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Diversity assessment and spatial structure of mangrove community in a rehabilitated landscape in Hagonoy, Davao Del Sur, Philippines

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Abstract. Mangrove rehabilitation has been initiated by the Philippine government to address the mangrove degradation. The mangrove landscape in Hagonoy, Davao del Sur is one of the rehabilitated sites in the country. Recent evaluation by the local government on the reabilitation effort revealed no assessment was conducted in terms of diversity and vegetation structure. The study was the first to provide baseline information on mangroves in the study area. A purposive sampling was employed in the study. There were 20 quadrats with a dimension of 10 m X 10 m installed. The results revealed 12 species from 7 families of mangroves. The biodiversity indices indicated a low species richness and Shannon diversity but high in abundance. Regeneration of seedlings was in good condition (*Avicennia marina and Rhizophora apiculata*). The sapling regeneration gave poor condition on three species (*A. marina, Rhizophora mucronata and Rhizophora apiculata)*. The vegetation analysis revealed 5 species with highest values (*A. marina, R. mucronata, R. apiculata, Sonneratia alba* and *Aegiceras corniculatum*). The spatial structure of mangrove community revealed less diversity which could be due to replanting of selected species.
Key Words: biodiversity, regeneration, vegetation, Hagonoy, Davao del Sur.

Introduction. Mangroves are trees with special characterisitcs to thrive in salt and brackishwater environment. They vary in size from shrubs to tall trees and are found along sheltered tropical mudflats or wetlands or in association with estuaries and lagoons (Primavera et al 2004). They may also extend inland along rivers, streams and their tributaries (Becira 2005). The species were known to adapt to oxygen poor environments and nutrient-rich muddy substrates that undergo variations in salinity (Sherman et al 1998).

The Philippines is considered as a mega diverse country in terms of marine flora and fauna. Biological diversity of coastal plants in the country is one of the richest in the world (Calumpong & Menez 1997). There are an estimated forty species, came from sixteen families, considered as true mangroves (Primavera et al 2004). Despite the biological significance of mangroves it suffered considerable degradation.

Coastal communities traditionally cut mangroves for charcoal, housing materials, boat construction, and medicine. The growing population among coastal villages has increased the demands for these materials. This was observed as a threat in Samar Island, Philippines (Mendoza & Alura 2001). In Sarangani Province, land reclamation in the past 30 years caused 50% of mangrove decline and greatly contributed to the decline of fishery products as well (de Jesus et al 2001). Overall, the conversion of mangroves into aquaculture ponds was seen as the single biggest threat to mangrove decline (Janssen & Padilla 1999; Primavera 1995; Samson & Rollon 2008).

Because of this degradation, the Philippine government initiated rehabilitation efforts in the country (Carating et al 2014). The sampling site in Paligue, Davao del Sur is one of those areas with rehabilitation activities. Unfortunately, the rehabilitated site has no record of assessment and monitoring according to the local government. It was suggested that mangrove management should be evaluated in terms of diversity and vegetation structure parameters (Ellison 2000). The success of any mangrove rehabilitation should be periodically monitored and evaluated (Uitto 2014).

Hence, it is the objective of the study to conduct an assessment on the mangrove rehabilitated landscape. The data gathered in the study will serve as baseline for future monitoring and rehabilitation activities.

Material and Method

The sampling area. This study was conducted from January to February, 2015 in Hagonoy, Davao del Sur, Philippines. The study area was located in southeastern Mindanao (Figure 1), geographically lying between 6°39'40.87''-125°22'50.90'' and 06°40'16.913''-125°22'48.842.'' The area was a mangrove rehabilitated site (Figure 2).

Figure 1. The sampling area showinng the Philippine map, Mindanao island (B) and the location of Hagonoy, Davao del Sur (C).

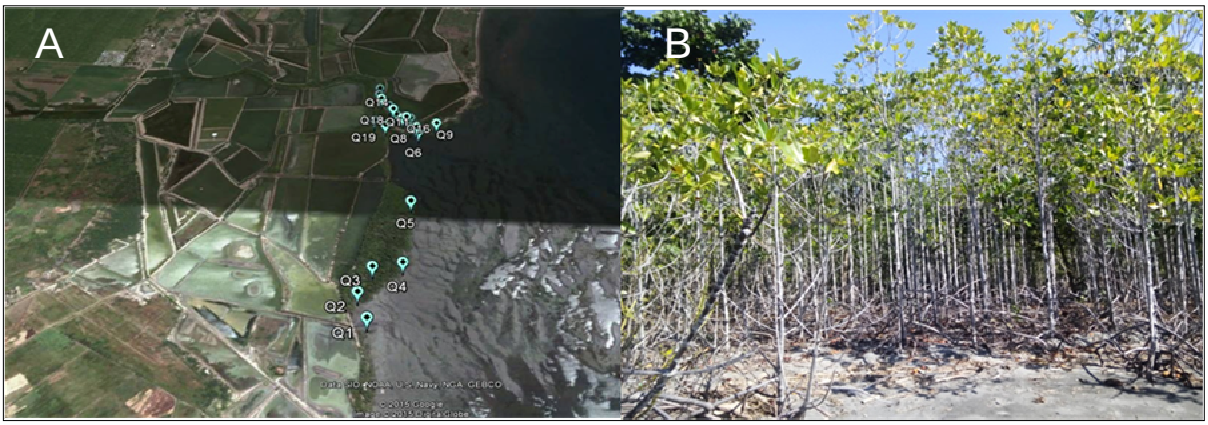

Figure 2. The sampling sites with the location of the quadrats (A) and the rehabilitated mangrove site (B).

Sampling plots establishment. Purposive sampling was employed in this study. Sampling quadrats (10 m X 10 m) were established to areas with sufficient mangrove cover. Regeneration plots consisted of 3 (1 m X 1 m) and were nested diagonically positioned within the main plot of 10 m X 10 m of every quadrats.

Mangrove inventory and diversity. The mangrove species considered was based on the description of true mangroves by Primavera et al (2004). The species of mangroves were indentified *in situ* using reliable identification guide from the book of Becira (2005). Mangrove species located outside the quadrats were included as part of species inventory. The diversity indices was computed using Paleontological Statistics (PAST) software (Hammer et al 2001) which includes species richness, abundance, dominance, evenness, Shannon and Simpson diversity indices.

Vegetation analysis. The vegetation analysis include the regeneration of seedlings and saplings and vegetation structure of mangroves. The formula for the regeneration of seedlings and saplings was computed based on Deguit et al (2004). The vegetation structure analysis was based on the formula given by Cheng (2004). Below are the different formulas used in the computation:

Regeneration/m^2 = total regeneration count/total no. of regeneration plots, in which:

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,
poor condition = < 0.50 regeneration per m^2

Vegetation structure. The computed values consisted of density, frequency, dominance and their relative values were used to compute for species importance values. This was shown below:

(a) Density = total number of individuals of a species in all quadrats /total number of individuals of all species in the study;
(b) Frequency = total number of quadrats in which the species occurred/total number of occurrences in the study;
(c) Dominance = total basal area of each tree of a species from all plots/total area of all the measured plots;
(d) Relative density = total number of individuals of a species X 100/total number of individuals of all species;
(e) Relative frequency (%) = total number of occurrences of species X 100/total number of occurrences of all species;
(g) Relative dominanace = (dominance for a species/total dominance for all species) X100;
(h) Species importance values (SIV) were calculated by summing up the relative dominance, relative frequency and relative density values.

Multivariate data analysis. The data on abundance was square root transformed so that rare species might exert influence in data analysis. Similarity matrix was constructed using Bray-Curtis index. Cluster dendrogram was generated to find natural groupings of mangrove community structure. The non-metric multidimensional scaling (nMDS) was used in the data ordination (Deguit et al 2004). The best strategy for spatial discrimination of species diversity is one that combines cluster analysis and nMDS (Cheng 2004).

Results and Discussion. The species composition consisted of 12 species belonging to 7 different families. One species, the *Nypa fruticans* was a mangrove palm. The rest of the species were shrubs and/or trees as their habit. There were 5 species observed outside the quadrats and these were *Osbornia octodonta, N. fruticans, Bruguiera cylindrica,*

Ceriops decandra, and *Rhizophora stylosa*. The species *Avicennia marina* was the most abundant while *Avicennia officinalis* was the least in abundance (Table 1).

Table 1

Species composition and abundance of mangroves in the sampling area

Family	*Species*	*Total*
Avicenniaceae	*Avicennia marina*	266
	Avicennia officinalis	1
Combretaceae	*Lumnitzera racemosa*	3
Myrsinaceae	*Aegiceras corniculatum*	2
Myrtaceae	*Osbornia octodonta*	0
Palmae	*Nypa fruticans*	0
Rhizophoraceae	*Bruguiera cylindrica*	0
	Ceriops decandra	0
	Rhizophora apiculata	90
	Rhizophora mucronata	141
	Rhizophora stylosa	0
Lythraceae	*Sonneratia alba*	15
Total number of individuals		518

Mangrove diversity. Among the 20 quadrats, the highest number of species richness and Shannon diversity was in quadrat 12 with 7 species and 1.486 diversity value. Abundance was highest in quadrat 20 with 97 individuals. Dominance was highest in quadrat 3 with a value of 0.9201. Dominance and evenness were highest in quadrats 8 and 10 but lowest in Shannon diversity. The entire sampling area has an average of 2.75 species richness and 25.95 abundance. The dominance and evenness can be considered as moderate values. Shannon diversity having an average value of 0.646 is considerably low. The biodiversity in the sampling area can be described as low in species richness but high in abundance (Table 2).

Table 2

Summary of the biodiversity metrics of mangroves in 20 sampling quadrats

QN	*SR*	*Abu*	*Dom*	*ShD*	*Eve*
Q1	2	19	0.7341	0.4362	0.7734
Q2	3	11	0.686	0.6002	0.6075
Q3	2	48	0.9201	0.1732	0.5946
Q4	3	20	0.44	0.9503	0.8621
Q5	4	10	0.36	1.168	0.8041
Q6	3	12	0.7083	0.5661	0.5871
Q7	3	20	0.515	0.791	0.7352
Q8	1	64	1	0	1
Q9	3	17	0.3495	1.073	0.9751
Q10	1	4	1	0	1
Q11	3	69	0.7698	0.4327	0.5138
Q12	7	19	0.3241	1.486	0.6314
Q13	2	14	0.8673	0.2573	0.6467
Q14	3	20	0.555	0.746	0.7029
Q15	2	24	0.5139	0.6792	0.9861
Q16	3	9	0.4321	0.9369	0.8507
Q17	2	11	0.5041	0.689	0.9959
Q18	3	22	0.5083	0.7925	0.7363
Q19	3	9	0.5062	0.8487	0.7789
Q20	2	97	0.8487	0.2848	0.6647
Average	2.75	25.95	0.627125	0.64556	0.77233

QN = quadrat number; SR = species richness; Abu = abundance; Dom = dominance; ShD = Shannon diversity; and Eve = evenness.

Seedling and sapling regeneration. The mangrove species with successful production of seedling and saplings were determined by its regeneration success. A total of 6 mangrove species were identified to produce seedlings during the sampling period. The species were *A. marina* and *R. apiculata* which gave good conditions, while the remaining species of *R. mucronata, S. alba, A. officinalis* and *L. racemosa* gave poor conditions (Table 3). On the other hand there were three mangrove species with successful sapling regeneration during the sampling period. These were *A. marina, R. mucronata* and *R. apiculata* (Table 4). However, none of them reached even the good condition. Unfortunately, during the sampling period, only few numbers of those species had been observed to be regenerated within the chosen quadrats.

Table 3

Summary of seedling regeneration ranked from highest to lowest

Species	*Total no. of species*	*Regeneration/m²*	*Condition*	*Rank*
Avicennia marina	59	0.967	good	1
Rhizophora apiculata	43	0.83	good	2
Rhizophora mucronata	23	0.4	poor	3
Avicennia officinalis	9	0.15	poor	4
Sonneratia alba	3	0.05	poor	5

Table 4

Summary of sapling regeneration ranked from highest to lowest

Species	*Total no. of species*	*Regeneration/m²*	*Condition*	*Rank*
Avicennia marina	7	0.1165	poor	1
Rhizophora apiculata	7	0.0665	poor	2
Rhizophora mucronata	2	0	poor	4.5
Sonneratia alba	0	0	poor	4.5
Avicennia officinalis	0	0	poor	4.5
Lumnitzera racemosa	0	0	poor	4.5

Vegetation analysis. The summary of values were shown in Tables 5-8. The vegetation analysis include abundance, frequency, dominance and their relative values. The summation of the relative values gave the species importance value. The results showed that *A. marina* was the species with highest abundance, frequency, dominance, and importance value. The species also can be categorized as the most influencial in the sampling area. There were 5 species which were consistent in the aforementioned parameters and these were *A. marina, R. mucronata, R. apiculata, S. alba* and *A. corniculatum.* In rehabilitation activities, these species should be considered because they exert greater influence in the vegetation structure in the sampling site.

Table 5

The five species with highest relative density ranked from highest to lowest

Species	*Relative density*	*Rank*
Avicennia marina	29.5	1
Rhizophora apiculata	12.75	2
Rhizophora mucronata	25	3
Sonneratia alba	3	4
Avicennia officinalis	0.25	5

Table 6

The five species with highest value of relative frequency ranked from highest to lowest

Species	*Relative frequency*	*Rank*
Avicennia marina	36.36363636	1
Rhizophora apiculata	27.27272727	2
Sonneratia alba	20	3
Rhizophora mucronata	12.72727273	4
Avicennia officinalis	1.818181818	5

Table 7

The five species with highest value of relative dominance ranked from highest to lowest

Species	*Relative dominance*	*Rank*
Avicennia marina	0.524150105	1
Rhizophora apiculata	0.190766675	2
Rhizophora mucronata	0.18800023	3
Sonneratia alba	0.091221646	4
Aegiceras corniculatum	0.003060469	5

Table 8

The five species with highest value of importance value ranked from highest to lowest

Species	*Important values*	*Rank*
Avicennia marina	66.38778636	1
Rhizophora apiculata	40.21349727	2
Rhizophora mucronata	37.91527273	3
Sonneratia alba	23.09122	4
Aegiceras corniculatum	2.321241818	5

Spatial structure of mangroves. The result using cluster analysis revealed that two major groups were formed at 40% similarity. Two quadrats formed 1 group which were quadrats 8 and 11 (Figure 3). While the other group consisted of 18 quadrats forming the second group. The data suggested that mangrove community in the sampling site were very similar such that less variability were observed. The rehabilitation of mangroves in the area using selected species might have an effect to the community structure. Three major species were utilized for mangrove rehabilitation as observed in the sampling area. These were *R. apiculata, R. mucronata,* and *A. marina*. The frequent replanting of the aforementioned species might have reduced the variability and diversity of species. As a result, quadrats were more similar suggesting that species diversity was low which was also reflected on low Shannon diversity value of 0.646.

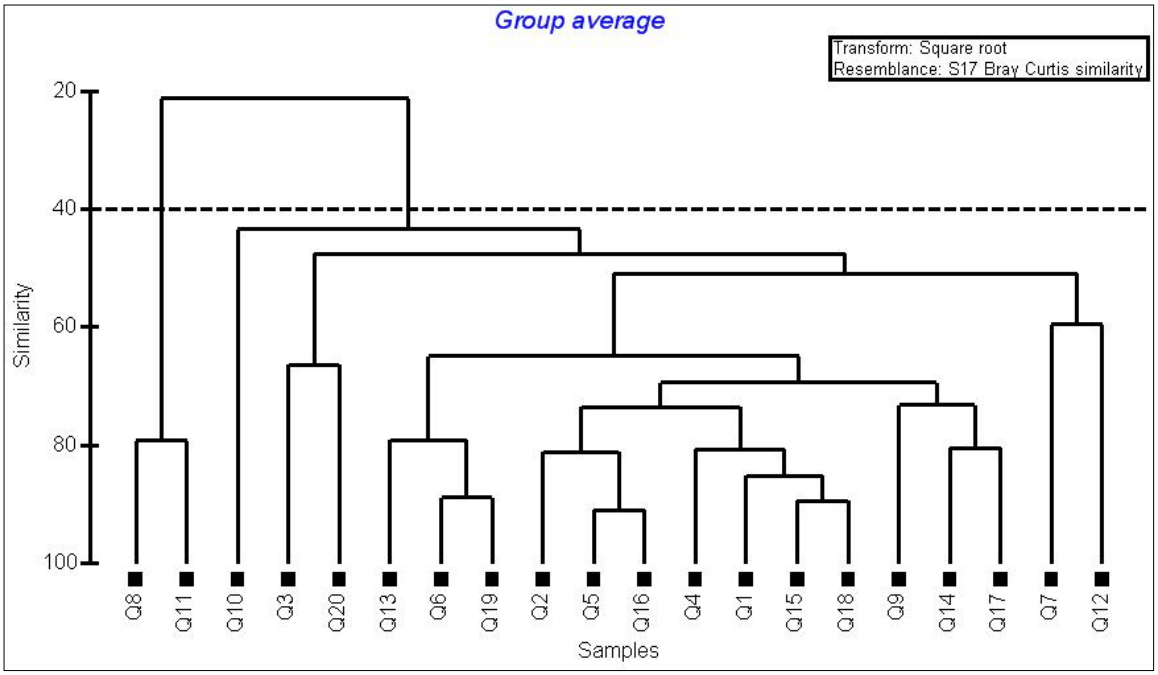

Figure 3. Cluster analysis showing similarity at 40% Bray-Curtis similarity.

The ordination of the data using non-metric multidimensional scaling (nMDS) also showed the formation of two groups at 40% similarity (Figure 4). The second big group clearly showed high degree of similarities among the sampling quadrats. The proximity of

the location of samples in a two dimensional plane also indicated similarities in nMDS. The data clearly indicated high degree of similarities and less diversity among the quadrats. There were 5 quadrats which stood out when the biodiversity metrics of species richness, abundance, and Shannon diversity were overlaid in nMDS. These were quadrats 7, 8, 9, 11, and 12 with high correlation to the considered biodiversity values. There was strong positive Spearman correlation in the 5 quadrats but the highest correlation was observed in quadrat 11. This implied that quadrat 11 has the best biodiversity índices among all the quadrats considered. The stress value of 0.13 in nMDS indicated good data ordination. The ordination also of the data clearly showed that the sampling quadrats were very similar in terms of the parameters measured. Less variations also were noted on the orthogonal plane. The same observation was also noted in the cluster analysis.

3

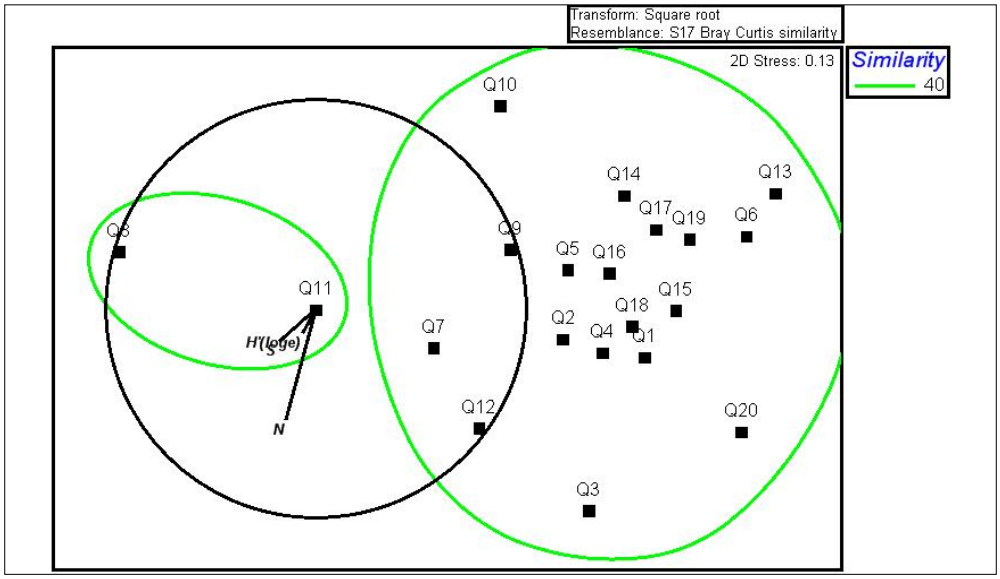

Figure 4. Non-metric multidimensional scaling indicated quadrat 11 have high correlation to biodiversity metrics.

Conclusions. The study revealed that mangrove species in the sampling area consisted of 12 species belonging to 7 famililes. The biodiversity indices were low in terms of species richness and Shannon diversity but high in abundance. Dominance and evenness were considerably in moderate values. The regeneration of seedlings showed *A. marina* and *R. apiculata* gave good condition. However, the species *A. marina, R. apiculata,* and *R. mucronata* gave poor sapling regeneration. There were 5 species with high in species importance value and these were *A. marina, R. mucronata, R. apiculata, S. alba* and *A. corniculatum.* The spatial structure of mangroves using cluster analysis and nMDS revealed high degree of similarities among the quadrats. It could also mean less diversity of mangroves in the sampling area and the rehabilitation using only 3 species could be the factor. The replanting of selected species does not promote diversity as indicated in the results.

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