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Diminishing mangrove forest structures in Davao City, Philippines

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ABSTRACT

The decline of mangrove coverage across the Philippines to 50% of its original coverage in present years has, led to significant reductions of ecological functions to fisheries and benefits to man. The mangrove forest in Davao City was assessed for its taxonomic list, Importance Value Index, abundance and distribution of mangrove regenerations, forest structure, and species diversity status. The study was conducted in Barangay Bunawan, Lasang, Panacan, Matina Aplaya, 76-A, and Bago Aplaya. All data were gathered by establishing sampling plots (10m x 10m) using the modified transect-plot method. Overall, a total of 34 mangrove species were listed, of which 21 were identified as true mangroves and 13 as mangrove associates. The 21 mangrove species were very low in species richness (54%). Importance Value Index showed that *Avicennia marina, Rhizophora apiculata,* and *Sonneratia alba*, respectively, as dominant mangrove species. The mangrove regenerations were in poor condition (<0.50) while relative abundances of growth stages consisted of mature stands at 46.04%, saplings with 27.78%, and seedlings with 26.18%. General diversity indices obtained a low value on the Shannon-Wiener diversity index (H'=1.42) and an average value on the species evenness index (E=0.61), all indicating stressful and unstable mangrove forests. Thus, the mangrove forest ecosystem has imbalances and eventually, only certain species would survive.

Keywords: Abundance, diversity, evenness, mangrove, mangrove associates

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INTRODUCTION

Mangroves are intertidal wetlands found along coastlines extending along the streams where the water is brackish (Faridah-Hanun et al., 2014) providing valuable ecosystem services (Bryan-Brown et al., 2020). They are an important area as a hatchery and nursery habitat for juveniles of fish and a large number of organisms like insects, reptiles, amphibians, birds, and mammals live in this habitat (Bitantos et al., 2017). Also, these provide nursery habitats for other associate faunal and flora assemblages, and other mangrove associate plants, which together constitute the mangrove forest community and provide commercial products like food, timber, fuel, and medicines for residents, and act as a buffer that protects coastal regions from natural disasters and coastal erosion (Liu et al., 2018; Pislan and Macombo 2021). The diverse flora and fauna associated with mangrove ecosystems can also provide opportunities for nature education, tourism, and scientific study, thereby providing additional social and economic benefits (Bitantos et al., 2017; Cuenca-Ocay et al., 2019). Mangroves play important roles in coastal protection from typhoons and storm surges, erosion control, flood regulation, sediment trapping, nutrient recycling, wildlife habitat, and nurseries (Mullet et al., 2014).

However, due to human activities such as urban development, aquaculture, mining, overexploitation, and coastal landfills, mangrove forests have been continuously destroyed over recent decades in nearly every country where they exist (Macusi et al., 2022). For instance, once covering over 20 million hectares globally, mangrove forests declined sharply to 15.2 million hectares in 2005, a reduction of approximately 30%; they are still disappearing at a rate of 1~2% per year worldwide (Liu et al., 2018). In the Philippines, the decline of mangrove coverage to over 50% of its original coverage in present years has, directly and indirectly, led to significant diminutions of ecological functions to fisheries and benefits to man and has posed potential threats to the diversity of mangrove species (Stoner, 2019). These mangroves are very diverse but face tremendousthreats (Garcia et al., 2014) such as their contribution to a wide array of fishery (seaweeds, fish, crabs, prawns, mollusks, and other invertebrates) and forestry (timber, firewood, tanbark for dyes, fibers and ropes, corks, etc.) products (Mullet et al., 2014) that may be attributed to over-exploitation by coastal dwellers and conversion to aquaculture, salt ponds, industry, and settlements (Primavera, 2000).

Many tropical countries have considered the sustainable management of mangroves a major priority in biodiversity conservation (Macintosh and Ashton, 2002). Several countries such as India and Sri Lanka have already come up with their local mangrove Red List of threatened species. However, in the Philippines, not a single mangrove species was included in the National Red List crafted by the Philippine Plant Conservation Committee and issued as a DENR Administrative Order (DAO) 2007–01 (Garcia et al., 2014). In Davao City, there are only a few available data on the remaining forest structure and diversity of the mangroves in the area. Considering that the mangrove forest is part of a protected area, this study aimed to investigate and determine the mangrove taxonomic list, Importance Value Index, abundance and distribution of mangrove regenerations, structure through its growth stages, and its diversity status.

METHODOLOGY

Study sites

The study was conducted in the remaining mangrove forests of Davao City situated in its six Barangays namely Bunawan, Lasang, Panacan, Matina Aplaya, 76-A, and Bago Aplaya (Figure 1). In this study, mangrove forest is generally used to refer to the habitat; on its broadest

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sense, an area defined as woody vegetation type occurring in marine and brackish environments, generally restricted to the tidal zone, which is the strip of coast starting from the lowest low water level up to the highest high water level (spring tide), also including the *Nypa* formation and the margins of mangroves (Giesen et al., 2007) and landward part of exposed coasts (Calumpong, 2007). These are the various vegetation types that constituted the "mangrove forest" as observed by the researchers in the study area. Further the term "mangrove species" was used to refer to an individual mangrove plant species found in the mangrove forest.

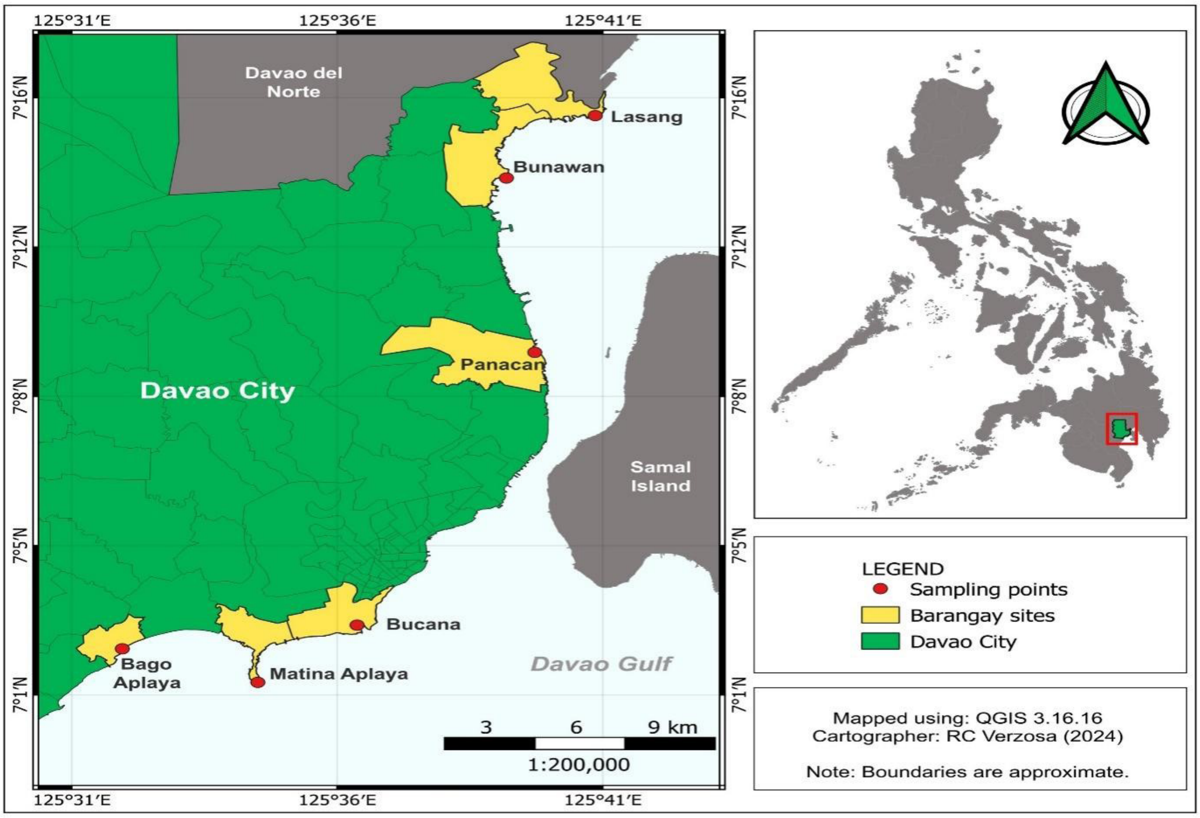

Figure 1. Map of the study area showing the geographical location of the six study sites of mangrove forest in Davao City.

Synopsis of sampling methods and techniques

This study employed the quantitative research approach (Creswell, 2014) using Non-experimental Design specifically Survey Research as an alternative research design. With this, the sampling research method was employed during data collection, analysis, and interpretation to attain all the objectives of the study. Under this method, the probability sampling method was adopted using a systematic sampling form of sampling (Schreuder et al., 2004; Pacardo et al., 2000). In application, all data were gathered by establishing sampling stations using the modified transect-plot method as the sampling technique introduced by the Fisheries Sector Program – Department of Environment and Natural Resources (FSP-DENR, 1990). Sampling stations were located in various barangays e.g. Barangay Bunawan had two transects with three plots in each transect, Barangay Lasang had four transects with three plots in three transects and two plots in one transect, Barangay Panacan had two transects with three and two plots in each transect, Barangay Matina Aplaya, Barangay 76-A, and Barangay Bago Aplaya had two transects with only one plot each as the mangrove strips were too thin. Distance per transect was about 100 m and the plot distance was established once only in the landward, middle ward, and seaward zone part of the mangrove strips. A total of 28 sample plots were surveyed over the mangrove forests.

Mangrove species taxonomic listing

The mature mangroves were counted a hundred percent taxonomic listing was done inside the main plots and included the species not found inside the main plots that can be found outside while traversing the mangrove forest. The saplings and seedlings mangroves were counted only in the main plots but only 50% of the main plots were for saplings while only five 1m x 1m were for seedlings. The traditional methods of plant identification were used specifically recognition and comparison methods (University of North Carolina, 1998). Mangrove species identification was done using the field guide to common mangroves of the Philippines and several other online sources up to the species level by Calumpong (2007), Primavera and Dianala (2009), and Giesen et al., (2007). Mangrove species that were identified were further grouped based on their ecological description as to true mangrove species and as to mangrove associates (Giesen et al., 2007).

Importance value index

The importance value index of the mangrove species was also computed. Diameters at the breast height of mature mangroves were used to calculate their basal area for relative dominance, the number of occurrences was for relative frequency, and number of counts was for relative density. These three figures were for the computation of the importance value index (IVI). To arrive at this Index the following as given (Obi, 2016) were followed:

(a) $$\text{Relative Frequency (R. F.)} = \frac{\text{Frequency of occurrence of species}}{\text{Total frequency of occurrence of all species}} \times 100$$

(b) $$\text{Relative Density (R. Den.)} = \frac{\text{No. of individuals of the species}}{\text{Total no of individuals in all species}} \times 100$$

(c) $$\text{Relative Dominance (R. D.)} \quad \frac{\text{Total basal area of a species}}{\text{Total basal area of all species}} \times 100$$

$$\text{Basal area} = \frac{\pi D2}{4}, \text{ where } D = \text{dbh}$$

(d) Important Value Index IVI = R. D + R. F + R. D

Abundance and distribution of mangrove regenerations

The regeneration value was computed using the formula (Deguit et al., 2004).

(a) $$\text{Reg per sqm} = \frac{\text{Tot reg counts}}{\text{Tot reg plots}}$$

Where:

Reg / m^2 = Regeneration per m^2

Tot reg count = Total regeneration count

Tot reg plots = Total no. of regeneration plots

Their corresponding condition was evaluated based on the following:

(b) Excellent condition = at least 1 regeneration per m^2;

(c) Good condition = 0.76 - 1 regeneration per m^2;

(d) Fair condition = 0.50 – 0.75 regeneration per m^2; and

(e) Poor condition = ‹ 0.50 regeneration per m^2.

Structure through growth stages

In this study, forest structure looked at the proportion of size-class groupings that

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were further defined as seedling, sapling, and mature and were reported as trees per hectare. These seedlings and saplings are regenerations of mangrove trees. Mature trees have girth at breast height (GBH) of more than 4 cm and a height of more than 1 m, saplings have GBH of less than 4 cm and a height of more than 1 m, whereas seedlings have a height of less than 1 m (English et al., 1997).

General diversity index

A diversity index is a mathematical measure of species diversity in a community providing more information about community composition than simply species richness (the number of species present) but also taking the relative abundances of different species into account (Beals et al., 2000). Thus, diversity indices provide important information about the rarity and commonness of species in a community and as one important tool in understanding community structure. The principal objective of a diversity index is to obtain a quantitative estimate of biological variability that can be used to compare biological entities in space or in time.

In this study, the following categories such as the Shannon-Wiener diversity index (*H'*) and evenness index (E) were determined. The Shannon-Wiener diversity index value is based on two factors: richness and evenness. The index takes into account the number of species living in a habitat (richness) and their relative abundance (evenness). Species richness is the quantity of the different species located within the mangrove community (Beals et al., 2000). Abundance (evenness) refers to the overall total of individual species present. The value of the Shannon-Weaver diversity index usually ranges from 1.5 to 3.5 and only rarely exceeds 4.5. On the other hand, the evenness index implies the of the individual species among the different species within the plots (Beals et al., 2000), and can be a measure of the relative abundance of each species. The more. evenly distributed individuals between species illustrate a higher species evenness, the more balanced and overall, the more diverse the ecosystem will be. It can be quantified by a diversity index as a dimension of biodiversity. In measuring the biodiversity indices (evenness and diversity index), the abundance curve calculator (Danoff-Burg & Chen, 2005) was used.

RESULTS AND DISCUSSION

Mangrove species taxonomic list

A total of 21 true mangrove species and 13 mangrove associate species were recorded belonging to 12 and 9 families were listed from 28 sample plots that were surveyed in the remaining mangrove forests of Davao City (Figure 2). This resulted in a total record of 34 mangrove species belonging to 21 families. Comparably, the recorded 21 true mangrove species are still low in terms of species richness as there were only 54% of the total listing of true mangrove species in the Philippines for instance in the studies of Giesen et al., (2007), 38 species, and Primavera (2000), 39 species. These recorded numbers of true mangrove species are lower compared to the rich mangrove forests in the country such as in Aurora, Luzon Island with 62 species (Rotaquio Jr. et al., 2007), and Palawan Island with 44 species (Garcia et al., 2014). Indeed, the mangrove forests in Davao City face tremendous threats and diminishing. This was obviously indicated by only a few coastal barangays (six barangays) having the remaining mangrove areas. The result of having few species showing higher relative abundances indicates continuous cutting of the remaining mangrove trees by some members from the adjacent communities for various economic uses. As seen and observed during sampling time, cuttings for firewood and materials for building a house, footbridge construction, and creating fishing gears were among usages.

On the other hand, these numbers are higher than the study findings conducted in some parts of Mindanao, such as in Malapatan, Sarangani Province with 16 species (41%) (Mullet et al., 2014); Sta. Cruz, Davao del Sur with 14 species (36%) (Cardillo and Novero, 2018); in Bacolod, Lanao del Norte with 11 species (28%) (Benecario et al., 2016); in Dinagat Island with 9 species (23%) (Cañizares & Seronay, 2016); in the Municipalities of Davao del Norte (Pototan et al., 2017) with 8 species (20%) in the Municipality of Carmen, 9 species (23%) in Tagum City, and 12 species (31%) in Panabo City; in Guang-Guang, Pujada Bay, Davao Oriental with 9 species (23%) (Yap et al., 2018), in Pamintayan, Dumanquillas Bay, Zamboanga province with 8 species (20%) (Bryan et al., 2017), and Davao Gulf with 7 species (18%) (Alcala et al., 2009). Hence, including the number of mangrove associate species recorded in this study, the findings connote higher species richness of mangrove species in Davao City compared to some studied mangrove forests in Mindanao provinces.

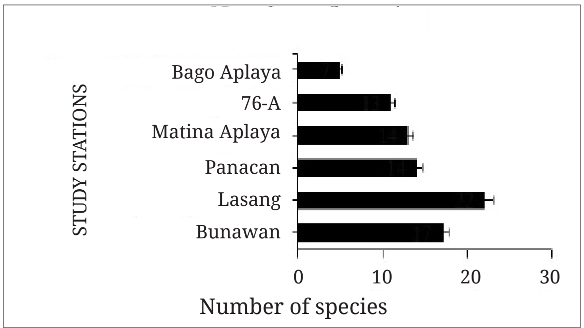

Figure 2. The number of mangrove species listed by Barangay/study station in Davao City.

One factor that may contribute to these differences in the number of species per study station is the continuous destruction of mangrove forests as observed during sampling time. Accordingly, the main drivers of mangrove destruction and loss are population growth, economic development, and demand for cultivated seafood (Lee and Primavera, 2014) whereas, pond culture is responsible for 50% of mangrove loss in the Philippines and 50–80% in Southeast Asia (Faridah-Hanun et al., 2014; Macusi et al., 2022). In Davao City, as a highly urbanized area, these drivers are observed during sampling time such as large conversion to aquaculture specifically in the mangrove areas of Barangay Lanang, and construction of coastal highway, conversion to industry and settlement sites in all sampled Barangays. Thus, these are believed to be the causes of the continuous mangrove destruction therein.

Importance value index

The importance value index (IVI) of a species was determined based on the total contribution that a species made to the community about the number of plants within the quadrats (relative abundance), its influence on the other species through its competition, shading, or aggressiveness (relative dominance), and its contribution to the community using distribution (relative frequency) in a study plot (Asadi et al., 2018). Species that have a high IVI will be more stable in terms of species resistance and growth, and have better adaptability, competitiveness, and reproductive capacity compared to other plants in a certain area (Mulyana et al., 2022).

The *Avicennia marina* (Forssk.) Vierh was the most important species in the area with the highest Importance Value Index (IVI) of 67.55 ratings, followed by *Rhizophora apiculata* Bl. and *Sonneratia alba* J.E. Smith as the second and third in rating. These were contributed by higher Relative Density and Relative Dominance since they have greater density and larger trunks. It has a lower Relative Frequency since most of the trees sampled were only confined to someplots and mostly not present in the whole sample plots. This account implies that *Avicennia marina*, *Rhizophora apiculata*, and *Sonneratia alba* were the most acclimatized in the study area (Obi, 2016). A study in Carmen and Panabo City showed the same that *Avicennia marina* and *Rhizophora apiculata* had species with the highest relative density and relative dominance implicating the species with the highest count per unit area (Pototan et al., 2017). In the study at Banay-banay, Davao Oriental (Pototan et al., 2021) *Sonneratia alba* has the highest importance value (59.8%) and has the largest contribution to mangrove biomass in the municipality. Subsequently, *Rhizophora apiculata* was next in rank to *Sonneratia alba*. The species of Rhizophora found in the Municipality are utilized for tannin extraction locally known as "tungog" production.

Notably, these species are all considered true major mangrove species - mainly restricted to the intertidal zone within deep water and high salinity (Rajpar and Zakaria, 2014). These three species in the same order revealed with highest relative abundances in all study stations. Accordingly, the dominant plant species in all mangrove zone forests around the world are generally trees in

Table 1. The taxonomic list and importance value index (IVI) of mangrove species found in the remaining mangrove forests of Davao City.

Official common name	Scientific name	Relative			IVI	Rank
		Density	Frequency	Domain		
Bungalon; Piapi	*Avicennia marina*	32.75	4.60	30.20	67.55	1
Bakauan Lalaki	*Rhizophora apiculata*	24.87	5.75	26.67	57.28	2
Pagatpat	*Sonneratia alba*	14.83	5.75	26.43	47.01	3
Bakauan Babae	*Rhizophora mucronate*	6.34	5.75	5.19	17.27	4
Bakauan Bato	*Rhizophora stylosa*	5.73	5.75	1.72	13.20	5
Api-api; Bungalon	*Avicennia lanata*	0.12	5.75	7.01	12.87	6
Nipa, Sasa, Sapsap	*Nypa fruticans*	3.05	5.75	0.00	8.79	7
Api-api; Bungalon	*Avicennia officinalis*	1.26	5.75	0.00	7.01	8
Tinduk-tindukan	*Aegiceras floridum*	1.99	3.45	0.48	5.92	9
Talisay	*Terminalia catappa*	1.22	4.60	0.10	5.92	10
Piagau	*Xylocarpus moluccensis*	1.18	4.60	0.00	5.78	11
Bani/Baluk-baluk	*Pongamia pinnata*	1.26	3.45	0.00	4.71	12
Langarai	*Bruguiera parviflora*	1.14	2.30	0.98	4.42	13
Bungalon puti	*Avicennia alba*	0.57	2.30	0.30	3.17	14
Malatangal	*Ceriops decandra*	0.57	2.30	0.06	2.93	15
Kulasi	*Lumnitzera racemose*	0.45	2.30	0.05	2.80	16
Katang- katang, Lagairai, Kamigang	*Ipomoea pes-caprae*	0.37	2.30	0.00	2.66	17
Tabigue	*Xylocarpus granatum*	0.24	2.30	0.04	2.58	18
Tuble / Tuba laut	*Derris trifoliata*	0.24	2.30	0.00	2.54	19
Alagaw dagat	*Premna obtusifolia*	0.24	2.30	0.00	2.54	20
Diliuatiao	*Acanthus ebracteatus*	0.16	2.30	0.00	2.46	21
Paku-laut	*Acrostichum aureum*	0.16	2.30	0.00	2.46	22
Cover crop	*Canavalia maritima*	0.16	2.30	0.00	2.46	23
Tui	*Dolichandrone spathacea*	0.12	2.30	0.00	2.42	24
Pagatpat; Pedada	*Sonneratia caseolaris*	0.28	1.15	0.47	1.91	25
Dapdap	*Erythrina orientalis*	0.08	1.15	0.15	1.38	26
Pagatpat baye	*Sonneratia ovata*	0.08	1.15	0.10	1.33	27
Malubago	*Hibiscus tiliaceus*	0.08	1.15	0.05	1.29	28
Saging-saging	*Aegiceras corniculatum*	0.12	1.15	0.00	1.27	29
Bito-bitoon	*Barringtonia asiatica*	0.08	1.15	0.00	1.23	30
Pandan laut	*Pandanus tectorius*	0.08	1.15	0.00	1.23	31
Bilang-bilang, Dampalit, Tarumpalit	*Sesuvium portulacastrum*	0.08	1.15	0.00	1.23	32
Buta-buta	*Excoecaria agallocha*	0.04	1.15	0.00	1.19	33
Noni /Great morinda	*Morinda citrifolia*	0.04	1.15	0.00	1.19	34
Total		100	100	300	300	

the families Avicenniaceae and Rhizophoraceae (Lewis and Flynn, 2014). This is supported by this study and some study findings in other parts of Mindanao (Yap et al., 2018; Mullet et al., 2014; Benecario et al., 2016; Cardillo & Novero, 2018; Pototan et al., 2017; Bitantos et al., 2017) connoting that mangrove forests in Mindanao are habitats for species mostly belonging to families Avicenniaceae and Rhizophoraceae. Further, the lower IVI ratings of mangroves show the rarity and few species in some study stations and can be implied to low species distribution in the study area. This distribution data further implied a gradual decline in the numbers of mangrove species in Davao City, thus needing immediate management actions.

Table 2. Abundance and distribution of mangrove regenerations in the six study stations in Davao City and their condition (poor, fair, good).

Scientific name	Barangay						Count	Mean	Remarks*
	Bunawan	Lansang	Panacan	Matina Aplaya	76-A	Bago Aplaya			
Avicennia marina	222	129	29	0	103	0	483	0.575	Fair
Rhizophora apiculata	88	29	176	0	12	10	315	0.375	Poor
Sonneratia alba	5	148	0	0	80	0	233	0.277	Poor
Rhizophora mucronate	0	0	0	31	18	68	117	0.139	Poor
Rhizophora stylosa	4	17	33	0	28	0	82	0.097	Poor
Avicennia lanata	0	0	0	11	0	0	11	0.013	Poor
Nypa fruticans	1	8	0	1	0	0	10	0.012	Poor
Avicennia officinalis	6	2	1	0	0	0	9	0.011	Poor
Aegiceras floridum	1	0	8	0	0	0	9	0.012	Poor
Terminalia catappa	1	6	0	0	0	0	7	0.008	Poor
Xylocarpus moluccensis	2	0	0	0	0	4	6	0.007	Poor
Pongamia pinnata	3	1	1	0	0	0	5	0.006	Poor
Bruguiera parviflora	5	0	0	0	0	0	5	0.006	Poor
Avicennia alba	0	5	0	0	0	0	5	0.006	Poor
Ceriops decandra	0	5	0	0	0	0	5	0.006	Poor
Lumnitzera racemose	0	0	0	0	4	0	4	0.005	Poor
Ipomoea pes-caprae	0	2	0	0	0	0	2	0.002	Poor
Xylocarpus granatum	0	1	0	0	0	0	1	0.001	Poor
Derris trifoliata	0	1	0	0	0	0	1	0.001	Poor
Premna obtusifolia	0	1	0	0	0	0	1	0.001	Poor
Acanthus ebracteatus	0	1	0	0	0	0	1	0.001	Poor
Acrostichum aureum	0	0	0	0	0	0	0	0	Poor
Canavalia maritima	0	0	0	0	0	0	0	0	Poor
Dolichandrone spathacea	0	0	0	0	0	0	0	0	Poor
Sonneratia caseolaris	0	0	0	0	0	0	0	0	Poor
Erythrina orientalis	0	0	0	0	0	0	0	0	Poor
Sonneratia ovata	0	0	0	0	0	0	0	0	Poor
Hibiscus tiliaceus	0	0	0	0	0	0	0	0	Poor
Aegiceras corniculatum	0	0	0	0	0	0	0	0	Poor
Barringtonia asiatica	0	0	0	0	0	0	0	0	Poor
Pandanus tectorius	0	0	0	0	0	0	0	0	Poor
Sesuvium portulacastrum	0	0	0	0	0	0	0	0	Poor
Excoecaria agallocha	0	0	0	0	0	0	0	0	Poor
Morinda citrifolia	0	0	0	0	0	0	0	0	Poor

* Excellent condition = at least 1 regeneration per m^2; Good condition = 0.76 - ‹1 regeneration per m^2; Fair condition = 0.50 – 0.75 regeneration per m^2; and Poor condition = ‹0.50 regeneration per m^2.

Abundance and distribution of mangrove regenerations

The abundance and distribution of mangrove regenerations are shown in Table 2 presenting data for every species to their corresponding study stations in terms of the average number of individual regenerations (saplings and seedlings) per square meter. These regeneration values were computed and their corresponding condition was evaluated based on the formula developed by Deguit et al., (2004). The general result in evaluating the abundance condition of regenerations was poor condition (<0.50) as shown by 33 species (97%) recorded, while only one species, *Avicennia marina*, had a fair condition with a general average evaluation value of 0.575. In South East Asia, over the past 60 years, a loss of 80% of mangrove area due to mangrove habitat clearance for coastal development, shrimp aquaculture, and others had led to species in many areas being locally extinct (Faridah-Hanun et al., 2014). This implies that the absence of some mangrove species in some parts of Davao City could be due to mangrove habitat clearances.

Structure through growth stages

Furthermore, the generalized forest structure as indicated by the three growth stages consisted mostly of mature stands with a relative abundance of 46.04%. At the same time, saplings and seedlings had relative abundances of 27.78% and 26.18%, respectively (Fig. 3). This finding also can be observed in the mangrove forests in Banay-banay is comprised of trees with mean GBH ranging between 10.7 and 30.5 cm, mean (Pototan et al., 2021). Furthermore, the abundance status of mangroves through scale showing the absence of species, rarity, and few in some study stations can be implied to low species distribution in the study area. This distribution data further implied a gradual decline in the numbers of mangrove species in Davao City, thus needing immediate management actions.

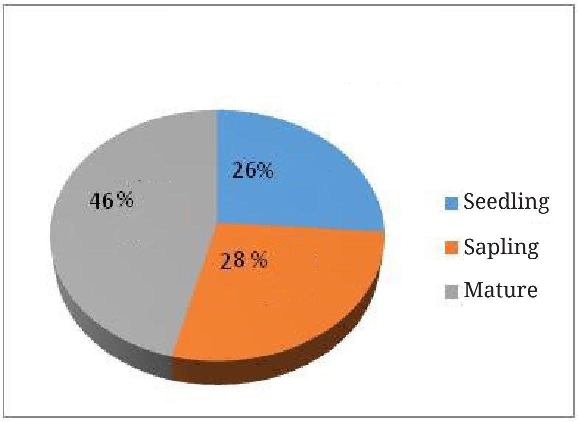

Figure 3. Relative abundance data (%) of mangrove species in terms of growth stages taken from the six study stations in Davao City.

General diversity indices

Generally, diversity indices (Figure 4) obtained low values on the Shannon-Wiener diversity index (*H'*=1.42) and an average value on the species Evenness Index (E=0.61). Shannon-Wiener diversity indices from all study stations varied from each other (1.13 – 1.65) all indicating low values. The overall diversity index was considered very low and is primarily due to the lack of species variation in the mangrove stands. Several studies coincidentally concluded that the mangroves had very low diversity indices due to their unique stand formation compared to other tropical forest ecosystems (Abino et al., 2014).

Further, the obtained evenness index from all study stations varied from 0.40 to 0.75 with an average of 0.61 (Figure 4). Evenness implies how even the distribution of the individual species among the different species within the plots sampled, thus also implied community stability – the higher the evenness the stable the community. The average value obtained (0.61) indicated that the mangrove community condition in Davao City is unstable and categorized that an E of between 0.5 to 0.75 means that the community is unstable, whereas the stress condition of communities when E is of between 0 to 0.5 (Palis et al., 2012). As shown in Figure 4 only Barangay Panacan

(0.40) had a stressed mangrove community while the rest were in an unstable condition. This implied that the decline in the number of mangrove species in Davao City could be attributed to human impacts. Generally, the diversity analyses for this study showed that the abundance was distributed to all study stations. Macintosh and Ashton (2002) explained that the high-low diversity and the moderate evenness indices respectively implied imbalances and an unstable mangrove community structure in Davao City. This connotes that many mangrove species have already vanish in the past thus, this ecosystem is highly become vulnerable. Pullin et al., (2013) argued that species extinction and vulnerability are associated with habitat loss and over-exploitation that may cause the loss of ecosystem functions (Faridah-Hanun et al., 2014). Further, Ashton et al., (2003) mentioned that anthropogenic and natural disturbances often result in diversity loss to natural ecosystems. That loss of diversity has a significant effect on ecosystem functioning (Palis et al., 2014).

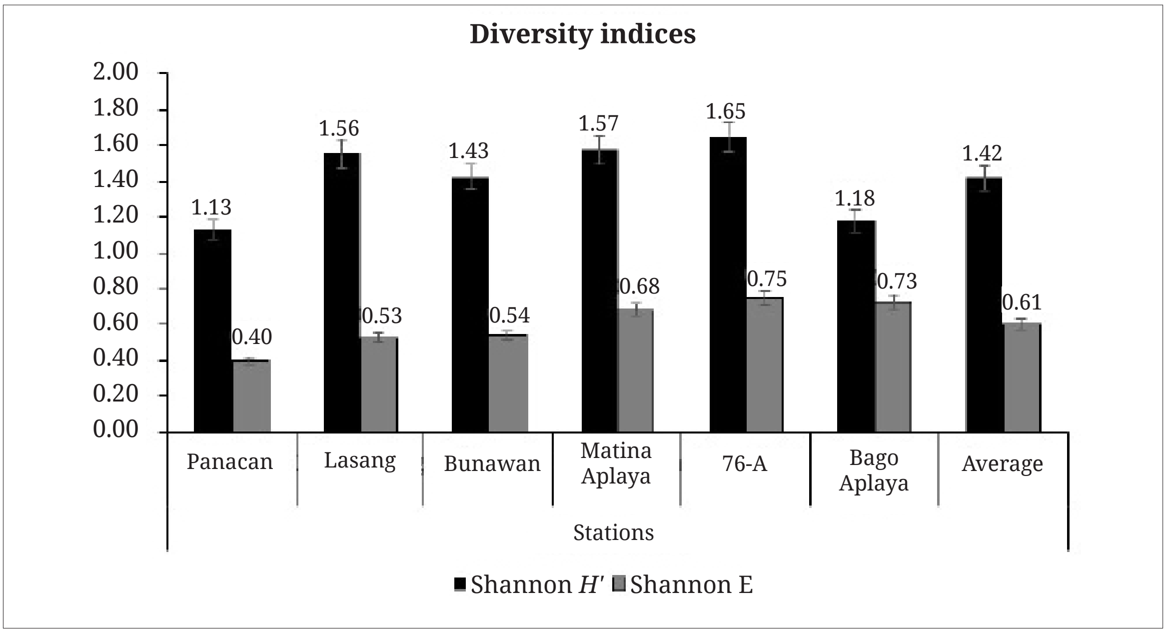

Figure 4. Diversity indices of the mangroves from the six study stations in Davao City.

CONCLUSION

A total of 21 true mangrove species and 13 mangrove associate species were found in this survey in the remaining mangrove forests of Davao City. There corded 21 true mangrove species were lower compared to the true mangrove species in the Philippines but these are higher than the study findings conducted in some parts of Mindanao. Among the species identified the *Avicennia marina* was the most important species with the highest importance value index of 67.55 rating, followed by *Rhizophora apiculata* and *Sonneratia alba* as the second and third rating. The abundance and distribution of mangrove regenerations had one species fair condition (*Avicennia marina*) while the rest of the species was in poor condition. The generalized forest structure as indicated by the three growth stages consisted mostly of mature stands with a relative abundance of 46.04% and the saplings and seedlings had relative abundances of 27.78% and 26.18%, respectively. Generally, diversity indices obtained low values on the Shannon-Wiener index (*H'*=1.42) and an average value on the species evenness index (E=0.61). This only affirmed that various lower diversity indices in all study stations showed mangrove forest ecosystems have declined leading to imbalance and unstable conditions connoting destruction throughout Davao City.

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From the above findings, sustainable management of mangrove forests must be implemented in the area involving the coastal dwellers in all of its projects such as 1) protection of the mangrove ecosystem through strict implementation of pertinent protecting policies for mangrove forest; 2) enrichment planting and reforestation projects using non-Avicenniaceae and Rhizophoraceae species so to increase density and diversity in the existing mangrove forests, and 3) re-establishment of mangrove forests projects in some coastal Barangays considering site-species suitability so to increase mangrove forest areas in Davao City.

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