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ORIGINAL RESEARCH PAPER

Crab biodiversity under different management schemes of mangrove ecosystems

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ABSTRACT: Reforestation is one of the Philippines' government efforts to restore and rehabilitate degraded mangrove ecosystems. Although there is recovery of the ecosystem in terms of vegetation, the recovery of closely-linked faunal species in terms of community structure is still understudied. This research investigates the community structure of mangrove crabs under two different management schemes: protected mangroves and reforested mangroves. The transect-plot method was employed in each management scheme to quantify the vegetation, crab assemblages and environmental variables. Community composition of crabs and mangrove trees were compared between protected and reforested mangroves using non-metric multi-dimensional scaling and analysis of similarity in PRIMER 6. Chi-squared was used to test the variance of sex ration of the crabs. Canonical Correspondence Analysis was used to determine the relationship between crabs and environmental parameters. A total of twelve species of crabs belonging to six families were identified in protected mangroves while only four species were documented in reforested mangroves. *Perisesarma indiarum* and *Baptozius vinosus* were the most dominant species in protected and reforested mangrove, respectively. Univariate analysis of variance of crab assemblage data revealed significant differences in crab composition and abundance between protected mangroves and from reforested mangroves ($P<0.05$). Canonical correspondence analysis showed that soil texture was found to greatly affect the distribution of crab assemblages and mangroves ($P<0.05$). Environmental factors and human intervention had contributed to the difference in crab assemblages in mangrove ecosystems.

KEYWORDS: *Analysis Of Similarity (ANOSIM); Analysis Of Variance (ANOVA); Non-metric Multi-Dimensional Scaling (NMDS); Perisesarma; Plymouth Routines In Multivariate Ecological Research (PRIMER); Protected Mangroves (PM); Reforested Mangrove (RM)*

INTRODUCTION

Mangroves, an intertidal forest occurring along tropical and subtropical coast is a home to a variety of plants, animals, and the microbial organisms that are highly adapted to intertidal environmental conditions (Neukermans *et al.,* 2007). This dynamic ecosystem is ecologically important to many organisms such as fish, mollusks, crustaceans, and birds (Nagelkerken *et al.,* 2007, Kairo *et al.,* 2008).

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Benthic fauna, particularly crabs, are one of the most dominant groups in mangrove ecosystems (Nagelkerken *et al.,* 2008). They have a significant role in nutrient recycling (Macintosh 1984, Steinke *et al.,* 1983, Dahdouh-Guebas *et al.,* 1997, Lee 1998, Bosire *et al.,* 2004), detritus formation and form an important link in the mangrove food web (Macintosh, 1984), and dynamics of the ecosystems through their feeding activities (Bosire *et al.,* 2004). Their burrowing activity changes the topography of mangrove floor and improves soil aeration (Warren and Underwood 1986, Ashton *et al.,* 2003a) and enhances bioturbation of soil sediments (Smith *et al.,* 1991, Ashton *et al.,* 2003a).

Macrobenthic are not well studied as compared to vegetation and tropic ecology (Lee, 2008). Thus, many mangrove-crab relationship remains poorly understood and inadequately valued ecologically and economically (Clough, 1993, Gilbert and Janssen 1998, Ashton *et al.,* 2003b). This leads to rapid degradation of mangrove resources over the last century (Duke *et al.,* 2007). In the Philippines, there has been a sharp decline of mangrove forest from half a million to 279, 000 hectares from 1951 to 1988 (Primavera, 2000, Walton *et al.,* 2007) to which aquaculture was the primary reason of mangrove loss.

Only recently, the value of mangrove services and products been appreciated by policy makers. Thus, massive reforestations were being implemented in many degraded mangrove ecosystems of the country to restore ecological function and associated goods and services. However, most of the reforestation efforts are mono-genus instead of a diverse forest (Walton *et al.,* 2007). As such, little is known about the recovery of closely linked species like mangrove crabs in mono-genus plantations. Furthermore, poor understanding of distribution and ecology of mangrove crabs and the impact of habitat conditions hinders the development of effective management strategies that successfully conserve faunal resources and their function in the mangrove ecosystem. The aim was to determine how varying habitat conditions in two different management schemes, influence the community of crabs. This study has been performed the community structures of mangrove crab species under different management schemes in *Rhizophora* dominated mangroves in some selected areas of Quezon Province, the protected mangroves (PM) and the reforested mangrove (RM) in Philippines during 2011-2012.

MATERIALS AND METHODS

Study area

This study was conducted in Pagbilao and Catanauan, Quezon Province (Figs. 1). The Pagbilao Mangrove Experimental Forest (PMEF) at Ibaba Palsabangon is a 145 ha natural, protected mangrove (CEP-Pagbilao, 2003) and was declared as PMEF in 1975, by virtue of Bureau of Forest Development (BFD) Administrative Order No. 7 (s. 1975). The second site located in Brgy. Matandang Sabang Kanluran, Catanuan represents the reforested mangroves (Fig. 2); a 15-year old plantation currently managed by the people's organization MASAKA, Bigkis-Lakas, and Community Planters (DENR CENRO-Catanuan, 2003a; DENR CENRO-Catanuan, 2003b).

Biodiversity transects and plots

The selected study sites featured similar dominance of *Rhizophora* mangroves to avoid bias between protected sites and reforested sites. The assessment was carried out using Transect-Plot Method. A total of nine (9) 100 m transect lines were laid perpendicular to

Fig. 1: Location map of protected mangroves in Pagbilao, Quezon province

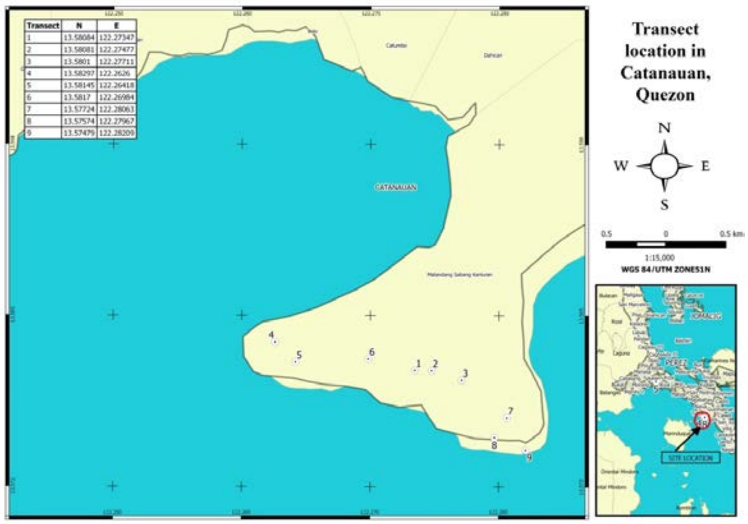

Fig. 2: Location map of reforested mangrove sites in Catanuan, Quezon province

the seashore in both sites with a distance of 50 m to 100 m. In each transect, ten 100 m^2 biodiversity plots were established. The location of each transect was marked using handheld Garmin eTrex Global Positioning System (GPS), however, only one GPS point was recorded in protected site due to bad weather conditions during the sampling period.

Mangrove trees and poll with Diameter at Breast Height (DBH)>4 cm size were assessed within the 100 m^2 quadrats. Inside the 100 m^2 quadrat, 25 m^2 was delineated randomly for sapling inventory (DBH<4 cm and height >1 m). 1 m^2 subquadrat was established for seedling inventory (height > 1 m) (English *et al.,* 1994).

For crab composition and density, a total of 180 25 m^2 plots were established for crab sampling in two sites. Sampling was carried out during spring ebb tides. Hooks and handpicking methods were used in crab collection. Hooks were used in deeper burrows (i.e. *Scylla* species burrows) while handpicking was applied to crabs with shallower burrows such as *Perisesarma* species (Macintosh *et al.,* 2002; Ashton *et al.,* 2003a). Collections of crabs were aided by local crab collectors. Unidentified species were stored in labeled plastic container fixed with 70% ethyl alcohol and brought to the *Philippine National Museum* for identification. Species Richness and Species Density was used for crab density. The maximum Carapace Width (CW) was measured to the nearest 0.1 mm using Vernier caliper. Crabs with a Carapace Length (CL) of < 3.5 mm were referred to as juveniles (Bunnuang *et al.,* 2005). The sex structure of crab was identified by its abdominal flap.

Environmental parameters of the sampling plots were also obtained. Parameters analyzed included soil pH, sediment texture/grain size, Organic Matter Content (OMC) and Nitrogen, Phosphorous and Potassium. Soil samples were analyzed at the Ecosystems Research and Development Bureau (ERDB) following their standard procedure.

Statistical analysis

Crabs and Mangrove Trees between the two conditions (protected and reforested) were compared using the Non-metric Multi-Dimensional Scaling (NMDS) and the Analysis of Similarity (ANOSIM) in PRIMER 6 (Clarke 1993). *Densities* of crab and tree were converted into its log transformed data for Bray; curtis similarity analysis. Sites were then ordinated into two dimensional space based on similarities using the NMDS. Factors affecting the patterns of similarity were analyzed using cluster analyses set at 20%, 40%, 60%, and 80% levels of similarity. The levels of similarity between mangrove forests were then analyzed using ANOSIM. Crab and tree species responsible for those differences were identified using a Similarity of Percentage (SIMPER) procedure in PRIMER 6. Species were then ranked according to the percent contribution to dissimilarity (MacKenzie and Bruland, 2012).

Relationships between crab community structure, soil characteristics (% organic matter, pH, N, P, K,

% sand, % silt, % clay), and mangrove tree abundance measures (species abundance) were examined using the BIO-ENV in PRIMER 6. Correlations between environmental variables, mangrove, and crab community structure were analyzed using the Canonical Correspondence Analysis in PAST: paleontological statistics software package (Hammer *et al.,* 2001).

RESULTS AND DISCUSSION

Environmental parameters

Soil textures in protected mangroves were characterized as sandy clay loam and clay loam texture; while, majority of the soil composition in reforested mangroves were characterized by sandy botttom (67%). Mean value for soil pH showed that protected mangroves were categorized as strongly acidic (5.29) while soil pH in reforested mangroves was slightly basic (7.26). Higher concentration of OMC was recorded in reforested mangroves (18.50) compared to protected mangroves (11.84). Mean values for % total N (0.59) and total P (4.81) in mangrove soils were lower in protected than in reforested mangroves (total N= 0.92; total P= 21.37). Considerable higher amounts of potassium were recorded in protected mangroves (113.39) almost three times the mean value obtained in reforested mangrove (42.77). Significant differences were determined on soil pH, P, and K content between protected and reforested mangroves (Tables 1 and 2).

Species richness and species density

A total of nineteen mangrove tree species belonging to 10 families and one mangrove associate (*Nypa fruticans*) were identified in protected mangroves, while only 13 tree species were found in reforested mangroves. For mangrove saplings, 11 species were identified in protected mangroves while 10 species were recorded in reforested mangroves. Seedling inventory revealed 9 species in protected while 8 species listed in reforested mangroves (Table 3).

The higher mean density in reforested mangroves compared to protected mangroves was attributed to the planting method employed in the area which is less than a meter. For tree species, *R. apiculata* dominates the protected area while *R. stylosa* occur dominantly in reforested site. The least dense species in protected mangroves were *S. caseolaris*, *L. littorea*, and *H. littoralis* while *E. agallocha* was the least dense in reforested mangroves. For sapling density, *R. apiculata* occurred densely in two sites. Seedlings of *R. mucronata* occurred abundantly in protected while *R. stylosa* dominates the reforested sites (Table 3).

Mangrove tree assemblages sampled from the reforested and protected mangrove forests clustered into two distinct groups at the 40% similarity level and six distinct groups at the 60% similarity level at a stress value of 0.1 (Fig. 3). Tree community structure significantly differed between the two sites (ANOSIM, $R = 0.7$, $p < 0.001$), which SIMPER analyses revealed were due to significantly higher densities of *Rhizophora stylosa* in the reforested sites (40.44 ± 36.15 no/m^2) than the protected sites. *R. stylosa* contributed to 20% of dissimilarity between these two sites. *R. mucronata* and *R. apiculata* had higher densities in the protected site and contributed to 25% of dissimilarity.

Table 1: Average data of environmental parameters in protected and reforested mangroves

Environmental Parameters	Protected mangrove	Reforested mangrove
pH	5.29	7.26
OMC (%)	11.84	18.50
Total N (%)	0.59	0.92
Total P (ppm)	4.81	21.37
K (me/100g)	113.39	42.77
Sand (%)	47.33	67.11
Silt (%)	25.56	12.44
Clay (%)	27.11	16.44

Table 2: One way ANOVA of environmental parameters in protected and reforested mangroves

Environmental parameters	F-value	P-value
pH	10.90	<0.001*
OMC (%)	3.274	0.089
Total N (%)	3.317	0.087
Total P (ppm)	20.706	<0.001*
K (me/100g)	70.833	<0.001*

*Significantly difference

Table 3. Tree density of mangrove species in protected and reforested sites

	Protected mangroves			Reforested mangroves		
Species	Trees	Saplings	Seedlings	Trees	Saplings	Seedlings
Aegiceras corniculatum	*1.89±	0.44 ±0.29	0.11±0.11	0.67±2.00	-	-
Avicennia alba	-	-	-	0.33±1.00	-	-
Avicennia marina	0.25±0.15	-	-	1.44±2.60	0.11±0.11	1.11±0.73
Avicennia officinalis	10.00±1.11	5.00±1.00	0.56±0.56	2.11±2.52	0.67±0.37	0.11±0.11
Avicennia rumphiana	0.78± 0.36	0.11±0.11	0.22±0.15	-	-	-
Bruguiera cylindrica	0.22±0.15	0.11±0.11	0.11±0.11	-	-	-
Bruguiera gymnorrhiza	0.11±0.11	0.22±0.22	-	2.11±2.52	0.56±0.29	0.44±0.18
Bruguiera parviflora	0.56± 0.24	0.11±0.11	-	-	-	-
Bruguiera sexangula	0.89± 0.42	0.67±0.44	2.56±1.21	-	-	-
Ceriops decandra	-	0.44±0.44	-	0.44±1.01	0.11±0.11	0.89±0.77
Ceriops tagal	4.33±1.20	5.22±2.09	1.89±1.15	12.13±9.52	6.22±2.95	4.00±1.94
Excoecaria agallocha	0.44±0.29	-	-	0.22±0.67		
Heritiera littoralis	0.11±0.11	-	-	-	-	-
Lumnitzera littorea	0.11±0.11	-	-	-	-	-
Rhizophora apiculata	26.00±6.83	16.56±4.27	7.56±1.83	23.56±15.70	23.56±6.03	4.89±1.81
Rhizophora mucronata	20.78±7.07	14.22±4.86	9.00±3.54	-	0.11±0.11	-
Rhizophora stylosa	-	-	-	40.44±36.15	16.33±6.83	10.88±4.17
Scyphiphora hydrophyllacea	0.44±0.33	0.11±0.11	-	-	-	-
Sonneratia alba	-	-	-	-	3.89±2.50	1.11±1.11
Sonneratia caseolaris	0.11±0.11	0.11±0.11	-	0.33±0.71	-	-
Xylocarpus granatum	7.56±2.19	5.44±1.22	2.44±0.63	0.44±1.01	-	-
Xylocarpus moluccensis	0.22±0.15	-	-			

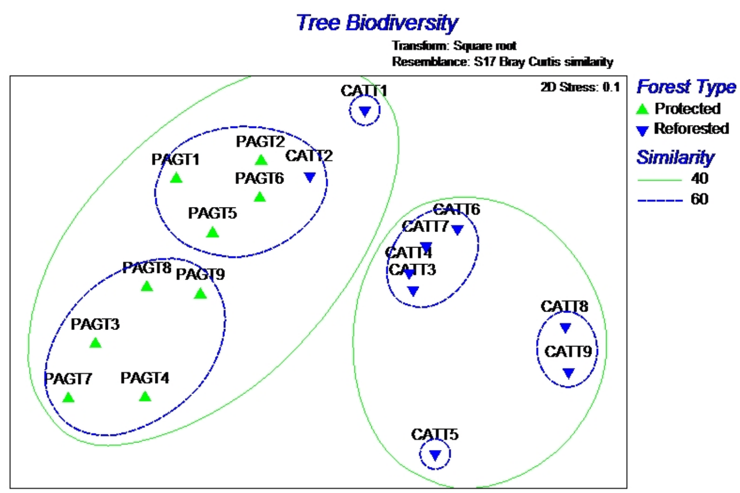

Fig. 3: NMDS plots of tree densities sampled from reforested and protected mangrove forests. Sites clustered into two groups at the 40% similarity level and six groups at the 60% level.

Crab density and size structure

A total of three hundred fifty-one (351) individuals of crabs belonging to six families in 12 species were caught from November 2010 to February 2011 sampling. The mean abundance of crabs was presented in Table 4. The mean abundance value of crabs in protected mangrove areas was significantly higher than the value obtained in reforested sites (F=21.210, P<0.05). The sex-ratio was significantly deviated from 1:1 expected male and female ratio of crabs (protected: χ^2= 67.64, P<0.05) (reforested: χ^2= 40.04, P<0.05) (Table 4). Almost all males of crabs collected in the area outnumbered the females except for *Labuanium politum* and *P. indiarum* in reforested mangroves.

Crab density sampled from the reforested and protected mangrove forests clustered into two distinct

Table 4: Species abundance and sex-ration of mangrove crabs in protected and reforested mangroves

Species	Protected mangroves				Reforested mangroves			
	Mean±SE	M	F	Sex Ratio	Mean±SE	M	F	Sex Ratio
Baptozius vinosus	*0.67±1.37	5	1	5:1	6.78±1.53	44	17	2.6:1
Chasmagnathus sp.	0.44±0.34	2	0					
Chiromantes eumolpe	0.11±0.11	1	0					
Labuanium politum	0.22±0.22	1	1	1:1				
Metopograpsus latifrons	0.89±0.51	8	0					
Neoepisesarma lafondi	0.78±0.32	7	0					
Perisesarma indiarum	22.78±3.49	126	79	1.6:1	0.89±0.35	4	4	1:1
Sarmatium crassum	2.22±0.60	8	12	0.7:1				
Scylla olivacea	1.22±0.3.2	8	3	2.7:1	0.67±0.24	4	2	2:1
Scylla serrata	0.11±0.11	0	1		0.11±0.11	0	1	
Scylla tranquebarica	0.44±0.11	4	0					
Uca sp.	0.33±0.24	3	0		0.33±0.33	3	0	

*The values are expressed as mean ± standard errors (SE)

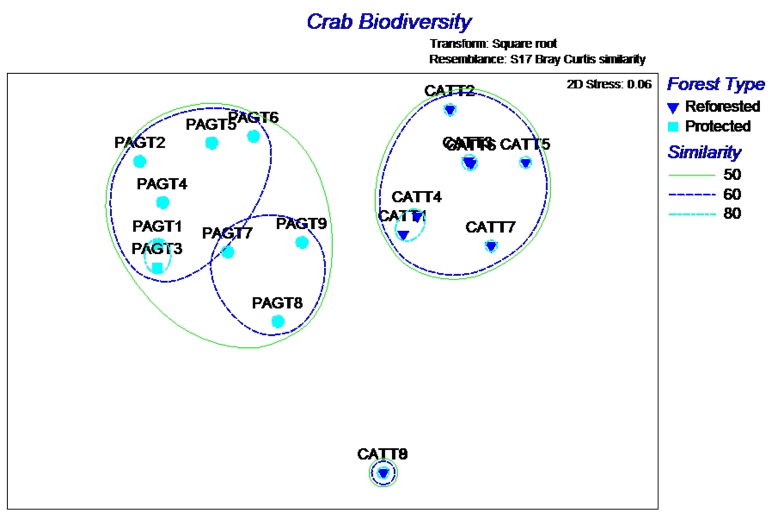

Fig. 4: NMDS plots of crab densities sampled from reforested and protected mangrove forests. Sites clustered into two groups at the 50% similarity level and three groups at the 60% level

groups at the 50% similarity level and three distinct groups at the 60% similarity level at a stress value of 0.06 (Fig. 4). This low stress value indicates that the patterns observed correspond to a robust ordination with minimal chance of biased interpretation (Clarke, 1993). Crab community structure significantly differed between the two sites (ANOSIM, $R = 0.7$, $p < 0.001$), which SIMPER analyses revealed were due to significantly higher densities of *P. indiarum* in the protected sites (22.78 ± 0.60 no/m^2) than the reforested sites (0.89 ± 0.35 no/m^2). *P. indiarum* contributed to nearly 40% of dissimilarity between these two sites. *S. crassum* also had higher densities in the reference site and contributed to 10% of dissimilarity. *B. vinosus* had higher densities in the reference sites and contributed to 20% of dissimilarity. The combination of four soil variables (pH, K, silt, clay) and one diversity measure (tree evenness) provided the best correlation with crab community structure, which was significant (BIOENV, $R = 0.7$, $p < 0.01$).

Class distribution on the carapace width of the mangrove crabs varied between species. Generally, the carapace width of the crab species ranged from 12 mm (*P. indiarum*) to 168.83 mm (*S. serrata*). For population comparison, size of CW of *B. vinosus* ranges from 27 mm -173 mm. Most of the collected individuals were bigger in protected area than in reforested mangroves indicating of their maturity. For *P. indiarum* in protected mangroves ranged from 12.97–74.96 mm compared to reforested mangroves with CW range of 19–40.09 mm (Fig. 5). A closer examination of the data showed that composition of the smaller crabs caught in protected mangroves indicates that most of the of *P. indiarum* were not fully mature as large proportion of the species had 12–19 mm CW. In contrast, most of the collected *P. indiarum* in reforested sites were already mature with 36–43 mm CW (Fig. 6). For *Scylla* species, most of the collected species in protected mangroves fall under the size class 48-64 mm CW indicating pre-maturity; however, there were few matured individuals with 116-132 mm collected in the reforested area (Fig. 7).

Canonical correspondence analysis

Canonical correspondence analysis (CCA) was used to evaluate the variability of crab density in relation to the environmental factors. Based on the CCA, Eigenvalue produced in Axis 1 was 0.41 explaining 61.94% variability while Axis 2 had an Eigen value of 0.09 with 15.12% variability. CCA confirmed statistically highly significant difference ($P<0.0034$) between crab species in protected and reforested mangroves using the Monte Carlo permutation test. Soil pH, K and % silt represent the most important variable gradients related to crab assemblages (Table 5). These environmental factors also influence the distribution of mangroves species (Fig. 8). Higher percentage of clay and silt favors the growth of *R. mucronata* (Rmuc) while high percentage of sand offers niche for *R. stylosa* to grow abundantly.

The results of the study suggest that environmental factors (e.g. soil type) and management scheme (protected vs reforested mangroves) strongly affect the community structure of crabs within the mangrove. The abundance of crabs between the two mangrove conditions was quantitatively correlated to the environmental factors. Soil texture found to influence the abundance of crabs between the study sites. The higher percentage of sand (67%) brought by the tidal

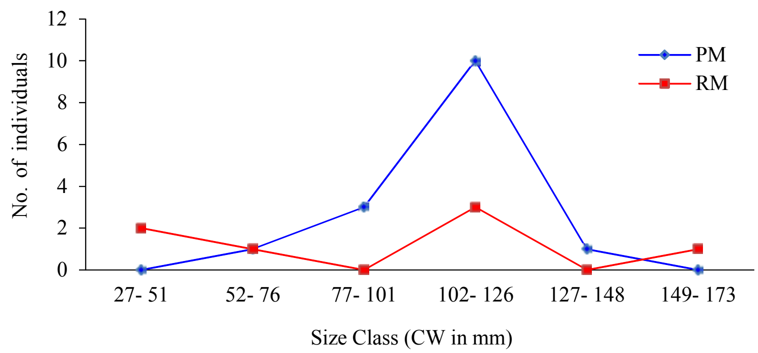

Fig. 5. Size class distribution of *B. vinosus* in protected mangrove (PM) and reforested mangroves (RM)

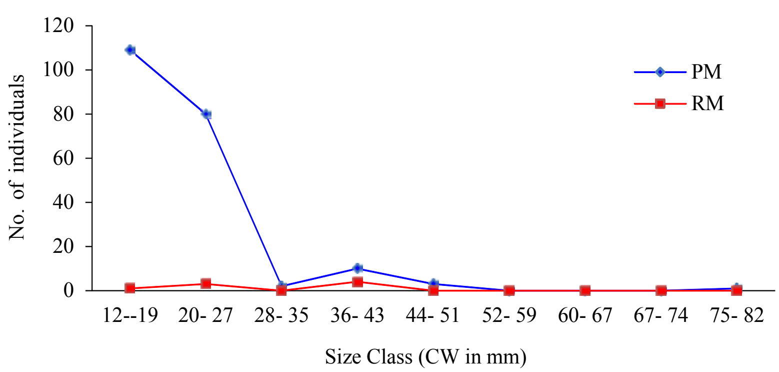

Fig. 6. Size class distribution of *P. indiarum* in protected mangrove (PM) and reforested mangroves (RM)

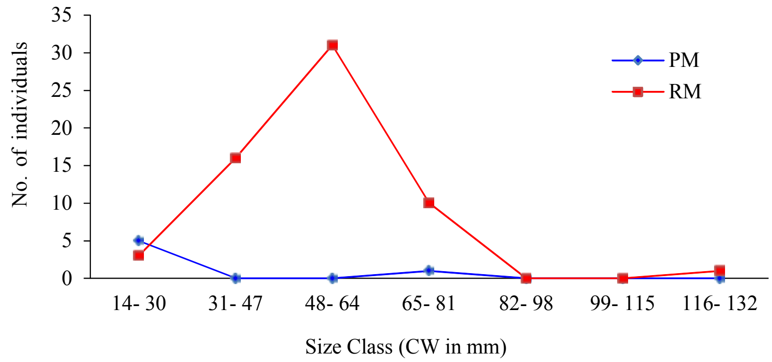

Fig. 7. Size class distribution of *Scylla* spp. in protected mangrove (PM) and reforested mangroves (RM)

Table 5. Inter-set correlations of significant ($P < 0.05$) environmental factors and mangrove vegetation with the first three ordination axes of the CCA

	Axis 1	Axis 2	Axis 3
pH	0.8823	0.0767	0.1214
OM (%)	0.5278	-0.0388	0.1419
N (%)	0.5032	0.0508	0.0486
P (ppm)	0.6128	0.0650	0.0072
K (me/100g)	-0.8556	-0.1095	0.0310
Sand (%)	0.7514	-0.4477	0.2995
Silt (%)	-0.8602	0.0528	-0.3470
clay	-0.6294	0.2551	0.1304
Avicennia officinalis (Aoff)	-0.5191	0.3177	-0.4986
Ceripos tagal (Ctag)	0.6049	1.0215	0.1736
Rhizophora apiculata (Rapi)	0.2800	0.31369	-0.1462
Rhizophora mucronata (Rmuc)	-1.1029	-1.8256	-1.3482
Rhizohpra stylosa (Rsty)	2.0987	-1.1375	0.9766
Xylocarpus granatum (Xgra)	-0.7786	-0.8318	1.2457

action and turbulence results to the higher abundance of *B. vinosus* (mean abundance of 6.78) as well as the *R. stylosa* in reforested sites. In contrast to this, the silt and clay in protected mangroves from the slow rate of inundation and low gradient (Satheeshkumar and Khan, 2009) provide favorable condition to *P. indiarum* and *R. mucronata* to thrive. Albeit of the little data available on the abundance of *P. indiarum*, its lower abundance in reforested mangroves concludes that soil texture plays a major role in the distribution and abundance of these crabs. The observed lower abundance of crab species in the reforested habitats especially in transects laid along seaward zone, exposed to waves, indicates their preference for more sheltered and inner forest areas. Macnae (1968) noted that a number of genera of crabs seek sheltered area in mangrove ecosystems for permanent burrows and for their protection.

Abundance of crabs within the mangrove ecosystems are well linked to the environmental parameters. The level of amount and the availability of OMC and other nutrients in protected and reforested mangroves are depicted by a combination of physical and biological factors (Kristensen *et al.,* 1998). The lower OMC recorded in the protected mangroves compared to reforested mangroves are depicted by the rapid uptake of nutrients by mangroves due to the abundance of crab burrows and deep structures that greatly enhance the surface area of the sediment-air or sediment water interface where exchange of CO^2 can take place, thus promotes decomposition process (Kristensen *et al.,* 1991; Thongtham and Kristensen, 2005).

The abundance of crabs is further influenced by the life cycle of crab species. The lower abundance of *Scylla* species recorded in two areas is attributed to spawning and migration cycle. Most of the female Scylla species migrates offshore on November to February during their spawning stage (Diele *et al.,* 2005) which is in accord with the sampling month of the study. In addition to the natural process, local community claimed that overharvesting for aquaculture and the cutting of mangrove trees causes the decline of crabs in the area. These claims are parallel to the study of Walton *et al.*, (2006), revealing that overharvesting of the species from juveniles for aquaculture and adult mud crabs for market impede the growth of juveniles to become adult, likewise it prohibits the adult mud crabs to reproduce, and thus cause decline of the abundance of this species.

The migration and spawning cycle influences also the sex-ratio composition recorded in the area. Generally, the result of the study found that the sex-ratio deviates to more males than females. This deviation can be exemplified to its spawning and migration. For population comparison, the reproductive period of female *P. indiarum* would migrate from mangrove interior to water edge increasing their relative frequency and proportion, especially during wet season (Christy and Morgan, 1998). Further, the study is also consistent with a study conducted by Lee and Kwok (2002) on *Perisesarma bidens* de Haan and *Parasesarma affinis* revealing more males and females

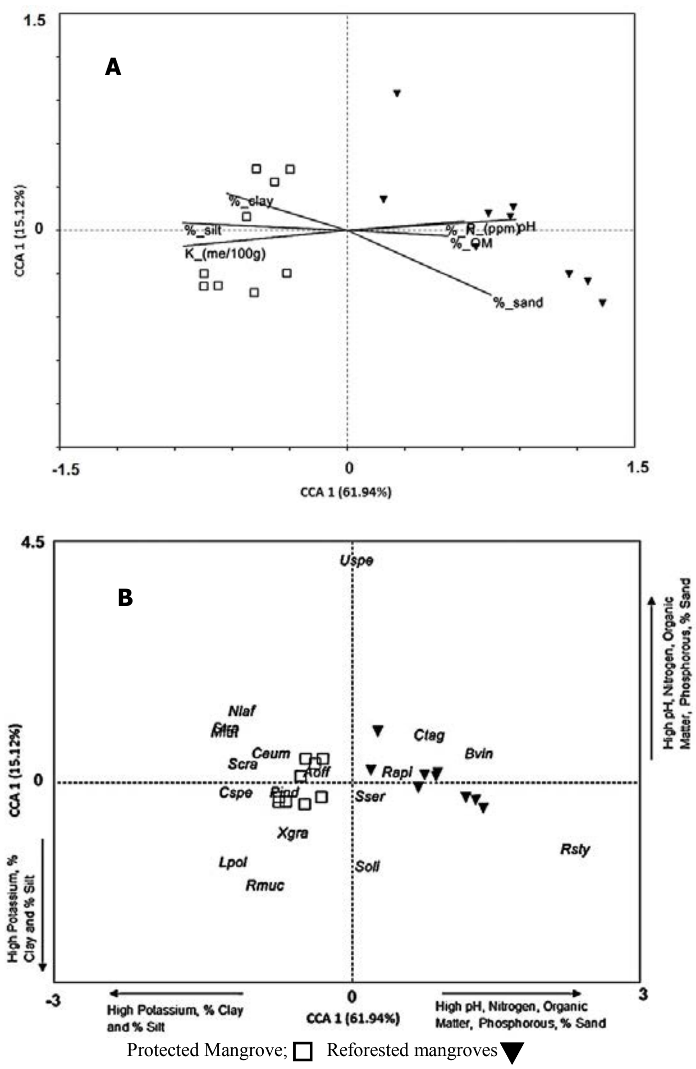

Fig. 8: Biplot illustrating the environmental factors prevailing in the protected mangroves and reforested mangroves (A) and the relative position of each site and the crab species and the mangrove species composition (B)

in the inner side during wet season due to their migration towards river systems. Similar to *P. indiarum*, lower number of *Scylla* species during the sampling was mainly caused by migration of female species towards offshore to extrude eggs. A similar study conducted by Hill (1975) cited by Fondo *et al.* (2010) found out that mature females of *Scylla* species were absent during December to February due to the environmental requirements of the first zoea stage forcing them to migrate offshore.

In addition to this, the migration and spawning activities of crabs influences the size structure. Mud crabs of different sizes inhabit different niches within mangrove forests and the adjacent subtidal zone (Walton *et al.,* 2006). Large crabs, especially female crabs, occupy intertidal zone for spawning where zoea and megalopa stage settled in the seagrass as nursery ground for a period of time. And this is the reason why there are no juveniles observed in the area. They were however, captured periodically in other inshore and offshore fisheries (Moser *et al.,* 2005).

In summary, there are strong potential patterns in distribution among crab density in this study. However, the large numbers of interactions among factors indicate that crab species occurrence and abundance are influenced by the location of the plots, sediment characteristics, vegetation, habitat conditions, and the collection/time of sampling during the conduct of the study. Many of the reforested area in the Philippines are homogenous. Although reforested mangroves are not fully recovered, the abundance of certain species revealed that crabs may occupy specific niche relative to their environmental requirements. Therefore, in many management efforts implementing by government agencies, one may consider planting heterogeneous species to enhance the ecosystems process.

CONCLUSION

This research demonstrates and concluded that the mangrove habitat conditions and key components strongly influence the composition and density of crab species within the mangrove ecosystems. Diverse mangrove stands offers a wider niche than monocultures resulting to an increased total resource use. This in turn may provide a variety of trophic pathways likely to support richer faunal communities. The reforested mangrove has not been restored to a mature condition, but replanting has brought the ecosystem back into use, though not to the extent of the mature mangrove. Relatively few mangrove species have been used in restoration projects mostly *Rhizophora* species (Field ,1996). However, knowledge of the physical setting and management efforts to restore biodiversity in mangrove ecosystem must underpin proper reforestation schemes. Multivariate techniques used to analyze the ecology of mangrove ecosystems vis-à-vis mangrove-crab-environment relationship provide detailed scientific evidence on factors affecting the abundance of the organisms within the ecosystem. The result showed that the major factor affecting the crab abundance in the area is soil texture and tidal inundation of the study area. The management strategies might have influenced the abundance of crabs' i.e. clustered planting. This survey serves as the baseline information for proper management of crabs. The data generated can be used in monitoring for proper management of mangrove resources. A more detailed research on the diet of these mangrove crabs are therefore recommended to determine whether crabs are more dependent on mangroves as source of foods.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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