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Research Article

Typhoon Damage Assessment of Natural and Planted Mangroves in Bais Bay, Negros Oriental, Philippines

Myron Gavriel F. Baring*, **Pablina L. Cadiz**

Institute of Environmental and Marine Sciences, Silliman University, Dumaguete City, Philippines

*Correspondence Email: myronfbaring@su.edu.ph

Abstract

Category 5 Typhoon Odette, internationally known as Rai, devastated the Central Philippines in December 2021, causing immense damage to the country's infrastructure, agriculture, and ecosystems. Coastal vegetative ecosystems, which include mangroves, are exposed to strong wind and wave energy during extreme weather events. Considering their importance in providing a myriad of ecosystem services to coastal communities, the post-typhoon assessment of mangroves will serve as a guide to future rehabilitation efforts. On August 13 and 14, 2024, 8 months after Typhoon Odette, the community structure characteristics (species composition, stem density, basal area, and regeneration potential) and damage severity of planted and natural mangrove forests were assessed in eight 10x10 m permanent plots located in Bais Bay, Central Philippines. Trees inside the plots were observed for signs of damage and were ranked in terms of damage severity. The differences in damage between natural and planted stands were statistically significant at χ^2=5.113; p=0.02. There was a weak association between stand type (natural or planted) and damage incidence (φ= -0.110), with reforested sites being more associated with damaged trees. *Rhizophora stylosa* showed low resilience, having the highest mortality rate of 15 trees, 14 of which were in planted sites. Most of the *R. stylosa* stands also failed to show refoliation 8 months after the typhoon, in contrast to *Sonneratia alba* and *Avicennia marina* trees which displayed refoliation as well as new stem sprouts despite also sustaining damage. Results of the study indicate that future mangrove planting projects should aim to plant a diverse set of mangrove species while following the correct species zonation of the forest (i.e., storm-resilient *Sonneratia alba* and *Avicennia marina* in seaward zones and *Rhizophora* in midward zones) to increase resiliency, especially in areas vulnerable to typhoons. Adequate space conducive for lateral growth should also be provided between planted trees.

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Introduction

Mangrove forests are highly productive coastal vegetative ecosystems found in the tropics and in the subtropics that have adapted to the physically and chemically harsh environment of the coastal belt margin through unique roots structures (pneumatophores, prop/stilt roots), salt-secreting glands, and viviparous seed germination [1-2]. Consequently, the adaptations to their environment have allowed them to act as a natural buffer against typhoons, storms, and floods [3]. These forests also serve as a source of food and income to nearby coastal communities, from the bioactive substances acting as medicine, to their complex root systems acting as breeding and feeding grounds for various commercially important marine organisms [4]. The once 200,000 km^2 global extent of mangroves has declined from 36 - 85% during the last quarter-century due to anthropogenic activities such as urbanization, aquaculture, and coastal reclamation and indirectly through pollution and upstream land use [5]. In the context of the Philippines, mangrove forests are important ecosystems that have an estimated worth of $3200 per year in flood reduction benefits alone. Despite the multitude of ecosystem services that they offer, there has been a loss of more than half of the country's mangrove cover over the past century. Much of this loss is inextricably linked to the aquaculture industry and happened from 1951 to 1988, when government incentives were put in place to promote the expansion of the fishpond industry [6-7]. There were no objections during the time as mangrove forests were regarded as "wastelands" or valueless land ready to be converted for aquaculture for the economic growth of the country. This was mostly due to failure in accounting for non-marketed services in the past, such as coastal protection. This erroneous valuation of mangroves has caused low government fees of Fishpond Lease Agreements and has substantially underpriced the rights to convert these ecologically important forests to ponds and does not even penalize suboptimal pond production. This, along with overlapping bureaucracy between the Department of environment and Natural Resources (DENR) and the Bureau of Fisheries and Aquatic Resources, legislative ambiguity, and a lack of political will has crippled the country's mangrove extent and the ecosystem services coastal communities could have benefited from [6].

Philippine mangrove cover has slowly been restored through massive, albeit questionable, rehabilitation efforts [8]. While small-scale community mangrove planting started in the early 1900s for wood supply and typhoon protection, planting for the purpose of rehabilitation only started to gain momentum in the 1980s due to revisions in forest land zoning. Large scale mangrove planting projects during this decade include the World Bank-funded Central Visayas Regional Project-I (CVRP-I) and the 1988 Integrated Social Forestry Program of the DENR. These two projects in particular were important in providing tenurial instruments to mangrove planters [6].

Despite tremendous effort throughout four decades and millions of dollars fed into mangrove reforestation efforts, assessments show low survivability in planted sites with CVRP-I sites only having 17-19% survivability 10 years after planting [9]. High mortality rates in reforested stands have been attributed to projects that generally prioritize "planting by convenience, not by ecology" [6]. This strategy favors the planting of *Rhizophora* species due to the ease of placing of their propagules in the substrate. In contrast, mangrove species in other genera, such as *Avicennia* and *Sonneratia*, are often neglected due to their seedlings having a labor-intensive nursery period compared to *Rhizophora* seedlings [10]. Some projects also plant *Rhizophora* propagules in lower intertidal to subtidal zones, which sometimes contain tidal flats and seagrass meadows to avoid ownership conflicts. In proper mangrove species zonation, *Rhizophora* stands thrive behind *Avicennia* and *Sonneratia* trees which are well adapted to strong wave energy and barnacle infestation [2, 11]. Such low survivability in mangrove rehabilitation programs is an indicator that there is a need to push for better training in mangrove ecology within government agencies, and for a more science-based approach under the supervision of technically skilled personnel [12].

The Philippines is highly vulnerable to typhoons due to its location along the Northwestern Pacific Basin, which is also known as "the typhoon belt" due to it being the most active tropical cyclone basin in the world [13-14]. It sees an average of 20 typhoons a year, with around 8 making landfall in the Philippines. The strong winds, coastal flooding and storm surges associated with typhoons threaten 60% of the Philippine population which live in coastal areas [15]. Climate change and anthropogenic stressors leading to land use change exacerbate these effects to coastal communities. In addition, constant exposure to natural disasters further worsens the socioeconomic status of families, preventing them from escaping poverty and leaving them more exposed and vulnerable to future disasters [16].

In December 2021, Super Typhoon Odette (international name Rai) passed through the Philippines causing displacement of coastal communities along with massive socio-economic damage to the country. It had a maximum recorded windspeed of 195 km h^{-1} near the center and gustiness of up to 240 km h^{-1} [17]. The typhoon caused 405 deaths, 1371 injuries, and the displacement of 9,109,480 individuals in 9,588 different barangays across the regions of Mimaropa, Bicol, Western Visayas, Central Visayas, Eastern Visayas, the Zamboanga Peninsula, Northern Mindanao, Davao, Soccsksargen, Caraga, as well as the Bangsamoro Autonomous Region in Muslim Mindanao. Damage to agriculture was estimated to be USD 427,900,000 and infrastructure to be at USD 564,050,000. In terms of damage to coastal ecosystems, an assessment done by Dolorosa et al. [18] in North-eastern Palawan also reported a significant reduction in hard coral cover (from 33.84 to 9.65%) as well as a decline in the populations of select macroinvertebrate species and other living organisms in both open-access and marine protected areas after the typhoon.

This study evaluated the impact of Typhoon Odette on the mangroves of Bais Bay, an area located in Central Philippines directly in Typhoon Odette's path which had a total of 41,475 individuals or 13,825 families affected and 13,825 damaged houses [17-19]. Information gathered on the extent and severity of damage will help guide future rehabilitation efforts in Bais Bay and other mangrove forests in a similar geographical setting. Limited data exists on the damage brought by Category 5 Super Typhoon Odette on coastal ecosystems. Although significant damage, possibly similar to the damage seen on the country's agriculture and infrastructure, is expected because they occupy the land-sea interface, where wave and wind energy is most intense [20]. Thus, an assessment done on coastal ecosystems such as mangroves in Bais Bay is important for its stakeholders to discover the severity of the damage and make informed decisions towards recovery thereafter.

Materials and methods

1) Study Site

Field surveys were conducted on August 13 and 14, 2022 on Category 5 Typhoon Odette disturbed mangrove stands situated in established 100 m^2 permanent plots set by the Philippine Higher Education Research Network (PHERNet) in Bais City. The plots are spread across small administrative divisions, called barangays, in Bais City. Plots in Sitio Sanlagan, located in Barangay Okiot (BN1: 9.584319°N, 123.155173°E; and BN2: 9.5831°N, 123.15443°E) and Talabong Mangrove Forest (BN3: 9.571352°N, 123.15896°E; and BN4:9.57182°N, 123.15844°E) were surveyed to represent natural stands in the area, and plots in Barangay Talungon (9.60656°N, 123.12877°E, labelled as BR1; and 9.60627°N, 123.13650°E, labelled as BR2) and Barangay Tamogong (9.60459°N, 123.13618°E, labelled as BR3 and 9.60585°N, 123.1384°E, labelled as BR4) for the planted stands [21] (Figure 1). The reforestation projects in Talungon and Tamogong were initiated by the city government in 2003 to 2007 funded by the Tortuga Foundation through the World Wildlife Fund for Nature, making the trees in these planted sites to be 14 and 18 years old as of Typhoon Odette's landfall.

The community structure was assessed by recording species diversity, stand basal area, and stems per hectare in the sites. Data gathered was used to compute for each species' Importance Value Index (IVI) (summation of relative density (Eq. 1) relative frequency (Eq. 2), and relative dominance (Eq. 3)). The IVI was then utilized in calculating species diversity (Eq. 4) and dominance indices (Eq. 5) [22]. Additionally, seedling (<1 m height; <4 cm stem diameter) and sapling (>1 m height; <4 cm stem diameter) count was recorded in the plots to measure the regeneration potential of the sites.

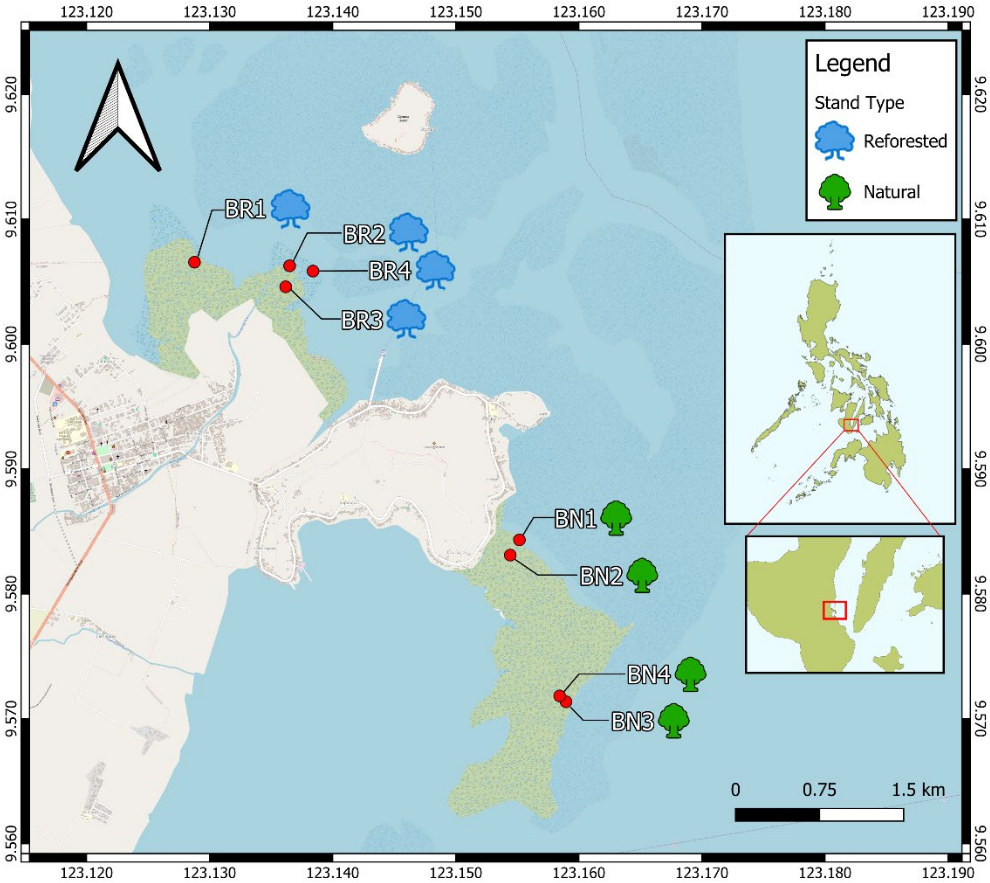

Figure 1 Plots evaluated in Sitio Sanlagan (BN1 and BN2), Talabong Mangrove Forest (BN3 and BN4), Talungon (BR1 and BR2), and Tamogong (BR3 and BR4). Map done in QGIS v3.34.1.

$$Relative\ density = \frac{no.\ of\ individuals\ per\ species}{total\ no.\ of\ individuals\ per\ species} * 100 \qquad \text{(Eq. 1)}$$

$$Relative\ frequency = \frac{frequency\ of\ species}{\Sigma\ frequency\ of\ all\ species} * 100 \qquad \text{(Eq. 2)}$$

Where: $frequency = \frac{no.\ of\ plots\ where\ species\ is\ found}{total\ no.\ of\ plots}$

$$Relative\ dominance = \frac{total\ basal\ area\ of\ species}{basal\ area\ of\ all\ species} * 100 \qquad \text{(Eq. 3)}$$

$$H' = -\sum_{i=1}^{S} \left(\frac{\text{Ni}}{N}\right) log \left(\frac{\text{Ni}}{N}\right) \qquad \text{(Eq. 4)}$$

Where: Ni = importance value of species i
N = sum of importance values of all species

$$N = \sum_{i=1}^{S} \text{Ni}$$

Where: S = total number of species in the sample

$$C = \sum_{i=1}^{S} \left(\frac{\text{Ni}}{N}\right)^2 \qquad \text{(Eq. 5)}$$

Where: Ni = importance value of species i
N = sum of importance values of all species

$$N = \sum_{i=1}^{S} \text{Ni}$$

Where: S = total number of species in the sample

The study utilized the damage assessment matrix of mangroves developed by Malabrigo et al. [23] to record damage in mangrove trees following Super Typhoon Haiyan in 2013. The matrix assesses tree damage on a scale of one to five, with one being no damage observed and five being a totally damaged tree (Table 1). Signs of recovery (refoliation and coppicing) were also noted by comparing accounts and documentation (images) of key informants on the status of the trees in the study sites immediately after the typhoon to their observed status 8 months post-typhoon. The key informants were also present during the assessments to confirm that observations of recovery. Man-made damage to mangroves in the study sites (i.e., clean cut/ sawed-off trunks, broken main trunk without a nearby felled tree) was not counted along with typhoon damaged trees for the impact assessment. The intensity of typhoon damage that hit the sites may have varied due to factors such as plot position, bathymetry, and distance from the typhoon, among others. However, these factors are beyond the scope of the study.

Table 1 Assessment matrix to measure damage severity from Malabrigo et al. (2016)

Assessment code	Illustration	Status of assessment	Descriptive status for evaluation
1		Not damaged	No damage to crown, branches, roots and trunk
2		Defoliated	Whole crown/branches fully or partially defoliated
3		Partially damaged	Tree partially damaged by the typhoon leaving them with broken branches, but the tree is still standing
4		Defoliated with some broken branches	Tree with combination of damage of 2 and 3 (with broken branches and defoliation)
5		Totally damaged	The tree is totally damaged by the typhoon, either uprooted or with broken main trunk

2) Statistical analysis

The Kolomogrov-Smirnov test for normality was used due to the large sample size of trees in the study (N = 420) and Levene's test was used to test for equal variance. The Kolmogorov-Smirnov test on DBH distribution of trees indicates that its data is not normally distributed (p=0.019) and thus non-parametric statistical analyses were used in this data set. A Chi-square test was used to infer whether the damage sustained in natural and reforested stands were statistically significant, and the Phi coefficient was utilized to indicate association between stand type and damage incidence. To test for differences in DBH between natural and reforested stands, a Mann-Whitney U test was used, and for differences in damage between categories, a Kruskall-Wallis test was applied.

Results and discussion

1) Community structure

The natural plots contained more species than the planted plots, with 7 species present (Table 2). The most common species among all plots are Avicennia marina and *Rhizophora stylosa*, both of which are present in seven of the eight total plots. *Rhizophora apiculata*, *R. mucronata*, *Osbornia octodonta* and *Ceriops decandra* were species that were only found in natural sites.

Reforested sites had a basal area (BA) of 23.16±4.91 m^2 ha^{-1} and a density of 7579.05±3805.26 stems ha^{-1} while natural sites had a BA of 68.93±68.93 m^2 ha^{-1} and a density of 6325±3400.37 stems ha^{-1}. Avicennia marina had the highest basal area (14.92± 4.26 m^2 ha^{-1}) and density (3725±2886.02 stems ha^{-1}) in reforested sites. In natural sites, *Sonneratia alba* had the highest basal area (45.28± 78.61 m^2 ha^{-1}) while *Avicennia marina* had the highest density (1975±2499.83 stems ha^{-1}) (Table 2).

Diameter at breast height (DBH) of planted stands had a range of 1.59-24.57 cm, with an average of 5.18± 3.38 cm; while DBH of natural stands had a range of 1.27-63.66 cm^2, with an average of 8.23±8.44 cm (Table 3). The Mann-Whitney U test indicates that the differences in DBH between natural and planted sites were found to be significantly different (p<0.000).

Table 2 Stem density, basal area, IVI, Shannon-Weiner, and dominance index of planted and natural sites

Location	Stem density ± SD (stems ha^{-1})	BA ± SD (m^2 ha^{-1})	RD (%)	Rdom (%)	RF (%)	IVI	H`	C
Natural sites								
All species								
Avicennia marina	1,975 ±2,499.83	10.43 ±9.19	31.23	15.14	23.08	69.44	0.34	0.05
Rhizophora stylosa	1,075 ±464.58	7.59 ±2.55	17.00	11.00	30.77	58.77	0.32	0.04
Rhizophora apiculata	25 ±50	1.05 ±2.10	0.40	1.52	7.69	9.61	0.11	0.00
Sonneratia alba	750 ±1,247.66	45.28 ±78.61	11.86	65.69	15.38	92.93	0.36	0.10
Ceriops decandra	1,900 ±3,800	1.78 ±3.56	30.04	2.58	7.69	40.31	0.27	0.02
Rhizophora mucronata	25 ±50	0.02 ±0.03	0.40	0.02	7.69	8.11	0.10	0.00
Osbornia octodonta	575 ±1,150	2.79 ±5.58	9.09	4.05	7.69	20.83	0.19	0.00
Total	6,325 ±3,400.37	68.93 ±68.93	100	100	100	300	1.68	0.21
Reforested sites								
All species								
Avicennia marina	3,725 ±2,886.02	14.92 ±4.26	49.15	64.40	40.00	153.54	0.34	0.26
Rhizophora stylosa	3,579 ±4,035.67	5.19 ±5.06	47.22	22.42	30.00	99.65	0.37	0.11
Sonneratia alba	275 ±221.74	3.05 ±3.05	3.63	13.18	30.00	46.81	0.29	0.02
Total	7,579 ±3,805.26	23.16 ±4.91	100	100	100	300	1.00	0.40

Note: BA – Basal area; RD – Relative density; Rdom – Relative dominance; RF – Relative frequency; IVI –Importance value index; H`- Diversity index, C – Dominance index

Table 3 Means and ranges of diameter at breast height and basal area of observed species

Location	Mean DBH ± SD (cm)	Range (cm)	Mean BA ±SD (m^2 ha^{-1})	Range (m^2 ha^{-1})	n
Natural					
All species					
Avicennia marina	6.77±4.65	1.91-26.26	0.53±0.79	0.03-5.42	45
Rhizophora stylosa	8.79±3.60	2.71-19.10	0.71±0.60	0.06-2.86	36
Rhizophora apiculata	-	-	-	-	1
Sonneratia alba	24.25±13.67	7.32-63.66	6.04±6.61	0.42-31.83	16
Ceriops decandra	3.19±1.34	1.27-11.46	0.09± 0.12	0.01-1.03	55
Rhizophora mucronata	-	-	-	-	1
Osbornia octodonta	7.57±2.15	4.46-13.31	0.48± 0.28	0.16-1.39	21
Total	8.23±8.44	1.27-63.66	1.1 ±2.95	0.01-31.83	175

Table 3 Means and ranges of diameter at breast height and basal area of observed species (*continued*)

Location	Mean DBH ± SD (cm)	Range (cm)	Mean BA ±SD (m^2 ha^{-1})	Range (m^2 ha^{-1})	n
Reforested					
All species					
Avicennia marina	5.97±3.92	1.59-22.28	0.40±0.60	0.02-3.90	98
Rhizophora stylosa	4.00±1.38	1.75-9.55	0.14±0.10	0.02-0.72	139
Sonneratia alba	10.50±5.85	3.97-24.57	1.11±1.33	0.12- .74	8
Total	5.18±3.38	1.59-24.57	0.3±53	0.02-4.74	245

Note: DBH – Diameter at Breast Height; BA – Basal Area; n – Number of trees

The biodiversity index (H') of reforested sites was 1.00 while the dominance index of planted sites (C) was 0.40. The H' of natural strands was 1.68 while C was 0.21. The patterns of indices suggest that natural stands harbored more species diversity than the reforested sites and as a consequence, a higher diversity index (H' = 1.68) and a lower index of dominance (C = 0.21) compared to reforested counterparts (H' = 1.00; C = 0.40). For the planted sites, *A. marina* had the highest importance value index (IVI) (153.54) followed by *R. stylosa* also having a relatively high IVI (99.65) which also indicates that reforestation projects in Bais did not primarily rely on Rhizophora propagules, as is the case for some reforestation projects [6, 10, 20]. *S. alba* and *A. marina* both have high IVI in natural stands, with 92.93 and 69.44, respectively (Table 2).

The arrangement of the spread out stems are the characteristics present in natural mangrove areas (Figure 2c and d), and these characteristics are in contrast with the uniformly arranged stems of reforested stands (Figure 2a and b). Since the natural stands have more space for lateral growth, they consequently have a broader range and a significantly higher mean DBH (8.23±8.44 cm) (Table 3). Despite having less density (stems ha^{-1}) than reforested stands, larger DBH values have given them larger basal areas.

Tree mortalities and broken stems from the typhoon may have contributed to the change in basal areas and densities in all sites due to broken stems. This decrease in both values is noted when compared to data of the permanent plots in previous years [21]. Stem density in Talabong decreased from 6,745 stems ha^{-1} in 2013 to 6325±922.16 stems ha^{-1} in 2022, (i.e., the current study) while basal area decreased from 117.27±79.82 m^2 ha^{-1} in 2015 to 68.93±3.83 m^2 ha^{-1} in 2022. In reforested sites, density decreased from 9,060±1700.88 stems ha^{-1} in 2013 to 7579.05±1109.324 stems ha^{-1} in 2022 (Table 2).

The presence of seedlings and/or saplings in all sites were noted. Saplings of *R. apiculata* and *S. alba* and seedlings of *C. decandra* were only found in natural sites (Figure 3). Seedling and sapling count of A. marina and the seedling count of *R. stylosa* having higher occurrences in reforested sites is consistent with previous reports in the same permanent plots [21]. More abundant recruitment in reforested sites can be attributed to their sparser canopy cover and, in turn, larger canopy gaps after storms which is favorable for seedling recruitment [24-25]. It should also be noted that observers may have missed saplings and seedlings due to some sites only being accessible during high tide, limiting the visibility of seedlings and saplings. Remarkable observations were made in the planted permanent plot of Barangay Tamogong, which held the majority of seedlings among the planted sites (4800 stems ha^{-1} for *A. marina* and 1600 stems ha^{-1} for *R. stylosa*). This did not display indications of a typical planted area (uniformly planted mangroves with small DBH). Thus, the presence of seedlings and saplings in all plots indicate that this regeneration pathway is present in both natural and reforested sites.

Figure 2 Uniformly reforested mangrove stands (a and b) observed to have minimal lateral growth and a lack of prop root growth compared to more spaced out, naturally occurring mangroves (c and d).

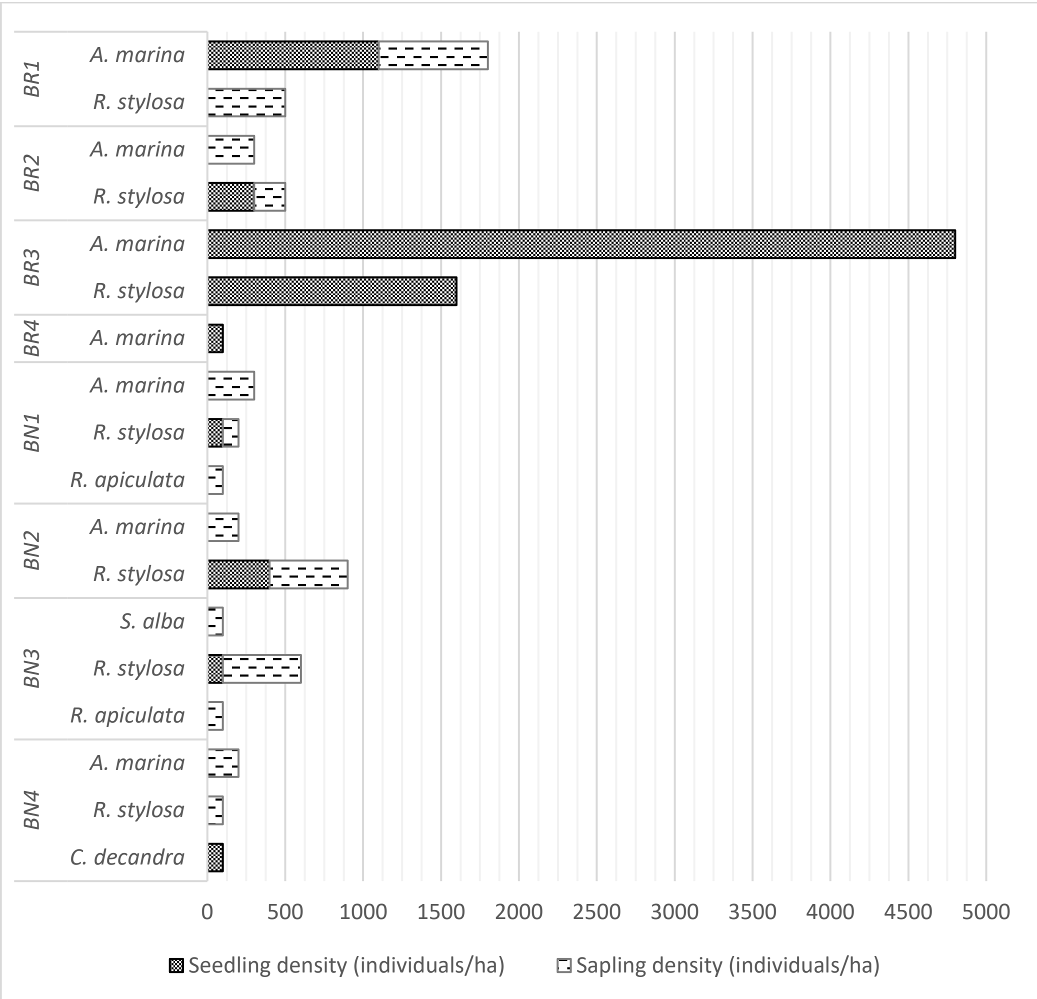

Figure 3 Seedling and Sapling density (stems ha^{-1}) in all plots.

2) Damage assessment

The damage sustained by mangroves from Category 5 Typhoon Odette are summarized in Table 4 and Table 5 according to the different damage categories by Malabrigo et al. [23]. Of the 420 trees that were observed, 345 were noted to have damage associated with the typhoon. In reforested areas, 85.71% of trees sustained damage (category 2–5), while 77.14% of trees sustained damage in natural stands. *R. stylosa* contributed the majority of the damage sustained in reforested sites (125 out of 210 trees) despite only being the second most prevalent species (in terms of IVI) next to *A. marina* (Table 2). Additionally, 14 of the 22 damaged/dead trees in planted stands were *R. stylosa* and more trees still showed defoliation. Similarly, the *R. apiculata* in Micronesia had the highest number of trees with no refoliation response after a typhoon [1]. For the natural sites, *C. decandra* was the highest contributor of damaged trees with 31.1% (42 out of 135) trees and *A. marina* being a close second with 30.4% (41 out of 135).

Table 4 Damage sustained by species in reforested and natural sites

Species	Damage code				
	1	2	3	4	5
Reforested					
A. marina	21	30	18	22	7
S. alba	0	1	1	5	1
R. stylosa	14	59	14	38	14
Total	35	90	33	65	22
%	14.29	36.73	13.47	26.53	8.98
Natural					
A. marina	4	15	13	13	0
S. alba	2	1	5	6	2
R. stylosa	16	4	6	2	1
R. apiculata	1	0	0	0	0
R. mucronata	1	0	0	0	0
C. decandra	13	15	15	12	0
O. octodonta	3	10	6	2	0
Total	40	52	45	35	3
%	22.86	29.71	25.71	20.00	1.71

Table 5 Damage sustained in the different plots by in reforested and natural sites

Plot	Damage code				
	1	2	3	4	5
BR1	14	17	11	10	0
BR2	13	47	7	19	3
BR3	4	7	3	1	1
BR4	4	19	12	35	18
Total	35	90	33	65	22
%	14.29	36.73	13.47	26.53	8.98
BN1	9	10	11	10	0
BN2	3	5	5	5	0
BN3	9	5	6	6	3
BN4	19	32	23	14	0
Total	40	52	45	35	3
%	22.86	29.71	25.71	20	1.71

The differences in damage sustained across stand type (natural and reforested sites) were statistically significant (χ^2=5.113; p = 0.024). The Phi coefficient (φ= -0.110) also shows that there is a weak association present between damage incidence and stand type (i.e., natural or reforested). This indicates that multi-species, multi-aged, and consequently multi-tiered natural stands are more resilient and less vulnerable to typhoon damage than reforested stands, which have been shown to have a lower biodiversity index in the community structure survey and are relatively uniform in age. This is in line with observed high vulnerability in monospecific *Rhizophora* plantations in a study of Villamayor et al. [27].

There was no significant difference that was found in the DBH of different damage categories (*p*=0.412), indicating that DBH of the trees did not appear to be a factor in the damage sustained in the study sites. This is similar to the findings of Malabrigo et al. [23] in their damage assessment in northern Palawan after Typhoon Haiyan that also found DBH not being a factor on a tree's resiliency to typhoons. The width of a tree's main trunk alone may not be a sufficient predictor of damage, and other factors such as wood density and species-specific physiology may play a role in the severity of damage a tree will sustain [28].

Natural sites had a higher relative frequency in healthy trees (code 1) and trees with broken branches (code 3), mainly attributed to small, young *C. decandra* trees. Reforested sites showed higher relative frequencies in defoliated trees (code 2), defoliated trees with broken branches (code 4), and dead trees (code 5) (Figure 4).

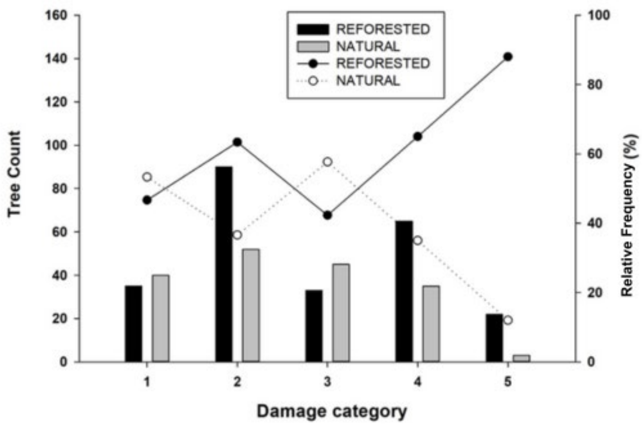

Figure 4 Count (bars) and relative frequencies (lines) of trees in differing damage codes.

The higher incidence of damage in reforested stands is connected to the uniform and compact arrangement of the trees present that causes less chance for lateral growth. This observation was also seen in planted stands at Bantayan Island [27], where the development of this uniformly planted *R. stylosa* may have contributed to its increased vulnerability due to the following factors: (1) The tall and slender trees in planted sites (Figure 2a and b) are exposed to wind speeds which get exponentially stronger with altitude; (2) there is a lack of space for lateral growth and complex root systems in the areas which assist trees against the strong wave action and wind associated with typhoons; and (3) increased height reduces photosynthetic capabilities (i.e. refoliation and coppicing potential) of individuals in order to keep up with the physiological demands needed for transpiration in taller trees [29].

Mangrove damage assessments after the 2013 Category 5 Super-Typhoon Haiyan showed that *Rhizophora* trees had shown poor recovery 2.5 and 4.5 months later in Eastern Samar [20], 6 months later in Ormoc and Tacloban, Samar [30] and in a 7-month period in Bantayan Island, Central Philippines [27]. A broad scale remote sensing study done 8 months post-typhoon from Samar to Palawan also showed similar results [31].

In this study, there was no severe damage of *Rhizophora* in natural sites compared to the planted counterparts. This suggests that *Rhizophora* may have less vulnerability when planted in its optimal abiotic conditions and in the right zone within the mangrove forest.

The severe damage observed on *Sonneratia alba* trees, with 20 of the 24 trees present in all sites having a damage code of 3 and above can be associated by the species being positioned in the land-sea interface, its usual niche when natural zonation is present in mangrove forests. *Sonneratia alba* trees have shown evidence of refoliation from pictures taken immediately after the typhoon and pictures 8 months after (Figure 5). Similar findings were observed by Kauffman and Cole [1] in Micronesia where *S. alba* had higher occurrence of mainstem breakage attributed to its stiffer stems, but mitigated the species being uprooted and windthrown. The study also noted the abundant basal and epicormic sprouts of the species. Although *S. alba* trees sustained considerable damage, their exceptional refoliation potential is a factor that makes them more resilient compared to Rhizophora species, as they have a reduced ability to coppice or refoliate attributed by its lack of apical meristem [20].

Refoliation of *A. marina* trees were also observed, despite sustaining considerable amount of damage. The likelihood of *Sonneratia* and *Avicennia* species naturally dominating the seafront developed adaptations to the stressors usually encountered in the area. This may further suggest that the preservation of original habitats should always take priority over rehabilitation and restoration. This idea is reinforced by the fact that natural stands showed better performance of resiliency and recovery. Less damage incidence as well as less mortality in natural stands can be attributed to their community characteristics. A biodiverse natural mangrove forest contains a multi-tiered and multi-stemmed stand capable of withstanding the stressors of the land-sea interface to a greater degree than improperly planted mangrove stands. The two most dominant species in these stands (*S. alba* and *A. marina*) have also been observed to have the ability to quickly refoliate and grow new branches, allowing them to quickly recover from damage. In contrast, *Rhizophora stylosa* trees that were located in planted stands had the highest mortality across all species due to its altered development and physiology from improper planting practices.

Figure 5 Picture of defoliated trees (mostly *Sonneratia alba*) in the Talabong Boardwalk taken immediately after Typhoon Odette (a and b) and pictures of the same site 8 months after (c and d).

Conclusion

Though reforested stands in Bais showed high seedling recruitment, regeneration pathways can still be improved if future projects followed science-based protocols (i.e., the fundamental ecology of mangrove forests). This is evidenced by the refoliation demonstrated by the naturally seaward mangrove, *Avicennia marina* in reforested sites. Some planted sites did implement multi species planting, with *A. marina* even surpassing the traditionally favored *Rhizophora* in terms of IVI value. *Avicennia* and *Sonneratia*, however, were planted within Rhizophora stands, not in front of them. Mangrove planting projects in the area are in the right direction by moving away from monospecific planting practices but can be further improved by following correct species zonation (i.e., storm-resilient *Sonneratia alba* and *Avicennia marina* in seaward zones and the more vulnerable *Rhizophora* species in midward zones). Expert consultation during the planning phases of projects could also prove to be instrumental to the success of reforestation and afforestation projects.

Multi-species planting can be further reinforced by investing resources in mangrove nurseries and giving adequate support (in the form of training workshops, seminars, and financial aid) to People's Organizations to have more success with the nursery phases of *Avicennia* and *Sonneratia* seedlings, which are labor intensive by nature. With climate change causing typhoons to become more frequent and intense, natural drivers (i.e. extreme weather events) have become one of the main influences of mangrove cover change and will continue to be for the indefinite future [32]. This decade old call to proper restoration and rehabilitation is therefore more critical than ever [6, 10].

Planted *Rhizophora* had poor resiliency and recovery against Typhoon Odette due to its inability to grow laterally, and thus compensated with vertical growth because they were planted in close proximity. Future projects can learn from this by spreading propagules farther apart, allowing space for lateral growth and root complexity in these mangroves. While the relatively young planted *Rhizophora* trees were reported to have refoliated after the typhoon, these trees will eventually lose their ability for epicormic growth and coppicing. Lifespan of *Rhizophora* trees will therefore be limited to the return periods of typhoons in the area [27].

Continuous monitoring of these permanent plots may give further information on how well Bais mangroves have refoliated. Damage assessments can be as late as 1.5 years after an extreme weather event for regeneration to adequately take place [20]. Further studies can focus on mechanisms of epicormic growth, and particularly how *Rhizophora* tend to lose it with age, so we may further understand this important part of mangrove biology.

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