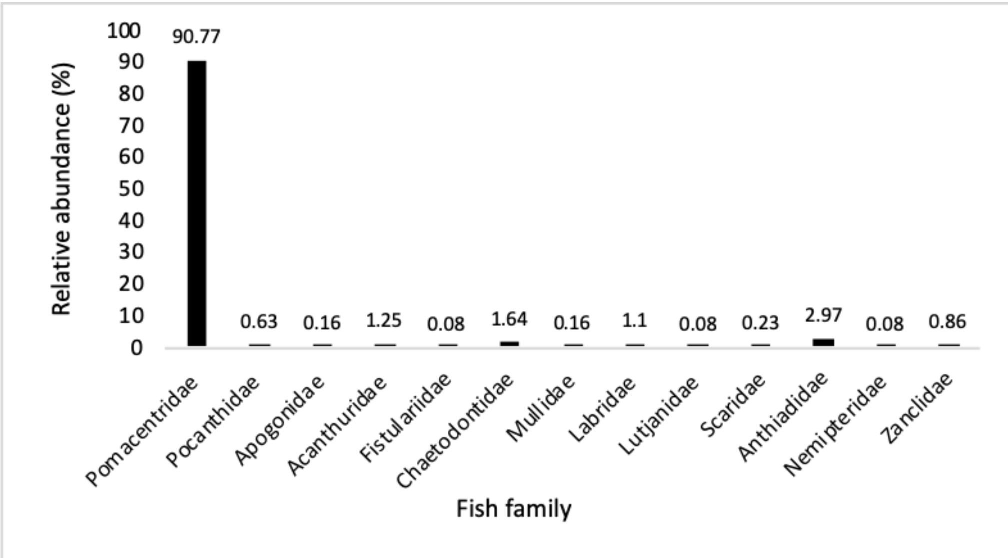

Figure 3. Relative abundance of reef fish by family.

Pomacentridae was the most abundant family in the small (1-5 cm) and medium size (6-10 cm) categories, with relative abundance of 99.65% and 84.28%, respectively. Acanthuridae, Chaetodontidae, and Zanclidae were the most abundant groups in the large size category with 25.45%, 21.82%, and 20%, respectively (Figure 4). Eighteen species under 6 genera of Pomacentrids were identified (Table 1). *Pomacentrus sp*. was the most abundant species with 65.72%, followed by *Chromis sp*. with 12.64%. The least abundant species were shared by *Dascyllus sp.* with 5.09%, *Abudefduf sp*. 4.85%, *Amblyglyphidodon sp*. 2.18%, and *Amphiprion sp.* 0.32%.

***Fish biomass**.* Length estimates and the number of individuals determine the biomass of the species. Miscellaneous species were distributed in the three size categories, with the highest biomass of 38.59 Mt Km^{-2} in the 6-10 cm group and collectively with a total biomass of 52.19 Mt Km^{-2} in the 3 size categories combined. Target species were distributed in the medium and large size groups, with a higher biomass of 8.21 Mt Km^{-2} in the large fishes and a total biomass of 9.67 Mt Km^{-2} with medium and large biomass combined. Indicator species were only distributed in the large size category with a biomass of 4.60 Mt Km^{-2} (Figure 5).

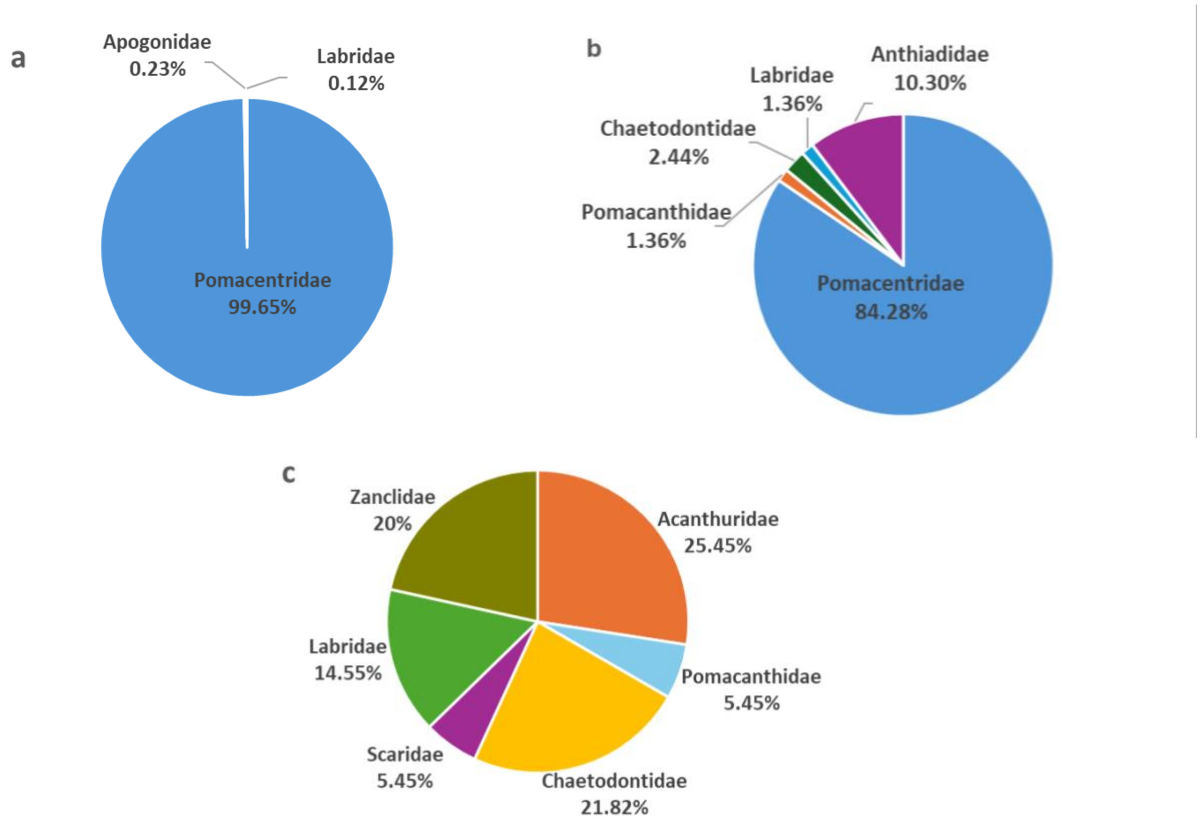

Figure 4. Percent relative abundance of fish families in the 3 size categories: a) 1-5 cm; b) 6-10 cm; c) >10 cm.

Family Pomacentridae recorded the highest biomass of 44.18 Mt Km^{-2}, followed by Acanthuridae 6.14 Mt Km^{-2}, Chaetodontidae 5.19 Mt Km^{-2}, Zanclidae 5.05 Mt Km$^{-2,}$ and Fistulariidae 4.51 Mt Km^{-2}. Based on Nañola et al (2006) fish biomass classification, the biomass of the miscellaneous species was very high, while target and indicator species biomass were low and very low, respectively (very low < 5, low 6-10, medium 21-40, very high > 41). Collectively, the total fish biomass in the area was very high, with 66.51 Mt Km^{-2}.

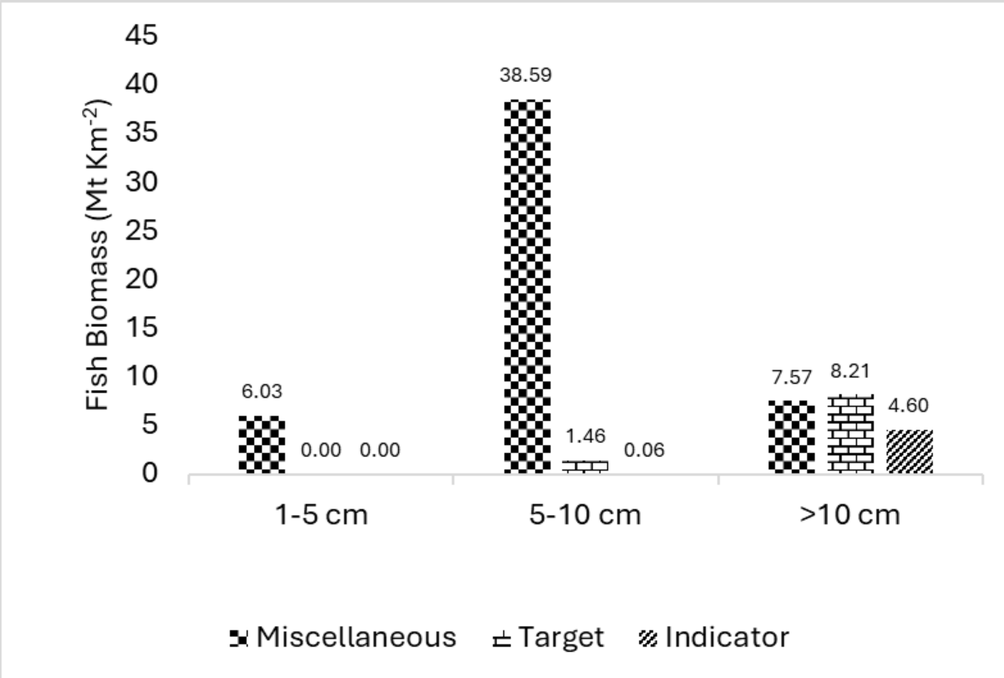

Figure 5. Biomass of the 3 utilization function categories of fish.

Water parameters. A t-test was used to determine if there was a significant difference in the water parameters between high and low tides at a 5% level of significance. Results of the analysis showed that total suspended solids and dissolved oxygen of surface waters did not differ significantly between tides. Temperature, salinity, and pH of the surface waters were significantly different between tides (Table 2).

Table 2
The environmental parameters (mean±SE) and statistical analysis results between high and low tide

Water parameters	*High tide*	*Low tides*	*T-test/Wilcoxon p-value*	*Remarks*
DO (mg L^{-1})	5.9±0.13	5.30±0.10	0.006	Significant
Temp (°C)	28.1±0.10	28.4±0.11	0.03	Significant
Salinity (ppt)	35.08±0.05	34.97±0.13	0.20	Not significant
pH	8.2±0.03	8.08±0.04	0.0003	Significant
TSS(mg L^{-1})	0.03±0.12	0.08±0.09	0.34	Not significant

Discussion. Pomacentrids are found throughout the world in tropical and warm temperate waters, with the majority of species occurring in the Indo-west and central Pacific region (Thresher 1984; Nelson 1994; Allen 1998).

Target species with a low average density of 4.77% (Figure 2) are not bound to stay permanently in coral reefs for their entire life span. The export of adults outside the marine reserves is known as the spillover effect (Bohnsack 1993). As protected fish populations become larger, more of them are likely to spill beyond the invisible boundaries of the MPA. There is net movement of fish across the boundary of a reserve into the fished ground, which would be expected to occur based on fundamental physical principles of random movement (Buxton et al 2014). Outside the reserve, the fish are vulnerable to predation by bigger fish, and the chance of being caught by fishermen is high. Target fishes from marine reserves are relatively naive to fishing and therefore more easily fished (Januchowski-Hartley et al 2013).

Absence of indicator species represented by butterfly fishes could either indicate that the corals in those areas are damaged, dead, or, with low percentage cover (Bell & Gazlin 1984). Corallivorous butterflyfish consume live coral tissue (Cole et al 2008), and live mainly in close association with the reef habitat, and the number of corallivores on a reef correlates with live coral cover (Bell & Gazlin 1984). The presence of 9 large individuals from 2 species of *Chaetodon* and 12 large individuals from two species of *Heniochus* was suggestive of a healthy coral reef.

Miscellaneous species represent an average of 92.74% of the overall mean fish abundance. This finding indicates that the area is highly productive. The miscellaneous category consists mainly of herbivores due to their territorial behavior, keeping other or the same species out, which would then result in damage to coral colonies (Green & Bellwood 2009).

Miscellaneous species had the highest biomass, followed by target and indicator species (Figure 5). Pomacentridae, aside from having the highest relative abundance of 90.77% in the miscellaneous group (Figure 3), also recorded the highest biomass. Current findings suggest that the presence of abundant species of branching corals of the genus *Acropora, Anacropora*, and *Pocillopora* with structurally complex and intricate lifeforms may explain the high abundance and biomass of Pomacentrids in the study area. However, most of these branching coral colonies are not too big and obviously can only accommodate pomacentrids to a maximum size of 10 cm. According to Hourigan (1986), *Acropora* species offer refuge to skip predation, food in the form of entrapped organic materials, and protection to fishes, especially the smaller ones. These explain the high abundance of Pomacentrids in 1-5 cm and 6-10 cm size categories. *Acanthurus nigrofuscus* also forms schools where the pomacentrids are present (Hourigan 1986).

Periodic changes in sea level cause fluctuations in seawater properties. Water parameters like dissolved oxygen, temperature, pH, salinity, and total suspended solids were expected to fluctuate with the tide. The reef under study has an average depth of 5m during low tide and 7m during high tide. Dissolved oxygen significantly decreased during low tide (Table 2). Physical and biological processes modulate dissolved oxygen decline rates; the net observed decrease is due to water column respiration (Adams et al 2013). Surface water temperature was lower during high tide. A rising tide was associated with low temperatures, and a falling tide with increasing temperatures. This is because water is already heated in the tidal flat (Kristensen and Christiansen 2008). During high tide, water temperature decreases because the incoming water from deeper ocean depths becomes colder. Changes in salinity with tide were insignificant in the study area, apparently due to the absence of freshwater input to the coastal area. Abrupt increases in surface water salinity are observed throughout the coastal region in response to variations in upstream river discharge; the prominence of these events highlights their importance in driving salinity increases (Haq et al 2024). There was also no significant difference in total suspended solids between high and low tides because the majority of the substrate in the area was rocky and coralline. Seawater pH significantly increased during high tide. The relatively higher values of pH during high tide are the result of the intrusion of saline water. Significant tidal and spatial variations of surface water pH may thus be linked strongly to the intrusion of seawater (Adams et al 2013).

Conclusions*.* The fish community structure in the MPA of Barangay Dalipuga, Iligan City, Philippines consisted of 8 target, 4 indicator, and 28 miscellaneous species distributed among 13 families. Miscellaneous species were the most abundant, followed by the target species, while the least abundant was the indicator species. Pomacentridae was the most abundant family in the 1-5 and 6-10 cm size categories, while Acanthuridae was the most abundant in the > 10 cm size category. The miscellaneous and the indicator species have the highest and lowest biomass, respectively. The family Pomacentridae has the highest biomass. The low biomass of target and indicator species suggested that the present fully-protected reef was previously exposed to environmental and climatic threats. It is recommended that an annual monitoring of fish species biodiversity, density, and biomass inside and outside of the MPA should be conducted to determine the impact of climate change on the community structure of fish in the MPA. Dissolved oxygen, temperature, and pH differed significantly between tides, while salinity and total suspended solids were not affected by the periodic tidal cycles.

Conflict of interest. The authors declare that there is no conflict of interest.

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