The following is the overall status of Subic Bay Freeport (SBF) mangrove forests based on the data gathered from February 6, 20, 21, and 28, 2025 mangrove monitoring.

It is important to note that according to the resource inventory report on the flora resources of Subic Watershed Forest Reserve (SWFR), mangrove forest assessment was not included in the terms of reference, however, they included it as part of their discussion using secondary data gathered from various studies such as that of Fernando *et al.* in 1998 (Dalmacio, 2001). It is therefore the aim of this status report to determine the species composition, diversity, and community structure features of the mangrove forests in SWFR. Additionally, this report also aims to provide a baseline on the biomass and carbon stock assessment of Subic Bay's mangrove forests.

Materials and Methods

Study Site

The Subic Bay mangrove forests are located in the Subic Watershed Forest Reserve and fall within Climate Type I where it is dry during the months of November to April, and wet during the rest of the year with maximum rain during the months of June to September (PAGASA, 2023). SBF mangrove forests has approximately 61.63 hectares and is divided into 8 sites. Four sites are seaward (Triboa Bay A and B, Nabasan Bay, and Ilanin Bay), while the other four sites are riverine (Boton A and B, Malawaan, and Binictican).

During the monitoring period for 2025, there were 7 mangrove sites that were visited by the monitoring team. These are Triboa Bay (A), Triboa Bay (B), Boton (A), Boton (B), Nabasan Bay, Malawaan, and Binictican.

Sampling Procedure

Circular sampling plots, with a diameter of 10m (or an area of 78.538m^2 per plot), were established on each site by laying a 100m transect perpendicular to the shore or riverbank. Each sampling plot is 25m apart, generating 5 sampling plots per transect (with an area of 392.699m^2 per transect). The number of transects laid on each site vary from 1 to 2, with reference to the recommendations of the monitoring conducted in the previous years and to the area of the mangrove forest. Table 1 summarizes the total sampling area per site.

Table 1. Site name, number of sampling plots, area per sampling plot, number of monitoring transects, and total survey area of SBF mangrove forests for the monitoring period of February 6 to 28, 2025

No.	Site Name (Location)	No. of Sampling Plots per Transect	Area per Sampling Plot (in m^2)	No. of Transect/s	Total Survey Area (in m^2)
1	Triboa Bay (A)	5	78.539	1	392.699

2	Triboa Bay (B)	5	78.539	1	392.699
3	Boton (A)	5	78.539	2	785.398
4	Boton (B)	5	78.539	2	785.398
5	Nabasan Bay	5	78.539	1	392.699
6	Malawaan	5	78.539	2	785.398
7	Binictican	5	78.539	2	785.398
Total Area Surveyed (in m^2)					**4319.689**

In each plot, all mangrove trees were identified using Calumpong and Meñez (1997) and Primavera, Sadaba, Lebata, and Altamirano (2004). Their diameters at breast height (DBH) were measured with approximately 1.3m from the ground or 30cm above the highest prop root for stilt-rooted species, following the sampling procedure of Paquit and Veragara (2024).

Community Structure Analysis

The community structure features of the mangrove forests were taken by computing the frequency (F), relative frequency (RF), density (D), relative density (RD), dominance (Dm), relative dominance (RDm), and the importance value of each species (SIV). Table 2 summarizes the formulas used per parameter.

Table 2. Summary of formulas used to describe the community structure of the mangrove forest

No	Parameter	Formula
1	Frequency (F)	$F = \frac{\text{no. of sites in which each species occur}}{\text{total number of sites examined}}$
2	Relative Frequency (RF)	*RF = (F / total frequency value of all species) * 100*
3	Density (D)	$D = \frac{\text{total number of individuals per species}}{\text{total area sampled}}$
4	Relative Density (RD)	*RD = (D per species / total D of all species) * 100*
5	Dominance (Dm)	$Dm = \frac{\text{area covered per species}}{\text{total area covered by all species}}$
6	Relative Dominance (RDm)	*RDm = (Dm of each species / total Dm of all species) * 100*
7	Species Importance Value (SIV)	*SIV = (RF + RD + RDm) / 3*

Diversity Analysis

Following the study of Pototan *et al* (2021), species richness, diversity, and evenness, dominance were computed using Shannon-Weiner Index of Biodiversity (H'), Pielou's index of Evenness (J), Simpson's Index of Dominance (C), and Effective Number of Species (ENS). Table 3 summarizes the formula for each index computed. Fernando's (1998) classification was utilized to interpret H' (Pototan *et al*, 2021). Additionally, Gevana and Pampolina (2009) biodiversity scale as cited by Catulay *et al*. (2024) was used to interpret Pielou's Index of Evenness. Figure 1 shows Gevana and Pampolina's (2009) biodiversity scale as lifted from Catulay *et al.* (2024).

Table 3. Summary of formulas used to describe the diversity of the mangrove forest

No	Index	Formula	Legend
1	Shannon-Weiner Index of Diversity (H')	$H' = -(\Sigma^S_{i=1} (p_i lnp_i)$	p_i : fraction of the entire population made up of species *i* S: species richness $\Sigma^S_{i=1}$: sum of species from 1 to S
2	Pielou's Index of Evenness (J)	$J = (H' / lnS)$	H': Shannon-Weiner Index of Diversity lnS: natural logarithm of species richness
3	Simpson's Index of Dominance (C)	$C = \Sigma^S_{i=1} (p_1^2)$	p_i : fraction of the entire population made up of species *i* S: species richness $\Sigma^S_{i=1}$: sum of species from 1 to S
4	Effective Number of Species (ENS)	$ENS = exp (H')$	H': Shannon-Weiner Index of Diversity

Relative Interpretation	Shannon (H') Index	Evenness Index
Very High	>3.5	0.75-1.00
High	3.00-3.49	0.50-0.74
Moderate	2.50-2.99	0.25-0.49
Low	2.00-2.49	0.15-0.24
Very Low	<1.99	0.05-0.14

***Figure 1**. Biodiversity scale by Gevana and Pampolina (2009) as cited by Catulay et al. (2024)*

Biomass and Carbon Stock Assessment

In order to get the biomass of each species, the common allometric equation for mangroves developed by Komiyama *et al.* (2005) as cited by Tobias *et al.* (2017) was used (see Figure 2 for the formula used as taken from Tobias *et al.*(2017)). It utilizes the DBH and wood density of each species. Appendix I shows the list of mangrove species and their corresponding wood densities used in this status report. The corresponding wood densities were taken from the technical report of Tobias *et al.* (2017).

(1) Aboveground biomass (BM_{AG}) = $0.251 \rho D^{2.46}$

(2) Root biomass (BM_R) = $0.199 \rho^{0.899} D^{2.22}$

Where ρ = the wood density of each species; and
D = the total diameter of each species

***Figure 2**. Allometric equation used to compute for the Above Ground Biomass (ABG) and Below Ground Biomass (BGB or Root Biomass) taken from Tobias et al. (2017)*

In computing for the carbon stock, the suggested carbon percentage of 47% by the Intergovernmental Panel on Climate Change (IPCC) was used. For the CO_2 equivalents, the computed carbon stock was multiplied to 3.67 which is the molecular weight of CO_2 (Paquit & Vergara, 2024).

Results and Discussion

Species Richness and Composition

A total of 821 individuals representing 16 mangrove species belonging to 7 families were observed and recorded during the 2025 monitoring period. Most of the species identified were from the family Rhizophoraceae with 9 out of 16 species (52.941%) belonging to this family. This is consistent with the findings of Gonzaga *et al*. (2022) and Serrano, Tangtham, Bualert, and Janyasuthiwong (2022).

In terms of species, Pototan (*Bruguiera sexangula*) was found to be the most abundant with 19.853% abundance. It is followed by Bungalon (*Avicennia lanata*, 18.392%), and Bakawang Lalaki (*Rhizophora apiculata*, 16.930%). Figure 3 shows the abundance of each species identified.

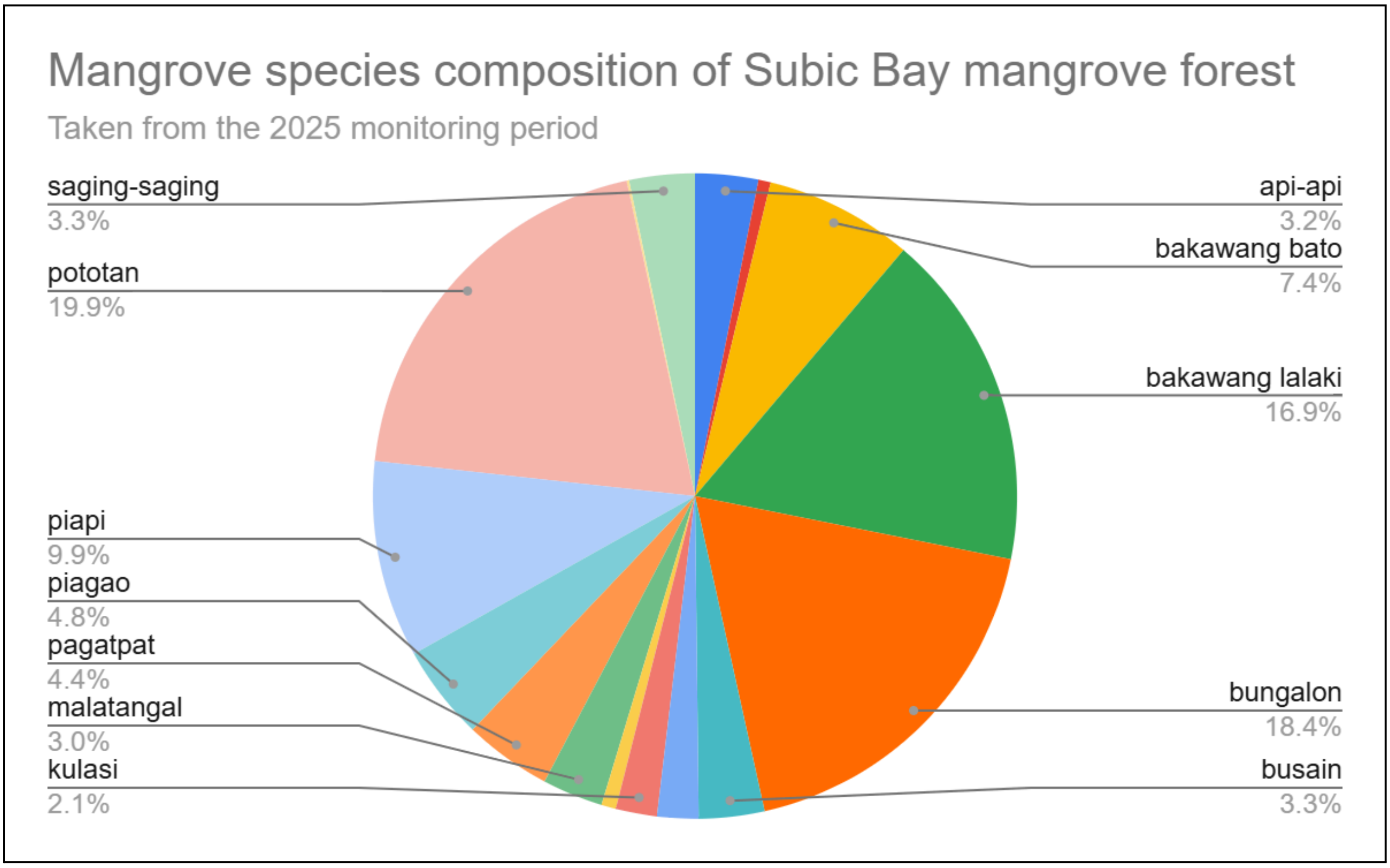

Figure 3*. Mangrove species composition of Subic Bay mangrove forests taken from the 2025 monitoring period*

Community Structure

Among the identified species, Bungalon (*A. lanata*) had the highest Species Importance Value indicating that it has the highest contribution to the biomass of SBF's mangrove forest. It is followed by Bakawang Lalaki (*R. apiculata*) and Piapi (*A. marina*).

In terms of relative dominance, Bungalon also had the highest computed value followed by Piapi and Bakawang Lalaki. This indicates that Bungalon had the major controlling influence on the SBF mangrove community possibly by virtue of its size.

In terms of relative density, Pototan (*B. sexangula*) had the highest computed value followed by Bungalon and Bakawang Lalaki. This indicates that Pototan has the highest number of individuals per unit area followed by Bungalon and Bakawang Lalaki.

In terms of relative frequency, Bakawang Lalaki was found to have the highest probability to be found on each monitoring site followed by Bakawang Bato (*R. stylosa*), Pagatpat (*Sonneratia alba*), Piapi, Bungalon, and Pototan. Appendix II shows the summary of the computed values for each of the species.

Diversity Analysis

The SBF mangrove forests had a species richness of 17 species. This is found to be half of the number of species observed in Banaybanay, Davao Oriental (Pototan, Capin, Dilemma, & Novero, 2021), and Puerto Princessa Bay (Dangan-Balon, Dolorosa, Sespeñe, & Mendoza, 2016) but higher than those observed in Iba and Botolan (Serrano, Tangtham, Bualert, & Janyasuthiwong, 2022), and Mahaba Island, Placer, Surigao del Norte (Catulay *et al.,* 2024).

Using the computed diversity indices (see Table 6 for the summary of the results), the computed Shannon-Weiner Index of Diversity was at 2.324 which is classified as “Low” under the categorization of Fernando (1998) and Gevana and Pampolina (2009). This is consistent with the studies of Dangan-Balon, Dolorosa, Sespeñe, & Mendoza (2016), Serrano, Tangtham, Bualert, & Janyasuthiwong (2022), Gonzaga *et al*. (2022), and Catulay *et al.* (2024).

In terms of species evenness, the computed value was 0.820 (82%) which is classified as “Very High” according to Gevana and Pampolina’s (2009) biodiversity scale. This means that individuals are relatively evenly distributed among the species which may imply that no species is dominating. This is supported by Simpson’s Index of Dominance with a computed value of 0.125 which is relatively not close to 1, confirming that there is no species dominating in SBF’s mangrove forests.

In terms of the Effective Number of Species (ENS), the value computed was 10.217 which means that the mangrove forests has an equivalent diversity with a community having 10 equally common species. Table 6 shows the summary of the computed indices and their consequent remarks.

Table 4. Computed indices for SBF’s mangrove forests and their corresponding remarks for the 2025 monitoring period

Index Type	Symbol	Value	Remarks
Shannon-Weiner Diversity Index	**H**	2.3240709287	Low
Pielou's Index of Evenness	**J**	0.8202950666	Very High
Simpson's Index of Dominance	**C**	0.1257778716	supports the value computed for J where no species dominate Subic Bay mangrove forests
Simpson's Index of Diversity	**D**	0.8742221284	close to 1, therefore there is 87.42% probability that two randomly selected individuals will be the same species
Effective Number of Species	**ENS**	10.21718318	area has an equivalent diversity with a community having 10 equally common species

Biomass and Carbon Stock Assessment

The total biomass computed for the 7 mangrove forests was 523.114 t ha^{-1} for the 2025 monitoring period. The total carbon stock density of SBF mangrove forests was 102.947tC while the estimated carbon sequestered was computed at 377.816tC. Table 7 shows a summary of the total biomass computed for each of the monitoring sites along with the biomass in tons per hectare.

Table 7. Total biomass, and carbon stock density of the 7 mangrove forests monitored for the 2025 monitoring period

	Triboa A	Triboa B	Boton A	Boton B	Nabasan	Malawaan	Binictican	Total
Total Biomass (in tons)	20.379	20.387	19.619	78.350	24.767	45.575	16.893	**225.969**
Biomass (tons per hectare)	47.176	47.197	45.417	181.378	57.334	105.505	39.108	**523.114**
Carbon Stock Density (tC)	9.268	9.263	8.923	35.782	11.286	20.756	7.670	**102.947**
Estimated carbon sequestered (tC)	34.013	33.994	32.746	131.320	41.418	76.176	28.149	**377.816**

Boton B had the highest biomass with 181.378t ha^{-1} as well as estimated carbon sequestered with 131.120tC. This is followed by Malawaan with a biomass of 105.505t ha^{-1} and estimated carbon sequestered of 76.176tC.

Boton B is known as one of the smallest mangrove forests being monitored in Subic Bay. However, in terms of individuals, it had the highest count with 164 individuals representing 10 species with Piagao (*Xylocarpus moluccensis*) being the most abundant species on this site. This mangrove site is a riverine mangrove forest with little anthropogenic disturbance recorded.

During the 2025 monitoring, Malawaan was recorded to have the highest Shannon-Weiner Index of Biodiversity computed which was 2.0179, although still considered as “Low” under Fernando’s (1998) categorization. This mangrove site is also a riverine mangrove site with little anthropogenic disturbance recorded.

It is important to note that for Triboa A, Triboa B, and Nabasan there were only 5 sampling plots observed for each of those sites while for Boton A, Boton B, Malawaan, and Binictican, each had 10 sampling plots observed (see Table 1 for reference). Additionally, Boton A and Binictican were reported to have recurring anthropogenic disturbances which ranges from improper waste disposal, unmanaged resource collection, to temporary and possibly illegal settlements.

Conclusion

This results of this monitoring period revealed:

1. there are 17 mangrove species observed with Bungalon (*A. lanata*) being the most abundant and that the family Rhizophoraceae is the most represented family in all sites;
2. SBF mangrove forests has a “low” biodiversity but this is consistent with other mangrove forest in the country;
3. despite having a low biodiversity index, there is no mangrove species dominating the SBF mangrove forests, indicating an even distribution of species in the mangrove sites;
4. the total biomass was at 523.114t ha^{-1} with a total carbon stock density of 102.947tC and an a total estimated carbon sequestered of 377.816tC
5. anthropogenic disturbances has shown to have an impact on the carbon sequestration ability of the mangrove forests of Subic Bay

Recommendation/s

With the results of this year’s monitoring period, a more specific mangrove conservation program can now be created focusing on the following:

1. this year’s monitoring period may be used as a baseline for the next monitoring that will be conducted in SBF’s mangrove forests provided that the monitoring methodology as well as analysis done on this period be followed with updates on the monitoring procedure as necessary;
2. a mangrove utilization guidelines or possibly a “no touch no entry” policy during particular periods may be pertinent to be created to reduce negative impacts to the mangrove forests which may hamper their climate change mitigation capability (i.e. carbon sequestration); and
3. conduct of mangrove monitoring should be done annually with a similar procedure to be able to compute the annual carbon sequestration ability of the mangrove forests of Subic Bay