PRISTINE MANGROVE COMMUNITY IN WONDAMA GULF, WEST PAPUA, INDONESIA

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ABSTRACT

The shoreline of Papua has extensive mangrove communities populated with large mangrove trees, making it a supportive habitat for many faunas with high productivity. The objective of this study is to know the health and structure of mangrove community in Wondama Gulf in the Cendrawasih National Park, West Papua. There is limited scientific data due to challenging and costly access to the area. This study collected canopy coverage and vegetation structure data from 107 circular plots using three plot areas (radians of 5 m, 2.5 m and 1 m) to determine three plant classes (*i.e.*, tree, sapling and seedling). Our survey data shows that Wondama has a pristine mangrove community with an average tree trunk diameter of 19.77 ± 6.55 cm. The large tree diameters negatively correlate with a low tree density of less than 1000 tree/ha. Wondama mangrove area also has a relatively high canopy cover (82.46 ± 6.43%) that is dominated by *Rhizophora*. The density and species composition of sapling-seedling suggest that the mangrove community has an excellent regeneration.

Keywords: Papua, mangrove, diameter, community health, regeneration

INTRODUCTION

Mangroves play a strategic role in maintaining the ecological balance of coastal ecosystems. On a global scale, mangrove communities have the potential to mitigate climate change by sequestrating carbon dioxide and increase climate change adaption by reducing sea level rise impact (Alongi 2012; Donato *et al*., 2011; Murdiyarso *et al*., 2015). Locally, communities use mangrove for food sources, construction materials, energy, traditional medicines and ecotourism (Arobaya & Pattiselanno, 2010).

Indonesia is known for having the largest mangrove habitat on the planet (Giri *et al*., 2011) with approximately 49.6% of mangrove areas in Indonesia are in Papua Island (Geospatial Information Bureau, 2012; Ministry of Forestry, 2013). Tropical climate with gently sloped coastal geomorphology and numerous large estuaries provides appropriate environments for mangrove communities. In addition, Papua mangrove faces relatively low anthropogenic pressure as evident by a low degradation rate of mangrove area in Papua compared to mangroves in western Indonesia (Ilman *et al*., 2016).

Wondama Gulf Regency is located along a semi-closed estuarine, small gulf setting that is a part of Cendrawasih Gulf National Park. There is limited scientific data due to challenging and costly access to the area. In this study, we present data on the health and structure of mangrove community in Wondama Gulf in the Cendrawasih National Park, West Papua.

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MATERIALS AND METHODS

Study Area

Wondama Gulf Regency is located in western Cendrawasih Gulf approximately 200 km from Manokwari City. The area has a hilly topography with five rivers that bring freshwater and nutrients to the area. The largest river flows from the southeast edge of Wondama Gulf. The gulf has a mixed semi-diurnal tidal cycle with two twice high and low tide daily. Substrate types vary from sand, mud and sandy mud (Table 1). We conducted the study in mangrove areas from Wamesa to Aisandami villages.

Community Structure Assessment

This study collected canopy coverage and vegetation structure data from 107 circular plots in twelve study sites referred to as WDMM herein (Figure 1). There were three different plot areas

Table 1. Site locations, mangrove habitat type and substrate description on each mangrove site in Wondama Gulf, West Papua.

No	Site	Location Island	Village	Mangrove Habitat	Substrate
1	WDMM01	Papua	Wamesa Tengah	Estuarine	Sandy mud
2	WDMM02	Papua	Sombokoro	Estuarine	Sandy mud
3	WDMM03	Papua	Sandei	Estuarine	Sandy mud
4	WDMM04	Papua	Dosner	Fringing	Sandy mud
5	WDMM05	Papua	Nanimori	Estuarine	Sandy mud
6	WDMM06	Yop	Yop	Fringing	Sandy mud
7	WDMM07	Yop	Yop	Fringing	Sandy mud
8	WDMM08	Ron	War	Fringing	Sandy mud
9	WDMM09	Papua	Aisandami	Fringing	Sandy mud
10	WDMM10	Papua	Warwai	Estuarine	Sandy mud
11	WDMM11	Papua	Moro	Fringing	Sand
12	WDMM12	Papua	Raisei	Riverine	Mud

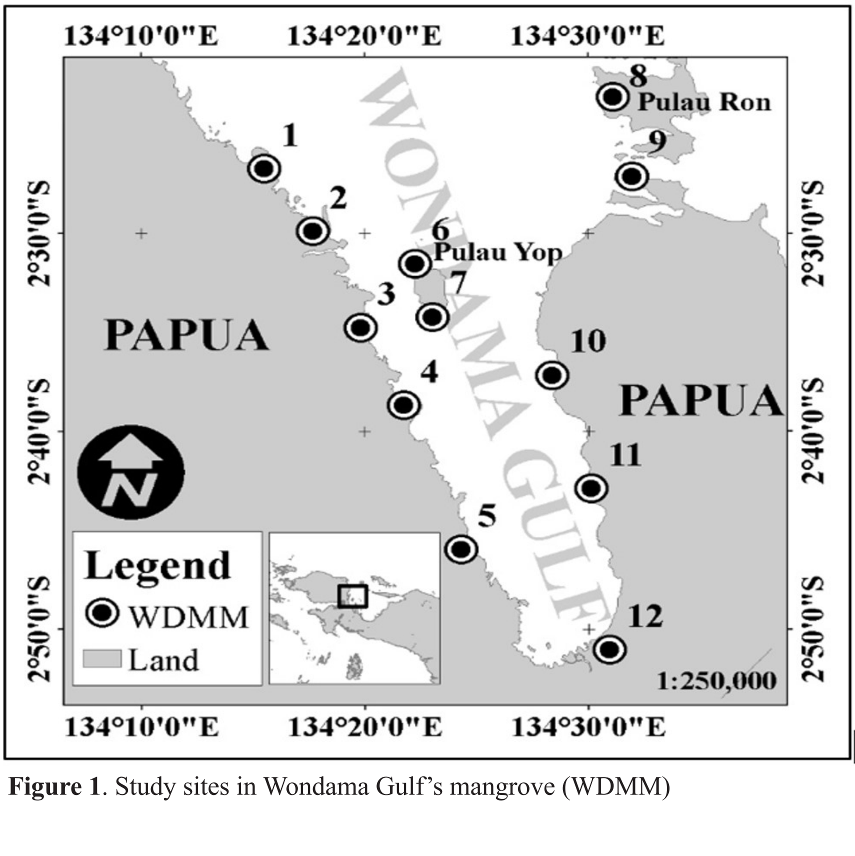

Figure 1. Study sites in Wondama Gulf's mangrove (WDMM)

to determine different classes among mangrove vegetations: 5 m-rad plot (tree class, diameter at breast height or DBH > 4 cm); 2.5 m-rad plot (sapling, DBH < 4 cm) and 1 m-rad plot (seedling, height <1 m). The class determination follows Asthon & Macintosh (2002). On each plot, the girth of trunk on breast height (GBH) was measured from each identified mangrove species. Species identification was based on Giesen *et al*. (2006).

Canopy Coverage Analysis

Mangrove canopy coverage was analyzed using the hemispherical photography method which was developed for assessing mangrove community health by Dharmawan & Pramudji (2014). As many as 98 photo samples from the twelve sites were captured by a Himax Polymer X 5MP front camera. Community canopy coverage were calculated as the ratio between the number of canopy pixel and the number of total pixel in a photo hemisphere and multiplied by 100 to get the percentage of canopy coverage.

Data Analysis

Univariate and normal distributed data (plant density from each class, trunk diameter, canopy coverage) were analyzed using ANOVA to identify a variance among sites then were followed by the Tuckey test. Correlations among sites were identified and clustered using Euclidean distance and Pearson analysis. Multidimensional scaling (MDS) based on the tree's important value index (IVI) was generated and combined with Pearson rank correlation to determine the site's group tendency.

RESULTS

Overall, Wondama has pristine mangrove communities with a canopy cover of more than 75% and large trunks (an average of 19.77± 6.55 cm with a maximum size of 78.59 cm; Figure 2). In this study, we find as many as 18 true mangrove species that are distributed in the twelve sites (Table 2). Site WDMM12 has the highest species diversity among sites with 13 species. Meanwhile, only five species are recorded in WDMM10 being a site with the lowest species number. *Rhizophora*

Table 2. True mangrove species diversity in Wondama Gulf, West Papua

No	Species	WDMM											
		1	2	3	4	5	6	7	8	9	10	11	12
1	*Aegiceras corniculatum*		v	v	v								v
2	*Avicennia alba*		v								v		
3	*Avicennia lanata*		v										
4	*Avicennia marina*				v			v	v	v	v	v	v
5	*Brugueira gymnirrhiza*	v		v	v	v	v	v	v		v		v
6	*Brugueira parviflora*		v			v		v			v		v
7	*Brugueira sexangula*	v		v	v			v			v		v
8	*Ceriops tagal*		v	v	v	v	v	v		v			v
9	*Lumnitsera littorea*	v											
10	*Nypa fruticans*								v			v	v
11	*Rhizophora apiculata*		v	v	v	v	v	v	v	v	v		v
12	*Rhizophora lamarckii*						v		v	v			
13	*Rhizophora mucronata*	v	v	v	v	v	v	v	v	v			v
14	*Rhizophora stylosa*						v						
15	*Sonneratia alba*	v		v	v		v	v	v	v	v	v	v
16	*Sonneratia caseolaris*	v		v	v		v	v	v	v	v	v	v
17	*Xylocarpus granatum*		v	v	v				v		v		v
18	*Xylocarpus mollucensis*	v	v	v									v
	Number of Species	7	9	10	10	5	8	9	9	7	9	4	13

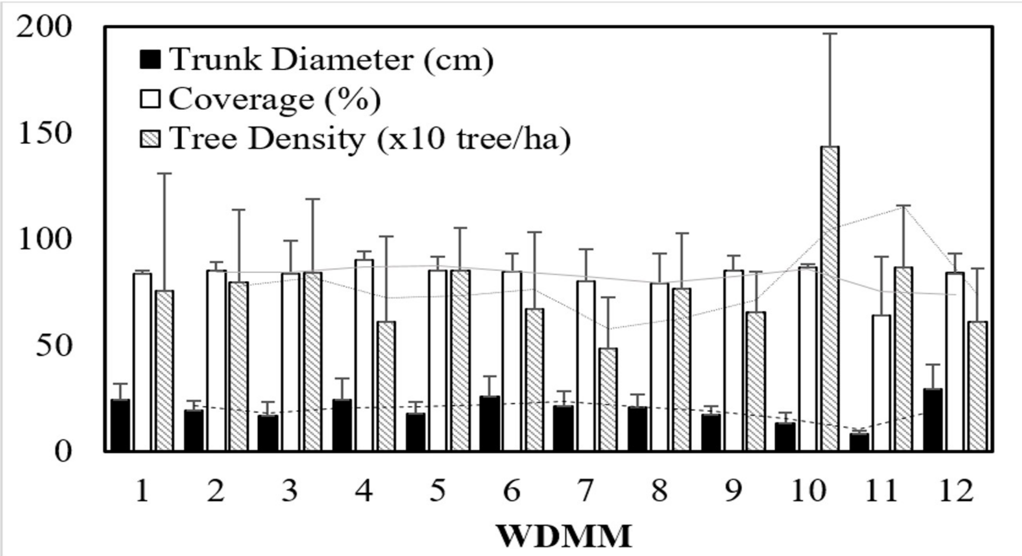

Figure 2. Tree trunk diameter, tree-sapling density and community canopy coverage of mangrove in study sites of Wondama Mangrove (WDMM) and those trend lines

and *Sonneratia* species can be found in most of the sites. And, tree density is less than 1000 tree/ha in most of the sites.

Our data show that tree diameter has a poor relationship with canopy coverage but significant negative correlations with tree and sapling density in our study sites (Table 3). The correlation between tree diameter and canopy coverage is weak (r=0.04, P>0.05). However, tree diameter has significant negative correlations with tree and sapling density with correlation coefficients of -0.76 and -0.59, respectively. There are also significant correlations between sapling and seedling density seedling coverage.

Multi-Dimensional Scaling (MDS) ordination shows the level of similarity of species structure among the sites (Figure 3). WDMM01 is widely separated from the other sites and dominated by *Rhizophora mucronata*. Sites WDMM02, WDMM04, WDMM05, WDMM06 and WDMM09 are grouped closely with mixed species composition of *R. mucronata* and codomination of *Brugueira gymnorrhiza* and *Ceriops tagal*. Another group (WDMM03, WDMM07, WDMM12, WDMM08 and WDMM10) tend to be dominated by *R. apiculata*. WDMM08 and WDMM10 share the highest similarities on species structure among the group.

Table 3. Pearson correlation rank among tree diameter and density, community canopy coverage, sapling and seedling density.

Parameters	Diameter	Coverage		Density		Species Structure	
		Tree-sapling	Seedling	Tree	Sapling	Tree	Sapling
Coverage							
Tree-sapling	0.04						
Seedling	-0.36	-0.21					
Density							
Tree	-0.76**	-0.03	-0.32				
Sapling	-0.59*	-0.21	0.69*	0.50			
Seedling	-0.02	-0.21	0.85**	0.14	0.53		
Species Structure							
Sapling						0.94**	
Seedling						0.91**	0.89**

**, significance level at alpha = 0.01
*, significance level at alpha = 0.05

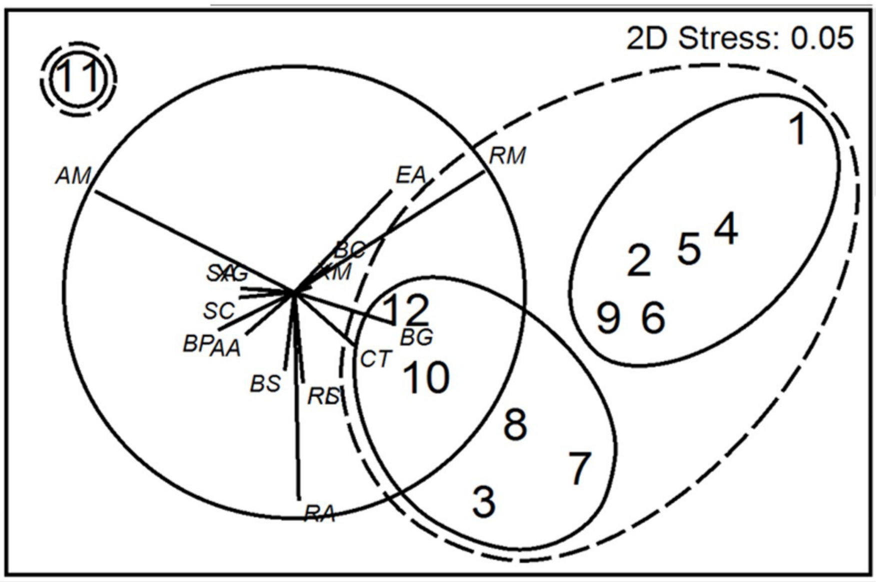

Figure 3. MDS ordination of study sites (WDMM01-12) based on important value index (IVi) of tree species. Abbr. (*AM=Avicennia marina*; *AA=A. alba; BC=Brugueira cylindrical; BP=B. parviflora; BS= B. sexangula; CT= Ceriops tagal; EA=Exoecaria agalocha; RA=Rhizophora apiculata; RL=R. lamarckii; RM=R. mucronata; RS=R. stylosa; SA=Sonneratia alba; SC=S. caseolaris; XG=Xylocarpus granatum; XM= X. mollucensis.*

Lastly, WDMM11 is standalone among the sites because its species composition is different from the others. This site is dominated by *Avicennia marina* and *Sonneratia alba*.

The regeneration of mangroves in Wondama is excellent based on sapling and seedling densities, as well as species structure. On average, mangrove communities in Wondama Gulf grow at 1204 ± 1397 individuals/ha (sapling) and 7226 ± 5746 individuals/ha (seedling; Figure 4). Sapling densities range from 255-3182 individuals/ha. Meanwhile, seedling densities vary between 1592-17097 individuals/ha. WDMM12 has the best regenerating mangrove with the highest seedling density and a sapling density over 1000 individuals/ha. The highest sapling community is found in WDMM11 by 3182 ± 3724 individuals/ha. There is also a significant correlation among special structures highlighting an excellent regeneration of mangrove communities in Wondama ($r= 0.94$ and 0.91, $P<0.01$; Table 3). Moreover, seedling regeneration to its sapling species structure is also highly related ($r=0.89$, $P<0.01$). In summary, the dominating species at the tree level has a significant contribution on sapling and seedling composition.

DISCUSSION

Our field measurements reveal that mangrove communities in Wondama Gulf have a relatively high diversity compared to other locations in Indonesia. Hinrich *et al*. (2009) found 21 species of mangrove in Segara Anakan which are a mix of true and associated plants. Compared to this site, tree density in Wondama is lower but with larger tree diameter. Other works show thirteen mangrove species recorded in Tanjung Lesung, Banten (Ati *et al*., 2014), eight in Kaledupa Islands of the Wakatobi Marine National Park (Jamili *et al*., 2009) and Ambon Gulf (Suyadi, 2009).

Considering Papua Island as having high mangrove diversity, our study sites show higher diversity compared to other mangrove studies in Papua. Prawiroatmodjo (2013) recorded eight true mangrove species from 17 total mangroves found in Salawati and Batanta, Raja Ampat. Other studies show 12 species in Waropen (Wonatorei, 2013), 10 species in Youtefa Gulf, Jayapura (Handono *et al*., 2014), 8 species in Waisai city, Raja Ampat (Mirino *et al*., 2016) and 5 species in Liki island, Sarmi Regency (Tanjung *et al*., 2015).

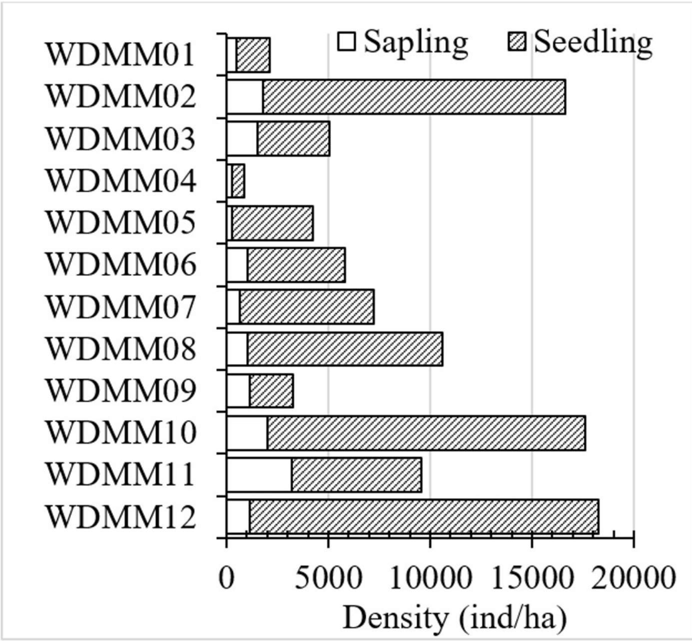

Figure 4. Sapling and seedling densities on each sites

The density of mangrove trees in Wondama is relatively lower compared to other pristine mangrove areas, which may be related to having larger tree diameter. Previous studies support a negative relationship between diameter and tree density. Dharmawan and Pramudji (2017) analyzed several mangrove sites in Indonesia and found that mangrove forests in eastern Indonesia tend to have relatively higher mean tree diameter and lower tree density. Mulyadi and Amin (2016) show a higher density (2467-3367 tree/ha) in Dumai, Riau Province, but with trunk diameters that range between 4-9 cm. Similarly, Calegrio *et al*. (2015) show a density of 10,810 tree/ha for a 3.7-7 cm mangrove forest structure, and Zhila *et al*. (2014) show a density of 1679 tree/ha for a 7.31-22 cm mangrove forest structure. The large mangrove tree diameter in Wondama implies older age of plants. For instance, 12-years old *Rhizophora* plantation in Kenya and Malaysia were consisted by 5132 ind/ha and 4000 ind/ha, respectively (Engo *et al*., 1998; Kairo *et al*., 2008).

Mangroves in Wondama show a preference for species distribution that may be related to the difference in salinity. *Avicennia alba* and *A. lanata* tend to grow in estuarine areas, whereas *A. marina* thrives in fringing sites. Our finding is consistent with Joshi and Ghose (2003) showing that *A. marina* tends to grow in higher salinity environments. The impacts of salinity on the physiological process have been shown in mangrove communities where salinity has negative correlations to assimilation rate, stomatal conductance and intercellular carbon dioxide concentration (Clough and Sim, 1989). Leaf area and osmotic potential on seedling may also decrease as salt concentration increases (Burchett *et al*., 1984).

Our study shows that *R. apiculata* and *R. mucronata* are more tolerant to a wider range of environment tolerants. *Rhizophora stylosa* and *R. lamarckii* are found only in fringing habitat. In contrast, *R. apiculata* and *R. mucronata* are easily found in all habitats. This is in line with Hoppe-Speer *et al*. (2011) and Ball *et al*. (1997). A comparison study between *R. apiculata* and salt-tolerant *R. stylosa* found a better growth rate of *R. stylosa* at higher salinity (Ball *et al*., 1997). Futhermore, salinity response in *Rhizophora* species could be identified from leaf biomass where exposure to higher salinity stimulates ticker leaves area and water content (Camileri and Ribi, 1983).

The distribution of *Brugueira gymnorrhiza* and *B. sexangula* show no specific preferences, whereas *B. parviflora* tended to be found in an estuarine environment. Sukardjo *et al*. (2014) noted that *B. parviflora* is more widely distributed with higher salinity and silt concentration in sediment. Weiss *et al*. (2016) discovered that estuarine mangroves have lower salinity gradient, higher soil organic carbon, and water-extractable phosphate than marine mangrove. Salinity also influences biomass carbon storage on *B. gymnorrhiza* seedling in Sundarbans (Agarwal *et al*., 2016).

Nypa fruticans is only distributed in a riverine setting with relatively lower salinity. Previous works found the similar distribution of *Nypa*, such as Bunt *et al*. (1982), Hamilton and Murphy (1988), Robertson *et al*. (1991), Ukpong *et al*. (1991) and Theerawitaya *et al*. (2014). Ukpong *et al*. (1991) also showed that the distribution of *Nypa* has a significant negative correlation to salinity. Robertson *et al*. (1991) found that *N. fruticans* grow in a 1-10 ppt salinity range.

Regeneration of mangrove in Wondama is excellent as evident by the number of seedling distribution. The favorable regeneration is also shown by significant correlations for species composition at all plant levels. Gan (1995) suggested that seedling densities of 5,000-10,000 can be considered as having a good regeneration of mangrove forest. However, young plants tend to be pressurized in pristine communities causing low density of sapling.

CONCLUSION

Our field survey in Wondama Gulf reveals the pristine state of its mangrove communities with its large tree diameter and high canopy coverage. Mangrove species distribution have specific habitat preferences depending on their environmental tolerance. The regeneration of mangrove communities in Wondama is also in an excellent state as suggested by density and species composition.

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