OCEAN LIFE
Volume 4, Number 2, December 2020
Pages: 51-62
E-ISSN: 2580-4529
DOI: 10.13057/oceanlife/o040201

Physicochemical factors influencing zonation patterns, niche width and tolerances of dominant mangroves in southern Oriental Mindoro, Philippines

AARON FROILAN M. RAGANAS[1,♥], DAMASA B. MAGCALE-MACANDOG[2]
[1]Department of Biological Sciences and Environmental Studies, College of Arts and Sciences, University of the Philippines Mindanao, Mintal, Davao City 8022, Philippines. Tel.: +63-82-293-0302, Fax.: +63-82-293-0312, ♥email: amraganas@up.edu.ph
[2]Institute of Biological Sciences, College of Arts and Sciences/School of Environmental Science and Management, University of the Philippines Los Banos, College 4031, Laguna, Philippines

Manuscript received: 9 June 2020. Revision accepted: 29 August 2020.

Abstract. *Raganas AFM, Magcale-Macandog DBM. 2020. Physicochemical factors influencing zonation patterns, niche width, and tolerances of dominant mangroves in southern Oriental Mindoro, Philippines. Ocean Life 4: 51-62.* Physicochemical factors are known for having strong influence on the spatial patterns and structural complexity of mangroves. In this regard, we aimed to contribute to filling up this information gap in the six mangrove ecosystems on the southern coast of Oriental Mindoro, Philippines. In each of the six mangrove ecosystems, the dominant mangrove species were identified in four mangrove ecotypes - seaward, riverine, middle, and landward - using a stratified random sampling method for vegetation survey. Physicochemical parameters of water, air and soil were also obtained from these ecozones. Results of the Principal Component Analysis revealed that temperature and water salinity are the factors that show strong influence on the spatial distribution of the dominant mangrove species. Canonical Correspondence Analysis revealed that *Avicennia marina*, *Sonneratia alba* and *Rhizophora apiculata*, are species associated with a highly saline environment, while *Xylocarpus granatum, Ceriops decandra, Avicennia rumphiana,* and *Rhizophora mucronata* are species associated with low to optimum saline environment. Most of these dominant species preferred ecotypes with low to optimum salinity levels as revealed by their individual niche width and tolerances. The different adaptations and dominance of these mangrove species provide insights in the identification of appropriate species that could be used as planting materials for the rehabilitation endeavours of the respective mangrove ecosystem.

Keywords: Dominant mangrove species, ecotypes, physicochemical factors, stratified random sampling, zonation patterns

Abbreviations: CA: Correspondence Analysis, CCA: Canonical Correspondence Analysis, CI-III: Dendrogram clusters, cm: centimeter, DO: Dissolved Oxygen, lux: amount of illumination, LZ: Landward Zone, MZ: Middle Zone, PAST: Paleontological Statistics, PCA: Principal Component Analysis, pH: degree of acidity and basicity of soil and water, ppm: parts per million, psu: practical salinity unit, RH: Relative humidity, RZ: Riverine Zone, SA: Marine water category classified as “protected marine waters”, SZ: Seaward zone

INTRODUCTION

In many environmental settings, the physicochemical factors are among the most important parameters that regulate the structural characteristics of a plant community. In the mangrove environment, physicochemical factors have a great influence on the structural development and productivity of the ecosystem (Das et al. 2019). The physiological tolerance of different mangrove species to waterlogging, salinity, sulfides, nutrients, sedimentation, soil texture, nutrients, and redox potential have been linked with their structural and distribution patterns (Cardona and Botero 1998; Sherman et al. 1998; Das et al. 2019). The development of each mangrove species is influenced by the physicochemical characteristics of soil, which may compromise their growth and structure (Perera et al. 2013; Harahap et al. 2015; Bomfim et al. 2018). Perhaps, the soils and mangrove vegetation have a strong interaction with each other, resulting in the formation process of both the soil and the characteristic of the growing mangrove plants (Bomfim et al. 2018).

Among the aforementioned physicochemical factors, salinity is considered as the limiting factor that has a critical role in the establishment and productivity of mangroves, aside from the influence inflicted by human and other biotic factors (Ball 2002; Feller et al. 2010; Kodikara et al. 2018). The variations in the salinity of water and the corresponding ability of different mangrove species to adapt in saline conditions have significant contribution to their growth and distribution patterns (Bomfim et al. 2018). Mangroves growing in habitats with lower salinity are likely to grow more rapidly than those living in the highly saline habitat (Perera et al. 2013). The differences in the mangrove environment conditions can result in the dominance of a particular species leading to their habitat differentiation.

Water quality is also among the parameters that provide basic scientific information in understanding the physical and chemical influences in the mangrove environment (Mariappan et al. 2016). The patterns of tidal inundation in different local settings influence the mangrove soil characteristics controlling species zonation in the mangrove ecosystem (Joshi and Ghose 2003; Chandarasekara and Dissanayake 2014; Bomfim et al. 2018). The increase in temperature due to climate change can also cause stress to mangrove seedlings (Lovelock et al. 2009; Gillis et al. 2019). Hence, mangrove forests depend on seedling survival for expansion and maintenance (Gillis et al. 2019). With these, it is apparent that the distribution of mangrove species is governed by the complexity of the mangrove environment conditions (Joshi and Ghose 2003; Van Tang et al. 2020).

In the Philippines, the study of physicochemical factors and its influence on mangrove distribution patterns is scarce. At present, such study has not yet been conducted in Oriental Mindoro province. From this perspective, the present study was carried out to investigate the ecology and spatial aspects of various dominant mangrove species in six mangrove areas in southern Oriental Mindoro, Philippines. Specifically, this study aimed to determine the physicochemical factors that may influence the mangrove zonation patterns, as well as their individual niche width and salinity tolerances. Knowledge from this study will be useful in guiding the local environment sectors in understanding the mangrove ecosystem complexity in the province. This will fill the information gap regarding physicochemical influences on the spatial distribution patterns of the dominant mangroves on the southern coast of Oriental Mindoro, Philippines.

MATERIALS AND METHODS

Study sites

The study sites are located at the southern district of Oriental Mindoro (Figure 1), consisting of six mangrove areas in the municipalities of Gloria, Bansud, Bongabong, Roxas, Mansalay and Bulalacao (from 12° 53'N and 121° 29'E to 12° 19'N and 121° 21'E). The coastal bays in these municipalities are commonly used for recreational activities such as bathing, swimming and diving. A number of marine reserves and protected areas are also located on the coast of these municipalities. According to the Department of Environment and Natural Resources Administrative Order 2016-08 (DENR-AO 2016-08) water classification standard, two of the coastal bays in the province are formally classified as Class SA. One of which is the Bulalacao bay, which happened to be one of the sampling sites. This water classification category is considered protected marine waters designated for national or local marine parks. The other coastal areas are classified as fishery water class I which are suitable for shellfish harvesting for direct human consumption (SOCOM 2015).

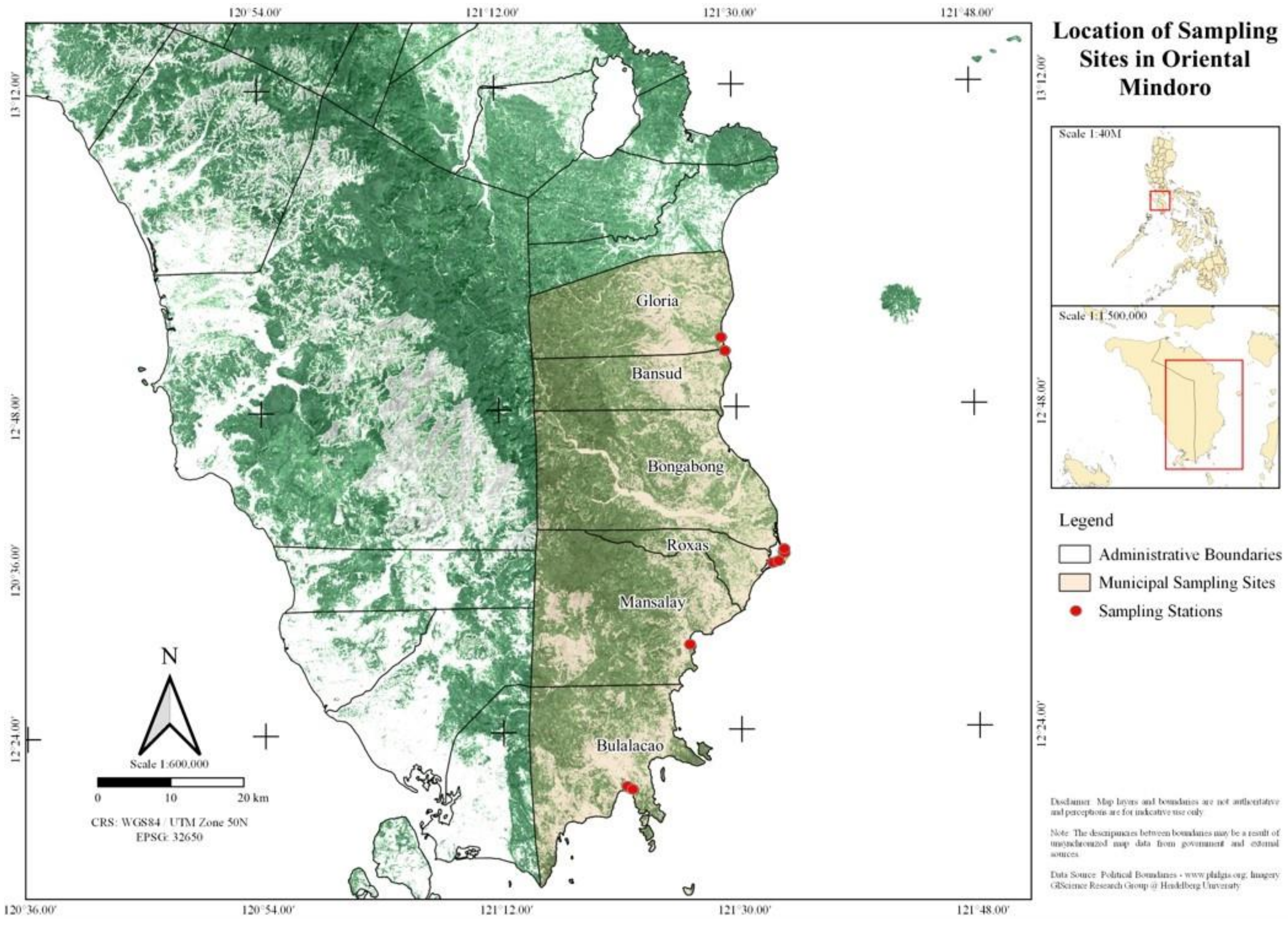


Figure 1. Location of sampling sites in the southern Oriental Mindoro, Philippines. Map generated using QGIS v. 3.3.10.

In terms of climate, the study areas have two climatic types: the type 1 climate (from western Mansalay to Bulalacao), with pronounced seasons, dry from November to April and wet during the rest of the year; and Type 3 climate (from Gloria to eastern part of Mansalay), with seasons, not very pronounced, relatively dry from November to April, and wet during the rest of the year (SOCOM 2015). However, the whole province is under climate type 3 according to Basconcillo et al. (2016), with short dry season from December to February and wet season the rest of the months. The average annual rainfall in the province is 2,285 mm with a mean of 177 mm during rainy days. The minimum amount of rainfall is 65 mm which happens in February, while the maximum is 325 mm which happens in October. Average annual temperatures are at a maximum of 33.4°C recorded in October, while the minimum is 19.2°C in December (SOCOM 2015).

The study sites were selected based on the zonal ecotypes observed in the mangrove ecosystem such as seaward, middle, landward, and riverine zones. The classification was based on the following features: seaward zone- situated at the intertidal zone where mangroves are daily submerged to seawater; middle zone- situated at the transition zone between the seaward and the landward zones, where a combination of species from both zones was observed. Landward- is the zone situated inland from the boundary of the middle zone, and riverine zone situated along the river banks.

Sampling procedures

A stratified random sampling method was employed to determine the dominant mangrove species across ecotypes-seaward, middle, landward, and riverine zones of each mangrove ecosystem. Five plots were established at each zone, in parallel or perpendicular with one another depending on the size and geomorphology of the mangrove stand. Each plot measuring 10 x 10 m^2 was laid within a 100-meter transect line with 20-meter intervals using Gareth's (1991) method. All the mangrove species found dominant in each ecotype were noted and identified up to species level using the field guide to Philippine mangroves by Primavera (2004) and with the help of the local field guides. The dominant mangrove species was identified through a vegetation survey, considering the species with highest importance value (Raganas et al. 2019, unpublished data). The identification of these dominant mangrove species was done to determine their distribution and zonation patterns across ecotypes in all mangrove areas. The result of this analysis was presented through a cluster dendrogram using the Jaccard similarity index (presence/absence data).

Physicochemical parameters

The physicochemical parameter data were taken from the five sampling plots established in each mangrove ecotype. A Geographic Positioning System (GPS) navigation device was used to obtain coordinates from all sampling plots. YSI Multi-parameter Professional Pro equipment was used to collect water quality data such as water pH, water temperature, dissolved oxygen, and water conductivity. Soil and air temperatures were obtained using a conventional thermometer, while sling psychrometer for relative humidity. Soil pH meter was used to determine the acidity and basicity of the mangrove soil. Sediment depths were measured through an improvised bamboo stick and then measured using a tape measure (cm). Light meter was used to obtain the light intensity in the mangrove forest's open and shaded canopies. All these physicochemical measurements were obtained three (3) times a day per ecotype; in the morning (7:00-9:00), noon (11:00-12:00), and afternoon (3:00-4:00) for two consecutive days. Data were collected from the third week of October to end of November in 2018. The readings from all the measurements were then computed to get the average. A total of 11 physicochemical parameters were considered in the study.

Statistical analyses

Parametric One-Sample t-Test was performed to test significant differences among the average values of physicochemical parameters obtained from all study sites. This parametric test was used after the data were log-transformed and obtained a normalized dataset. Various multivariate statistical tools were also performed such as the Principal Component Analysis (PCA), Canonical Correspondence Analysis (CCA), and Correspondence Analysis (CA) in the analyses of data. Principal Component Analysis was used to identify variables of the dataset with maximum variances. It gives information on variables in the data set with high importance and removes variables that were redundant or less important. It is an ordination diagram that consists of points and lines (vectors) that represents the dependent and independent variables. The 11 physicochemical components chosen in the study were used for this analysis to determine their influence on the six mangrove ecosystems. These variables were grouped into two categories: the non-water components including air and soil temperatures, soil pH, relative humidity, light intensity (open and shade), and sediment depths (cm); and the water quality components which include water salinity, water pH, water temperature and dissolved oxygen. The water salinity value (psu) was derived from the water conductivity data to determine the total concentration of salts suspended in the sea and riverine waters. These components were analyzed in the Paleontological Statistics (PAST) package software version 4.02 (Hammer et al. 2001) using correlation matrix (normalized variance-covariance) since variables are of different units. The eigenvalues of each environmental component were compared to the significant Jacliffe cut-off score of 0.7. Components with eigenvalues higher than the cut-off value were considered significant, while components with eigenvalues below the cut-off score were considered insignificant and were excluded in the final analysis.

On the other hand, CCA is also an ordination method used to determine the association between dominant mangrove species and physicochemical components. The significant physicochemical components determined from the PCA and the abundance data of dominant mangrove species were used to generate the model for CCA analysis.

The model explains the relationship between the dominant mangrove species and the highly important physicochemical components determined by the PCA. The model presented includes points that represent the species and vectors (lines) that represent the highly influential physicochemical components. The axes with the highest accounted variances were used as they best represent the data in the model. Meanwhile, the niche width and tolerances of the dominant mangrove species were determined using Correspondence Analysis (CA). This analysis was used to determine the habitat preference and tolerances of the dominant mangrove species with respect to salinity. All the results from both CCA and CA were also generated using PAST software version 4.02 and presented through bi-plots.

RESULTS AND DISCUSSION

Mangrove species dominance across ecotypes in the study sites

Seven mangrove species were found dominant across ecotypes in the six mangrove areas. The dominant mangrove species include *Avicennia marina* (Forssk.) Vierh., *Avicennia rumphiana* Hallier f., *Ceriops decandra* (Griff.) W.Theob., *Rhizophora apiculata* Blume, *Rhizophora mucronata* Lam., *Sonneratia alba* Sm. and *Xylocarpus granatum* J.Koenig (Figure 2). The seaward zone in the mangrove stands of Gloria, Bansud and Bongabong were not considered due to the absence of mangroves in the zone. Dendrogram revealed that four of the dominant mangrove species namely *A. marina*, *A. rumphiana*, *R. apiculata* and *R. mucronata* have the ability to dominate in most or all of the ecotypes. Meanwhile, *C. decanda* and *X. granatum* can dominate the inland ecotypes (middle and landward zones), while species *S. alba* dominates in the riverine zone only, specifically in the mangrove stand of Bansud. Common dominant species found in most mangrove sites were *A. marina, A. rumphiana,* and *R. apiculata*. Among these mangrove areas, the mangrove stand in Gloria has unique dominant species as depicted in the dendrogram, leading to its separation from the two major clusters (CI and CII). The separation is mainly attributed to species *X. granatum,* which was found co-dominating the *R. mucronata* in the landward zone of the mangrove stand. There were no clear species zonation patterns observed in most of these mangrove areas, because one or two particular species can dominate in most ecotypes or the entire mangrove stand.

Physicochemical factors across mangrove sites

Non-water components

Table 1 presents the physicochemical data obtained from six mangrove areas. Amongst all mangrove areas, Gloria (30.3˚C) had the highest average air temperature, while Mansalay (27.4 ˚C) had the lowest. In terms of ecotypes, the middle zone (31.5˚C) of Bansud had the highest average air temperature while Mansalay also recorded the lowest, particularly in the seaward zone (25.3˚C). A similar trend was observed for the average soil temperature with Gloria had the highest (29.7˚C), particularly in the seaward zone (31.0˚C), while Mansalay (26.8 ˚C) had the lowest, particularly in riverine zone (25.5˚C). The lower air and soil temperatures recorded in Mansalay may be attributed to the rainy weather during data collection.

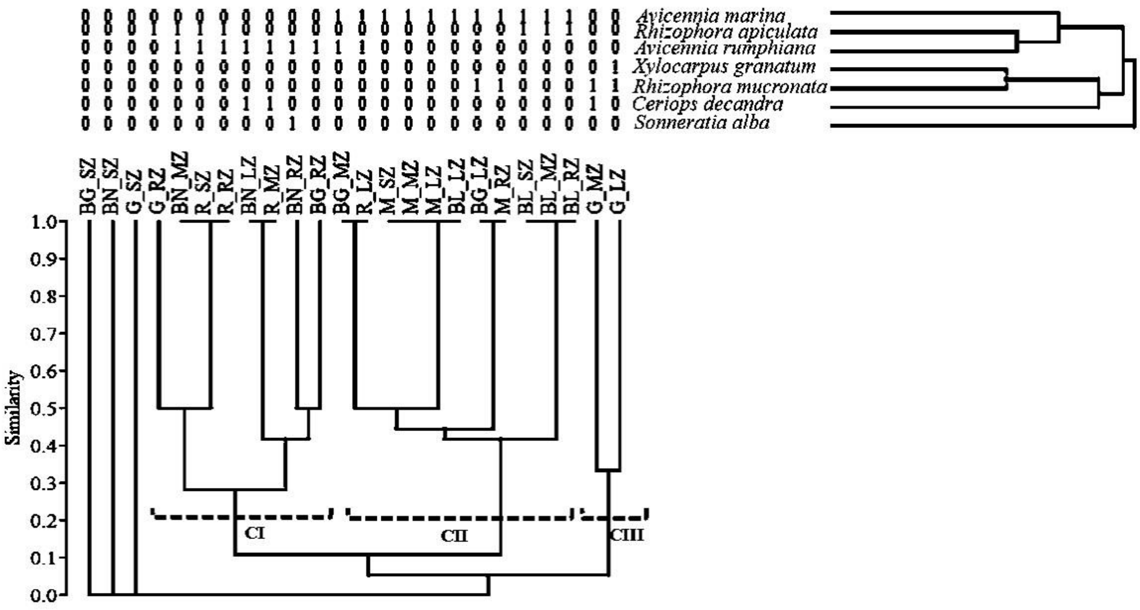


Figure 2. Mangrove species dominance across ecotypes in six mangrove areas using Jaccard similarity index. Site codes: Gloria (G); Bansud (BN); Bongabong (BG); Roxas (R); Mansalay (M); Bulalacao (BL). Ecotypes: Seaward Zone (SZ); Middle Zone (MZ); Landward Zone (LZ); Riverine Zone (RZ). CI-III means clusters. Graph modified from Raganas et al. (2020)

In terms of relative humidity (RH), the mangrove stand in Roxas had the highest average RH with 91.3 %, while Bulalacao had the lowest with 87.5 % only. A huge disparity was observed in the light interception in the open and closed canopies in all mangrove sites. Results show that light intensity in the open area was significantly higher compared with the area under canopy. This is due to the fact that the canopy intercepts the light from reaching the ground. Among the mangrove areas, the highest average light intensity was recorded in Roxas (12430.8 lux), particularly in the landward zone (15414.7 lux), while the lowest was recorded in Mansalay (3713.2 lux) particularly in the middle zone (1330.3 lux)

A similar trend was also observed in the light interception under mangrove canopies in all study sites. Statistical analysis revealed that light intensities in the open canopies across mangrove sites were significantly different with each other, with Mansalay and Bulalacao being significantly lower. This was attributed to the rainy and gloomy weather in the specific time of the day during survey in these mangrove sites. On the other hand, Roxas showed significantly higher light intensity among sites, attributed by the highest intensity obtained from the riverine zone.

With regards to soil pH, results show that most of the mangrove soils were slightly acidic to slightly alkaline. The average soil pH ranges from 6.5 to 7.2, which is a condition favorable for the growth of mangrove plants. The slightly alkaline soil recorded in Bongabong was attributed to the high pH recorded in the seaward zone (9.3). For the average sediment depths of the mangrove soils in all study sites, results show that the mangrove stand in Bulalacao had the highest sediment depth (75.1 cm), while Bongabong showed the lowest (16.3 cm). The highest sediment deposited in Bulalacao, particularly in the seaward zone (103.4 cm) was attributed to the various networks of interconnecting rivers located within the mangrove stand. Sediments from the upland areas were possibly carried out through these river channels during rainy season and deposited in the seaward zone. Meanwhile, the slightly elevated topography of the riverbank in the mangrove stand of Bongabong was assumed to be the result of the lower sediment deposition in the mangrove area. Statistical analysis revealed that the sediments in the mangrove stands of Mansalay and Bulalacao were significantly deeper than the other mangrove stands. Deepest sediment deposition was recorded in the riverine zones of most mangrove sites except in Bulalacao.

Water components

The highest average water salinity across study sites was recorded in Gloria (16.9 psu), while lowest was recorded in Bansud (7.3 psu). In terms of ecotypes, the salinity level between sea and riverine waters across mangrove sites showed some degree of disparities. As observed, sea waters had a higher salinity level compared with the riverine waters. This is due to the fact that sea waters have higher salt concentrations than riverine waters. The seaward zone of Gloria (22.1 psu) recorded the highest salinity level, while Bansud (10.7 psu) recorded the lowest. Among riverine zones, highest salinity was also recorded in Gloria (11.6 psu), while lowest was recorded in Mansalay (2.1 psu).

For the average water temperature across study sites, Bansud (28.9˚C) recorded the highest, while Mansalay (26.1˚C) recorded the lowest. Across ecotypes, the seaward zone in Bansud (29.5 ºC) recorded the highest, while Mansalay (25.6 ºC) recorded the lowest. For the riverine zones, the highest was recorded in Bongabong (28.8 ºC), while the lowest was recorded in Mansalay (26.5 ºC). Results further revealed that the average water temperature in the seaward zones of the mangrove stands in Gloria, Bansud and Roxas were a bit higher compared with the riverine zones. This is in contrast with the results recorded from the mangrove stands in Bongabong, Mansalay and Bulalacao, where riverine zones have higher average water temperature. The high water temperature recorded in the riverine zones of the latter mangrove areas was attributed to the sunny weather condition during the data gathering.

In terms of water pH, the seaward and riverine zones across mangrove sites show little variation only. As observed, the water pH in the seaward zones was higher compared with the riverine zones. But highest water pH was recorded in Bongabong (8.3), while lowest was recorded in Mansalay (7.8). Among the seaward zones, both Bongabong and Roxas recorded the highest water pH (8.6), while Mansalay (8.2) recorded the lowest. For the riverine zones, the highest pH was recorded in Bansud (8.0) while the lowest was recorded in Mansalay and Bulalacao (7.4). Moreover, both zones have alkaline water with values above neutral (pH>7). The high pH level in the seaward zone was also attributed to the higher salt concentrations in the seawater.

For the dissolved oxygen (DO) present in water, results show that riverine waters had higher presence of DO than the sea waters. Across sites, highest DO was recorded in Gloria (6.0 ppm), while lowest was recorded in Bulalacao (4.3 ppm). Among the seaward zones, Bansud recorded the highest DO (5.7 ppm), while Bulalacao recorded the lowest (3.9 ppm). Among the riverine zones, the highest DO was recorded in Gloria (7.4 ppm), while lowest was recorded in Bulalacao (4.6 ppm) as well. The average DO present in the sea and riverine waters across mangrove sites are favorable for maintaining aquatic life which is above 4 ppm, except in the seaward zone of Bulalacao which is quite below the threshold.

All the variations in the physicochemical data across study sites were influenced by the specific conditions during the time of survey, zonation and location. Rainy and gloomy weathers were experienced in other study sites especially in Mansalay and Bulalacao, hence, under climate type 3 (Basconcillo et al. 2016) with rainy season during sampling months.

Physicochemical influences across ecotypes

Principal component analysis revealed six out of 11 physicochemical parameters showed significant influence on the distribution and dominance of various mangrove species in different ecotypes across mangrove sites. Of the 11 physicochemical parameters tested, four non-water and two water components were found significant (Tables 2 and 3). The non-water components (Table 2) with eigenvalues greater than Jacliffe cut-off score (0.7) are air and soil temperatures, relative humidity, and light intensity (open space) with eigenvalues of 2.81, 1.26, 1.10, and 1.03; and accounted variances of 40.17%, 17.95%, 15.67%, and 14.77%, respectively. For water components (Table 3), PCA shows that water temperature and salinity had significant influence as indicated by their eigenvalues of 2.08, 1.20, with accounted variances of 51.88% and 29.98%, respectively. The results were also presented in scree plots (Figure 3) showing the downward curve of eigenvalues (largest to smallest) contributed by the 11 physicochemical parameters tested for the analysis.

Ordination diagram (Figure 4) depicts grouping of mangrove ecotypes as influenced by the six highly correlated physicochemical components. The distribution of ecotypes is greatly influenced by temperature and salinity. Upper axes are ecotypes with higher salinity level and more open areas as indicated by the increasing light intensity, water, soil and air temperatures. These ecotypes are the seaward and riverine environs of the mangrove forests in the study sites. Meanwhile, the lower axes are ecotypes with low salinity levels with relatively cooler temperatures (high relative humidity) represented by the middle and landward zones of the mangrove forests. These ecotypes are not regularly inundated by seawater, hence situated inland and somehow have relatively intact forest canopies.

Table 1. Physicochemical data across ecotypes in six mangrove ecosystems in southern Oriental Mindoro, Philippines

		Non-water components							Water components			
Site	**Ecotype**	**Air temp (˚C)**	**Soil temp (˚C)**	**RH (%)**	**Light open (lux)**	**Light shade (lux)**	**Soil pH**	**Sediment depth (cm)**	**Water salinity (psu)**	**Water temp (˚C)**	**Water pH**	**DO (ppm)**
Gloria	Seaward	29.0[a]	31.0[a]	86[a]	10364[c]	1511[a]	8.4[a]	0	22.1[a]	28.2[a]	8.5[a]	4.6[a]
	Middle	30.5[a]	29.0[a]	93[a]	9472[b]	1223[a]	5.6[a]	12[a]	0	0	0	0
	Landward	30.5[a]	28.5[a]	93[a]	8627.3[a]	1287.3[a]	5.3[a]	14.6[a]	0	0	0	0
	Riverine	31.3[a]	30.2[a]	86[a]	9327.7[b]	1430.7[a]	7.1[a]	66[b]	11.6[a]	27.7[a]	7.6[a]	7.4[a]
	Average	30.3[A]	29.7[A]	89.5[A]	9447.8[D]	1363.0[A]	6.6[A]	23.2[A]	16.9[A]	27.9[A]	8.1[A]	6.0[A]
Bansud	Seaward	29.6[a]	29.3[a]	93[a]	9844.7[c]	2536.7[c]	8.0[a]	0	10.7[a]	29.5[a]	8.3[a]	5.7[a]
	Middle	31.5[a]	28.4[a]	86[a]	9233.7[c]	2295.7[c]	6.5[a]	34[a]	0	0	0	0
	Landward	28.3[a]	28.1[a]	93[a]	8079.3[b]	863[a]	6.8[a]	9[a]	0	0	0	0
	Riverine	29.8[a]	28.7[a]	86[a]	7617.7[a]	1577.7[b]	6.4[a]	90[b]	3.9[a]	28.3[a]	8.0[a]	6.1[a]
	Average	29.8[A]	28.6[A]	89.5[A]	8693.9[C]	1818.3[A]	6.9[A]	33.3[AB]	7.3[A]	28.9[A]	8.2[A]	5.9[A]
Bongabong	Seaward	29.5[a]	28.9[a]	86[a]	10113[c]	1165[a]	9.3[a]	0	16.1[a]	28[a]	8.6[a]	4[a]
	Middle	28.0[a]	28.5[a]	93[a]	9045[b]	1083[a]	6.3[a]	18[a]	0	0	0	0
	Landward	28.0[a]	28.6[a]	93[a]	8036.3[a]	1882.3[a]	6.4[a]	16[a]	0	0	0	0
	Riverine	29.5[a]	27.0[a]	86[a]	10473[c]	1452[a]	6.6[a]	31[a]	3[a]	28.8[a]	7.9[a]	5.3[a]
	Average	28.8[A]	28.3[A]	89.5[A]	9416.8[D]	1395.6[A]	7.2[A]	16.3[A]	9.6[A]	28.4[A]	8.3[A]	4.7[A]
Roxas	Seaward	27.5[a]	27.9[a]	93[a]	10710.3[b]	2905.7[b]	8.0[a]	63[b]	12.6[a]	28.3[a]	8.6[a]	5.5[a]
	Middle	29.3[a]	27.5[a]	93[a]	8468[a]	1541[a]	6.5[a]	13[a]	0	0	0	0
	Landward	30.2[a]	29.7[a]	93[a]	15414.7[c]	2136[b]	5.2[a]	11[a]	0	0	0	0
	Riverine	28.3[a]	28.2[a]	86[a]	15130.3[c]	4145.7[c]	6.3[a]	43[b]	6.3[a]	27.5[a]	7.8[a]	5[a]
	Average	28.8[A]	28.3[A]	91.3[A]	12430.8[E]	2682.1[B]	6.5[A]	32.5[AB]	9.5[A]	27.9[A]	8.1[A]	5.3[A]
Mansalay	Seaward	25.3[a]	25.9[a]	92[a]	4260.3[c]	953.3[b]	7.9[a]	56[b]	20.3[a]	25.6[a]	8.2[a]	4[a]
	Middle	27.9[a]	28.5[a]	93[a]	1330.3[a]	516[a]	6.5[a]	24[a]	0	0	0	0
	Landward	28.3[a]	27.3[a]	86[a]	5900[d]	1644.3[c]	6.7[a]	41[b]	0	0	0	0
	Riverine	28.2[a]	25.5[a]	86[a]	3362.3[b]	933.7[b]	6.6[a]	128[c]	2.1[a]	26.5[a]	7.4[a]	5.3[a]
	Average	27.4[A]	26.8[A]	89.3[A]	3713.2[A]	1011.8[A]	6.9[A]	62.3[B]	11.2[A]	26.1[A]	7.8[A]	4.7[A]
Bulalacao	Seaward	28.5[a]	27.0[a]	86[a]	6985.3[b]	1259.3[b]	7.7[a]	103.4[c]	17[a]	27.9[a]	8.5[a]	3.9[a]
	Middle	25.5[a]	26.0[a]	85[a]	6647[b]	1247.3[b]	6.3[a]	88[bc]	0	0	0	0
	Landward	28.8[a]	27.5[a]	93[a]	3031.3[a]	880.7[a]	6.3[a]	47[a]	0	0	0	0
	Riverine	29.2[a]	27.0[a]	86[a]	6158.7[b]	1187.7[b]	6.5[a]	62[a b]	3[a]	28.3[a]	7.4[a]	4.6[a]
	Average	28.0[A]	26.9[A]	87.5[A]	5705.6[B]	1143.8[A]	6.7[A]	75.1[B]	10[A]	28.1[A]	8.0[A]	4.3[A]

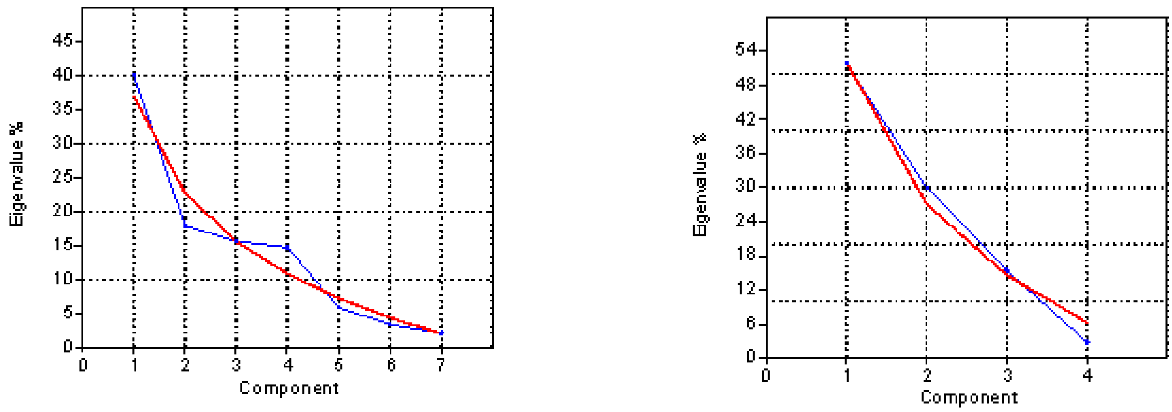
Note: RH (Relative humidity); lux (amount of illumination); cm (centimeter); psu (practical salinity unit); DO (Dissolved Oxygen); ppm (parts per million). Values presented are the average measurements of each physicochemical component. Superscript letters indicate significant differences (p=≤ 0.05) at 95% confidence level, using One Sample t-Test. Uppercase letters indicate comparisons of physicochemical average means across sites, while lowercase letters indicate comparisons across ecotypes per site

Table 2. Eigenvalues and accounted variances of non-water components used in the PCA analysis based on the Jacliffe significant cut-off score of 0.7, at 95% bootstrapped confidence intervals

Principal components	Eigenvalue	% Variance
Air temperature	2.81	40.17
Soil temperature	1.26	17.95
Relative humidity	1.10	15.67
Light intensity (open)	1.03	14.77
Light intensity (shade)	0.41	5.88
Soil pH	0.24	3.41
Sediment depth	0.15	2.16

Table 3. Eigenvalues and accounted variances of water components used in the PCA analysis based on the Jacliffe significant cut-off score of 0.7, at 95% bootstrapped confidence intervals

Principal components	Eigenvalue	% Variance
Water temperature	2.08	51.88
Water salinity	1.20	29.98
Water ph	0.62	15.40
Dissolved oxygen	0.11	2.74



A B

Figure 3. Scree plots of non-water (A) and water (B) components with their eigenvalues (red) and accounted for %variances (blue)

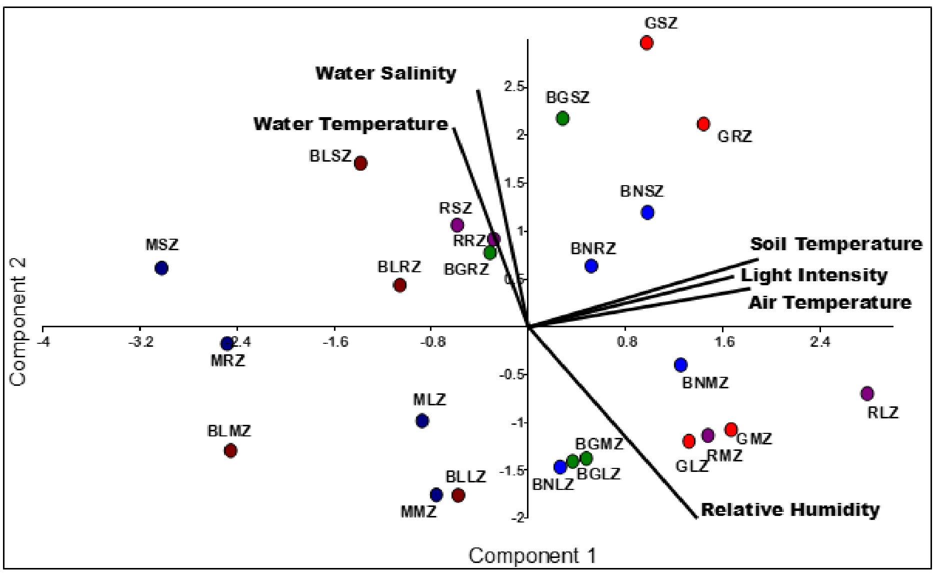


Figure 4. Bi-plot showing the significantly influential physicochemical components across ecotypes in all mangrove sites. Site codes: Gloria (G); Bansud (BN); Bongabong (BG); Roxas (R); Mansalay (M); Bulalacao (BL); Ecotypes: Seaward (SZ); Midzone (MZ); Landward (LZ); Riverine (RZ)

The diagram further shows mangrove areas with presence and absence of mangroves along the seaward zone. Mangrove areas without mangroves along the shore are situated at the right-hand axes, while those having mangroves along the shore are situated at the left-hand axes. Absence of mangroves along the shore was observed in Gloria, Bansud and Bongabong which was also portrayed in the cluster dendrogram (Figure 2).

Association between dominant mangroves and influential physicochemical components

Figure 5 presents the association between the dominant mangrove species and the significantly influential physicochemical components in six mangrove sites. Axes 1 and 2 (Table 4) were used to plot the CCA model since they showed higher accounted variances (52.59%; 31.81%). The diagram depicts the distribution of various dominant mangrove species as influenced by the highly influential physicochemical components determined by the PCA. Upper axes are mangrove ecotypes near the sea as indicated by the increasing salinity level, while lower axes indicate habitats away from the sea. The diagram suggests that dominant mangrove species found closer to the sea are the species *A. marina*, *R. apiculata*, and *S. alba*. These species are considered with high tolerance to salinity, thus, can be found thriving in a highly saline ecotype. The species *A. rumphiana* and *R. mucronata* are found adapted to moderately saline ecotype, while *C. decandra* and *X. granatum* are adapted to ecotypes with lower salinity, such as in the transition zone to the inland parts of the mangrove forest. Diagram further suggests that species *R. mucronata*, *C. decandra* and *X. granatum* are the species found at ecotypes with high relative humidity which indicates association to dense canopy cover. The shrub species *C. decandra* was mostly encountered under the canopies of taller mangrove trees, hence the species association to these ecotypes. Species *A. rumphiana* was associated to zones with high light intensities, air and soil temperatures indicating mangrove areas with open canopies. *Sonneratia alba*, on the other hand, is considered a generalist species situated near the central axis. It means that this species can be associated with any of these conditions of the ecotypes.

Niche width and tolerances of dominant mangroves

Bi-plot (Figure 6) presents the niche width and position of the dominant mangrove species with regards to their tolerance to salinity. Diagram shows that most of the mangrove species preferred habitats away from the sea. Species *A. marina*, *S. alba* and *R. apiculata* most likely preferred waterlogged and highly saline habitats such as in the seaward and riverine zones (right-hand axes). For instance, *A. marina* can extend its niche towards the seaward zone and can tolerate much higher salinity. However, the said species was also found dominant in other ecotypes as observed in the mangrove stands of Bongabong, Mansalay and Bulalacao (Figure 1). Species *S. alba* preferred estuarine habitat, but the species was also observed thriving, ranging from the seaward up to the landward zones in some mangrove areas. A similar pattern was also observed for *R. apiculata* where the species can be found in any ecotypes, but more preferred riverine habitat.

Table 4. Eigenvalues and accounted variances of the dominant mangrove species and significant physicochemical components computed for Canonical Correspondence Analysis

Axis	Eigenvalue	%Variance
1	0.22	52.59
2	0.14	31.81
3	0.05	10.99
4	0.02	4.51
5	0.00041	0.10
6	2.71E-08	6.37E-06

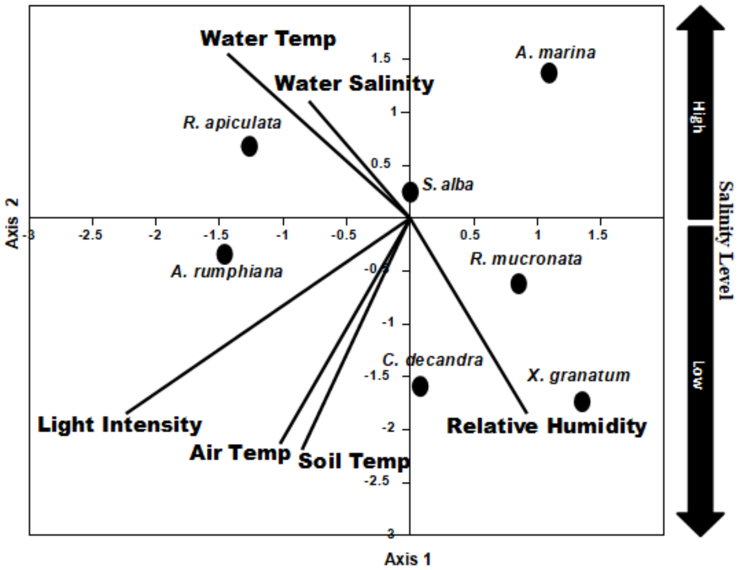


Figure 5. Bi-plot showing the association between dominant mangrove species and significantly influential physicochemical components

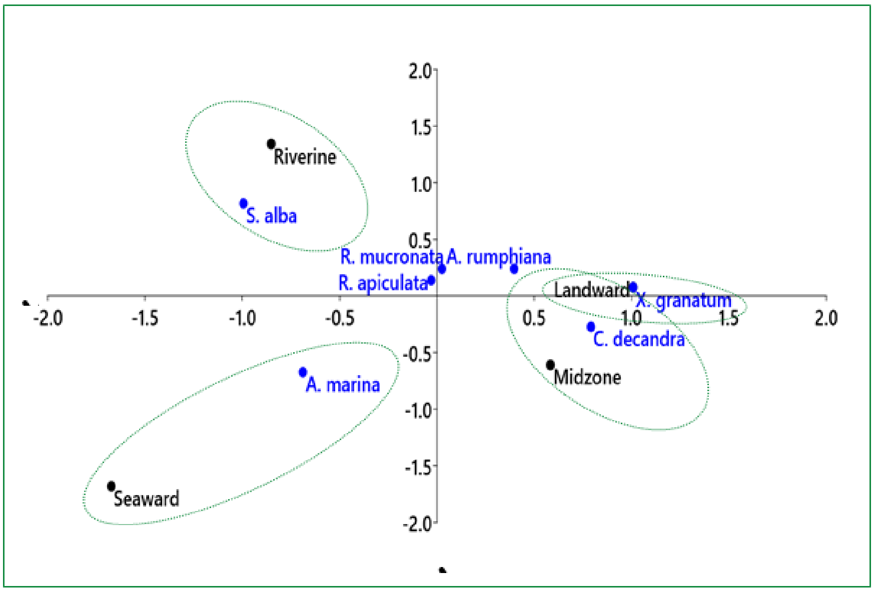


Figure 6. Niche width and tolerances of dominant mangrove species across ecotypes

Meanwhile, species *R. mucronata*, *A. rumphiana*, *C. decandra* and *X. granatum* are the species that preferred inland ecotypes (left-hand axes). Species *X. granatum* preferred landward habitat, hence considered a back mangrove species. *Ceriops decandra* has niche width ranging from middle to landward zones of the mangrove forests. Moreover, species *R. apiculata*, *R. mucronata* and *A. rumphiana* are situated near the central axis which means that these species can be found in all ecotypes. However, the dominance of *R. mucronata* in a particular ecotype was attributed to the rehabilitation activities where the species was used as planting material in most mangrove sites. Generally, these three species, together with *A. marina* can extend their niche from seaward up to the landward zones (see Figure 2), thus considered to be species with wider niche width and salinity tolerances.

Discussion

The average measurements of the physicochemical parameters related to climates such as temperature, relative humidity, and light intensity depending upon on the weather conditions during the data collection. At any site, the air temperature is higher than the soil temperature. The canopy cover may keep the soil temperature cooler than the air above it (von Arx et al. 2012). The higher soil temperature than the air temperature recorded in the seaward zone of Gloria is attributed to the sandy texture of the soil in this zone. Sandy soil has a rougher texture, low water holding capacity, and low moisture content, thus absorbing more heat when the temperature rises, making the soil warm. Perhaps, we presumed that it is one of the reasons for the absence of mangroves along the shore in the mangrove stand. The lowest temperatures recorded in Mansalay are attributed to the rainy weather during the conduct of the study. The slightly acidic to slightly neutral soil pH (6.5 to 7.2) in all mangrove sites are favorable for the growth of dominant mangroves (Mustapha et al. 2016). The salinity level (<25 psu) in all mangrove areas are also favorable for the growth of mangrove seedlings, but the range of tolerance may depend upon on the adaptability of each dominant species (Chen and Ye 2014; Siddique et al. 2017). The higher salinity level recorded in the seaward zones is attributed to the high salt concentration present in sea waters than the riverine waters. Difference in temperature may affect salinity levels which may also have a cascading effect on the pH and DO present in the sea and riverine waters (Wilde 2006). The variations in the physicochemical gradients across ecotypes are also influenced by the characteristics of forest canopy in respective mangrove stand, as well as by the weather condition during the time of survey.

On the other hand, the six significant components identified by the PCA are highly correlated variables. Most of these variables are influenced by the temperature. For instance, light is important for the growth of plants (Hatfield and Prueger 2015). The variation in the amount of light affects the temperature of the surroundings such as the air, water and soil. In particular, too much exposure of soil to light especially in areas with open canopy can result to higher soil temperature. Mangrove soils have the capacity to keep the salinity level high especially when the soil loses moisture due to high temperature (Ward et al. 2016). The spatial distribution of the dominant mangrove species leading to their dominance in a particular zone or the entire zones of the mangrove forest can be linked to the influence of temperature in the surroundings. Some studies reported that temperature is one limiting factor in the mangrove environment (Bomfim et al. 2018; Gillis et al. 2019). High temperature can affect mangroves especially during the establishment of seedlings. It can inhibit the rooting of mangrove seedlings, thereby reducing their ability to stabilize in the soil (Gillis et al, 2019). Perhaps, there is a critical period for mangrove seedlings where they need to develop root structures to establish in soil because waves and water currents can possibly wash them away (Wang et al. 2018; Gillis et al. 2019). Salinity also affects the distribution and productivity of mangrove plants (Chen and Ye 2014). Some studies reported that salinity determines the survival and growth performances of mangrove seedlings and an indicator for their establishment and development (Hoppe-Speer et al. 2011; Chen and Ye 2014; Mariappan et al. 2016). This could be one of the reasons for the zonation and spatial patterns of the dominant mangroves in the study areas. Since high salinity can affect the seedling establishment, this could somehow lead to habitat partitioning among mangrove species, favouring those that are suitable in the condition. Eventually, this could resolute into the displacement of other species leading to their dominance in a particular ecotype. Several studies had already been conducted regarding the growth performances of mangrove species under different salinity regimes. Studies of Hoppe-Speer et al (2011), Mahmood et al (2014a), and ChenandYe (2014) found out that some mangrove species have maximum growth performances in minimum salinity, ranging from 0 to 10 psu. However, an increase in salinity can decrease the biomass growth of the mangrove seedlings (ChenandYe 2014; Mahmood et al. 2014b; Kodikara et al. 2018). It was reported that salinity concentration above 25 psu is lethal to mangrove plants (Chen and Ye 2014; Siddique et al. 2017). Since our results for salinity concentrations are below the 25 psu threshold, therefore, this might be the reason why other dominant species considered with low to medium salt-tolerance can thrive in the seaward zone.

Some mangrove areas have no specific zonation patterns as typically described for various mangrove species. We observed that one or two particular species can dominate a mangrove stand, which was also described by Feller et al (2010). In our findings, species considered with medium salinity tolerance such as *A. rumphiana* and *R. mucronata* can also thrive close or along the seaward zone. However, the dominance of *R. mucronata* in some ecotypes of the mangrove areas was attributed to the rehabilitation activities where the species was used as a planting material. The dominance of *A. rumphiana* along the seaward zone in Roxas might be due to the topography in the zone and the location of the sampling site near the estuarine where seawater and freshwater mixed together favouring the growth of the species. In contrary, species with high tolerance to salinity such as *A. marina* can also dominate inlands in some mangrove areas. The absence of distinct zonation patterns could also be attributed to various factors including species population dynamics, physiological adaptation, and physical conditions of the mangrove stand (Naskar 2004; Feller et al. 2010). These three aspects could be among the reasons for the meager degree of zonation patterns observed in the present study. In terms of the adaptability of dominant mangrove species, our findings support the results from other studies conducted, stating that *S. alba*, *R. apiculata*, and *A. marina* are the species that grow in ecotypes with medium to higher salinities such as in estuarine and seaward zones (Reef and Lovelock 2015). However, these species can also be found dominant in low saline habitats such as in the middle and landward zones of the mangrove stand. This scenario is not already new, since it was also observed across mangrove areas around the world. This explains why species distribution patterns in some mangrove environments are difficult to identify because some show no distinct zonation pattern at all (Bunt 1996; Schmiegelow et al. 2014; Eswaran et al. 2017). According to Schmiegelow et al (2014), even with great competition for the same resources among mangrove species, niche partitioning does not necessarily determine the composition of species in the plant community. Coexistence can possibly happen among mangrove species, hence, facilitation can occur leading to their coexistence over a particular habitat.

In the Philippine setting, the result of the present study somehow agrees with the adaptations of various mangrove species to certain levels of salinity as reported by Primavera et al. in 2008 and 2011. Accordingly, the mangrove species considered with high salinity tolerances are *A. marina*, *S. alba* and *R. apiculata*, hence, portrayed in the CCA and niche tolerance results (Figures 5&6). The dominant mangrove species with low to optimum salinity tolerances are *X. granatum*, *C. decandra*, *A. rumphiana* and *R. mucronata*. The varying ecophysiological adaptations of these mangrove species to different salinity levels somehow imply suitable conditions where they can grow best. However, we cannot deny the fact that zonation patterns in other mangrove ecosystems are difficult to delineate since some species can dominate an entire stand.

The specialized rooting systems, salt-secreting glands and reproductive strategies of various mangrove species are among their adaptive mechanisms towards salinity. The stilt or prop roots, which are common to *Rhizophora* species, are believed to be more adapted to regularly flooded habitats. The specialized respiratory areal roots (pneumatophores) of *Avicennia* and *Sonneratia* are more adapted to highly saline habitat (e. g. seaward). While the knee root system such as in *Ceriops* and buttress root type of *Xylocarpus* are more adapted to inland habitats (Warming 1883; Feller et al. 2010; Srikanth et al. 2015). The salt-exclusion mechanisms of the dominant mangrove species are also their advantage for adapting in highly saline habitat. For example, the ultra-filtration mechanism of *R. apiculata* and *R. mucronata* in their roots enables them to survive in the seaward through selective absorption of ions, maintaining low salinity concentration in their body (Noor et al. 2015). Other species such as *A. marina* and *S. alba* have developed secretory structures on their leaves and roots that could enable them to secrete excess salts (Krishnamurthy et al. 2017). These characteristics confer the survival advantage of these mangrove species in a saline environment. With regards to the mangrove reproductive strategies such as vivipary, cryptovivipary, and vegetative propagation described by Bhosale and Mulik (1991) and Feller et al (2010), viviparous species are said to be more advantageous when growing on the sea borders as their propagules can easily establish after being detached from the mother tree. All these ecological adaptations of dominant mangrove species are essential in understanding their survival advantages under different mangrove environment conditions. This offers clarification on the individual species distribution patterns, which are all influenced by the physicochemical factors prevailing in the mangrove environment. Competition appears when the conditions become limiting, wherein those that are highly adapted to it could out-compete others and become dominant.

Overall, the dominance of mangrove species over a particular ecotype suggests favorable conditions for the species. Temperature and salinity showed strong influence on the spatial distribution patterns of these dominant mangroves in the study areas. Species *A. marina*, *S. alba*, and *R. apliculata* are tolerant to highly saline environment as revealed in the CCA and niche tolerance results. Other mangrove species can also thrive close to the sea, except for *X. granatum* but most of them preferred low to optimum saline habitats (inland and riverine). The dominance of one or two species in most or entire mangrove stand makes it difficult to delineate zonation patterns in these mangrove areas. Moreover, all the multivariate tests applied in the analyses have provided results useful in portraying significant conclusions in this study. Even though, this study utilized only limited environmental parameters in the analyses, but the results are somehow comparable with other similar studies conducted. With this, we recommend further studies especially prolonged observation of the physicochemical factors in these mangrove areas. Since, we only obtained all the data in a very limited period of time. Other physicochemical and biotic factors such as the enigmatic effects of hydrologic systems, soil nutrient contents, soil salinity, soil oxygen conditions, heavy metals, and microorganism complexes should also be considered to fully understand the complexity and dynamics in these mangrove ecosystems. Nevertheless, the dominance of mangrove species in a particular ecotype provide insights as to what species could be used for the future rehabilitation undertakings in these mangrove ecosystems.

ACKNOWLEDGEMENTS

The authors would like to thank the Asia Pacific Network (APN) through the APNIS Project (Plausible alternative futures of island mangroves in the Asia-Pacific: Scenario-based analysis and quantification of mangrove ecosystem services in coastal hazard mitigation and climate change adaptation (CRRP2018-03MY-Hashimoto) for their financial support in the conduct of this study. Due recognition is also expressed to the provincial and municipal agriculture offices of Oriental Mindoro, for their assistance during the conduct of the study. The authors declare that no conflict of interest in the publication of this study.

REFERENCES

Ball MC. 2002. Interactive effects of salinity and irradiance on growth: implications for mangrove forest structure along salinity gradients. Trees-Struct Funct 16: 126-139.

Basconcillo J, Lucero A, Solis A, Sandoval Jr BE, Koizumi T, Kanamaru, H. 2016. Statistically downscaled projected changes in seasonal mean temperature and rainfall in Cagayan Valley, Philippines. J Meteor Soc Japan 2 (94A): 151-164.

Bhosale LJ, Mulik NG. 1991. Endangered mangrove areas of Maharashtra. Proceedings of the Symposium on Significance of Mangroves, Pune, India.

Bomfim MR, Santos JA, Costa OV, et al. 2018. Morphology, physical and chemical characteristics of mangrove soil under riverine and marine influence: A case study on Subaé River Basin, Bahia, Brazil, Mangrove Ecosystem Ecology and Function, Sahadev Sharma, IntechOpen, London, United Kingdom.

Bunt JS. 1996. Mangrove zonation: an examination of data from seventeen riverine estuaries in tropical Australia. Ann Bot 78: 333-341.

Cardona P, Botero L. 1998. Soil characteristics and vegetation structure in a heavily deteriorated mangrove forest in the Caribbean coast of Colombia. Biotropica 30: 24-34.

Chandarasekara W, Dissanayake N. 2014. Effects of mangrove zonation and the physicochemical parameters of soil on the distribution of macrobenthic fauna in Kadolkele mangrove forest, a tropical mangrove forest in Sri Lanka. Adv Ecol 2014: 1-13.

Chen Y, Ye Y. 2014. Effects of salinity and nutrient addition on mangrove *Excoecaria agallocha*. PloS One 9 (4): e93337. DOI: 10.1371/journal.pone.0093337.

Das L, Patel R, Salvi H, Kamboj RD. 2019. Assessment of natural regeneration of mangrove with reference to edaphic factors and water in Southern Gulf of Kachchh, Gujarat, India. Heliyon 5 (8): e02250. DOI: 10.1016/j.heliyon.2019.e02250.

Department of Environment and Natural Resources (DENR). 2016. Water quality guidelines and general effluent standards. DENR-AO 2016-08. http://water.emb.gov.ph/wp-content/uploads/2016/06/DAO-2016-08-WQG-and-GES.pdf

Eswaran Y, Dharanirajan K, Subramanian J, Saravanan, Balasubramaniam J. 2017. Distribution and zonation pattern of mangrove forest in Shoal Bay Creek, Andaman Islands, India. Indian J Mar Sci 46: 597-604.

Feller I, Lovelock C, Berger U, McKee K, Joye S, Ball M. 2010. Biocomplexity in mangrove ecosystems. Ann Rev Mar Sci 2: 395-417.

Gareth W. 1991. Techniques and fieldwork in ecology. Collins Educational Publishers, Hammersmith, LondonGillis LG, Hortua DAS, Zimmer M, Jennerjahn TC, Herbeck LS. 2019. Interactive effects of temperature and nutrients on mangrove seedling growth and implications for establishment. Mar Environ Res 151: 104750.

Hammer O, Harper D, Ryan P. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontol Electron 4: 1-9. Version 4.02 https://folk.uio.no/ohammer/past/

Harahap N, Lestariadi RA, Soeprijanto A. 2015. The effect of soil quality on the survival rate of mangrove vegetation. J Eng Appl Sci 10 (7): 154-156.

Hatfield JL, Prueger JH. 2015. Temperature extremes: Effect on plant growth and development. Weather Clim Extrem 10: 4-10.

Hoppe-Speer SCL, Adams JB, Rajkaran A, Bailey D. 2011. The response of the red mangrove *Rhizophora mucronata* Lam. to salinity and inundation in South Africa. Aquat Bot 95: 71-76.

Joshi H, Ghose M. 2003. Forest structure and species distribution along soil salinity and pH gradient in mangrove swamps of the Sundarbans. Trop Ecol 44 (2): 195-204.

Kodikara KAS, Jayatissa LP, Huxham M, Dahdouhguebas F, Koedam N. 2018. The effects of salinity on growth and survival of mangrove seedlings change with age. Acta Bot Bras 32: 37-46.

Krishnamurthy P, Mohanty B, Wijaya E, Lee D, Lim T, Lin Q, Xu J, Loh C, Kumar P. 2017. Transcriptomics analysis of salt stress tolerance in the roots of the mangrove *Avicennia officinalis*. Sci Rep 7: 10031. DOI: 10.1038/s41598-017-10730-2.

Lovelock C, Ball M, Martin K, Feller I. 2009. Nutrient enrichment increases mortality of mangroves. PLoS One 4 (5): e5600. DOI: 10.1371/journal.pone.0005600.

Mahmood H, Saha S, Serajis S, Siddique MRH, Abdullah SMR. 2014b. Salinity influence on germination of four important mangrove species of the Sundarbans, Bangladesh. Agric For 60 (2): 125-135.

Mahmood H, Saha S, Siddique MRH, Hasan MN. 2014a. Salinity stress on growth, nutrients and carbon distribution in seedlings parts of *Heritiera fomes*. Intl J Energy Environ Eng 1 (4): 71-77.

Mariappan N, Ethirajan V, Hari Nivas, A. 2016. A study of water quality status of Mangrove Vegetation in Pichavaram Estuary. J Agric Ecol Res Int 5: 1-11.

Mustapha A, Gandaseca S, Rosli N, Hamzah A, Tindit A, Nyangon L. 2016. Soil pH and Carbon at Different Depth in Three Zones of Mangrove Forest in Sarawak, Malaysia. Malays For 79: 164-173.

Naskar K. 2004. Manual of Indian Mangroves, New Delhi: Daya Publishing House, India

Noor T, Batool N, Mazhar R, Ilyas N. 2015. Effects of Siltation, Temperature and Salinity on Mangrove Plants. Eur Acad Res 2 (11): 14172-14179.

Perera KAR, Amarasinghe MD, Somaratna S. 2013. Vegetation structure and species distribution of mangroves along a soil salinity gradient in a micro tidal estuary on the north-western coast of Sri Lanka. Am J Sci 1: 7-15.

Primavera JH, Esteban JMA. 2008. A review of mangrove rehabilitation in the Philippines: success, failures, and future prospects. Wetland Ecol Manag 16 (5): 345-358.

Primavera JH, Rollon RN, Samson MS. 2011. The pressing challenges of mangrove rehabilitation: Pond reversion and coastal protection. In: Reference Module in Earth Systems and Environmental Sciences. Treatise on Estuarine and Coastal Science. Elsevier, Amsterdam

Primavera JH, Sabada RS, Lebata MJHL, Altamirano JP. 2004. Handbook of Mangroves in the Philippines-Panay. SEAFDEC Aquaculture Department, Iloilo, Philippines

Raganas AFM, Hadsall AS, Pampolina NM, Hotes S, Magcale-Macandog DB. 2020. Regeneration capacity and threats to mangrove areas on the southern coast of Oriental Mindoro, Philippines: Implications to mangrove ecosystem rehabilitation. Biodiversitas 21 (8): 3625-3636.

Raganas AFM, Magcale-Macandog DB, Hadsall AS, Pampolina NM, Hotes S. 2019. Regeneration capacity of mangrove ecosystems on the southern coast of Oriental Mindoro, Philippines: Implication to future mangrove rehabilitation. [Dissertation]. University of the Philippines, Los Banos. [Philippines]

Reef R, Lovelock CE. 2014. Regulation of water balance in mangroves. Ann Bot 115(3): 385-395.

Schmiegelow J, Marcos M, Gianesella S, Maria F. 2014. Absence of Zonation in a Mangrove Forest in Southeastern Brazil. Braz J Oceanogr 62 (2): 117-131.

Sherman RE, Fahey TJ, Howarth RW. 1998. Soil-plant interactions in a neotropical mangrove forest: Iron, phosphorus and sulfur dynamics. Oecologia 115: 553-563.

Siddique M, Raqibul H, Saha S, Salekin S, Hossain M. 2017. Salinity strongly drives the survival, growth, leaf demography, and nutrient partitioning in seedlings of *Xylocarpus granatum* J. König. Iforest 10: 851-856.

Srikanth S, Lum S, Chen Z. 2015. Mangrove root: adaptations and ecological importance. Trees 30: 451-465.

State of the Coasts of Oriental Mindoro (SOCOM) 2015. The provincial government of Oriental Mindoro. [Philippines]

Van Tang T, Rene ER, Binh TN, Behera SK, Phong NT. 2020. Mangroves diversity and erosion mitigation performance in a low salinity soil area: case study of Vinh City, Vietnam. Wetland Ecol Manag 28: 163-176.

von Arx G, Dobbertin M, Rebetez Martine. 2012. Spatio-temporal effects of forest canopy on understory microclimate in along-term experiment in Switzerland. Agric For Meteorol 166-167: 144-155.

Wang W, Li X, Wang M. 2018. Propagule dispersal determines mangrove zonation at intertidal and estuarine scales. Forests 10 (3): 245.

Ward RD, Friess DA, Day RH, MacKenzie RA. 2016. Impacts of climate change on mangrove ecosystems: a region by region overview. Ecosyst Health Sustain 2 (4): e01211. DOI: 10.1002/ehs2.1211

Warming. 1883. Tropiche Fragment II. *Rhizophora mangle* L. Bot Jahrb 4: 519-548.

Wilde F. 2006. Chapter A6. Section 6.1. Temperature: Techniques of Water-Resources Investigations. US Geol Surv 2: 22. http://water.usgs.gov/owq/FieldManual/Chapter6/6.1_ver2.pdf