Mangrove Community Structure in Papuan Small Islands, Case Study in Biak Regency

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Abstract. Mangrove plays the importance of roles for the small island sustainability, both physically and ecologically. In the high-risk Pacific Ocean’s islands, small islands in Biak face typhoons, earthquakes, high waves, and tsunami effects. The study was conducted at 100 10mx10m-quadratic-plots scattered on seven small islands in Biak-Numfor Regency. Research objectives were to investigate the mangrove community structure of each island, i.e., canopy coverage, density, and morphological size, and to analyze the correlation among those parameters. The result found that mangrove was in pristine condition, large individual size with low anthropogenic threats. They were covered by a medium and dense canopy from 61.32±3.04% in Pasi to 93.88±0.14% in Meos Mangguandi. Substrate significantly influenced the level of canopy coverage and the MDS ordination of species composition. Sonneratia alba tended to be dominant in rocky sand in Pasi, Owi, Padaidori, and Wundi, while Ceriops and Rhizophora were mostly occupied the muddy sand, or Bruguiera gymnorrhiza has the highest domination in sandy mud substrate in Auki, Pai, and Meos. The canopy coverage had a significant correlation only with total density but none with the others. The height of the tree (up to 21.2 m) was found highly related to the diameter size (max: 124 cm).

1. Introduction
Indonesia has the largest mangrove area in the world, which is distributed at approximately 22.6% of global mangrove area [1]. Papua archipelago consisted of West Papua and Papua, which has the most proportion of mangrove in Indonesia, which is about 40% of Indonesian mangrove [2]. The islands were mostly located in the Pacific Ocean, delivering highly risked by facing high wave impact, tsunami and typhoons [3][4]. Moreover, most of the small Papuan islands in the Pacific Ocean are lack of information and governance due to distance from the city center. On the other hand, they are pristine and surely have fascinating marine biodiversity.

Mangrove has essential roles, both physically and ecologically, for the small island sustainability. They could reduce wave energy, storm effect, and tsunami [5][6][7], prevent abrasion-erosion [8][9], control saltwater intrusion [10], and protect coastal residences. Mangroves also provide wood resources for civil infrastructures [11][12]. Ecologically, mangrove is acted as the habitat and producer of the food web for marine and terrestrial habitats [13]. Moreover, mangrove could provide alternative food sources for local residents [14].

Study on mangrove community structure in Papuan small islands is lack of opportunity due to high cost and remotely accessed. This study was conducted in Biak Numfor Regency, which directly faces
to the Pacific Ocean. The study was aimed to analyze mangrove structure in Papua small islands and the correlation among vegetative parameters.

2. Methods

2.1 Site Description
The study was conducted in seven islands in Biak Numfor Regency (Figure 1). The islands were dominantly oceanic and typical sandy to a muddy substrate. Some sites were unique in their habitat condition. For instance, in Auki and Pai, mangroves grew in the middle of the island which only exposed to saltwater through the intrusion of tiny caves. Most of the mangrove habitat was a narrow area. The rocky sand habitat was typical in Pasi, Owi, and Wundi island. However, the others were covered by softer substrate i.e. sand, sandy mud, or muddy sand.

![Figure 1](image1.png)

**Figure 1.** Distribution of mangrove measurement in seven small islands in Biak Regency

2.2 Mangrove Community Measurement
The univariate data (coverage, density, diameter, and height) were collected from 100 10m x 10m-quadratic plots, which were scattered in stratified random sampling on each mangrove zones. On each plot, we collected the canopy coverage percentage using hemispherical photography method [15]. Besides, the diameter at breast height (DBH) was measured from all stands level i.e. tree (DBH≥4 cm); and sapling (DBH<4 cm) in the entire plot area. Species were identified during each diameter measurement [16]. Mangrove height was estimated using Protractor combining tangential equation of angle and measuring distance. The seedling was counted in 10 m x 10 m plot.

2.3 Data Analysis
Univariate data were analyzed descriptively for its average and standard error (SE). Analysis of variance (ANOVA) and Tukey test was applied to identify differences of each parameter among sites. MDS ordination was made based on mangrove species importance value index (IVI), and its Euclidian Distance among sites. The correlation among variables was analyzed using Spearman rank analysis.
3. Results
A recent study found that canopy coverage of mangrove community in all sites was consistently higher than 50%, which was varied from 61.32±3.04% in Pasi island to 93.88±0.14% in Meos Mangguandi (Figure 2). It was implied that mangrove sites were in medium (<75%) and dense covered (≥75%). The Meos’s canopy coverage had no significant difference with the mangrove sites that had dense coverage. Tukey analysis classified that mangroves in Pasi and Owi were significantly different from Meos’s. Those sites were covered less than 75%, which were 61.32±3.04%; 70.97±3.06%, respectively.

Overall, mangrove total density ($d_{tot}$) was 21.4±4.1 ind.100m$^{-2}$ on average, which was varied from 11.3±6.1 ind.100m$^{-2}$ in Wundi to 37.3±1.5 ind.100m$^{-2}$ in Meos Mangguandi. The density of mangrove in Wundi, Owi and Padaidori were different significantly with Pai and Meos (ANOVA: F=4.012; Sig. 0.003). It implied that mangrove in sandy mud substrate had a higher mangrove density. In the higher plants community, tree density was ranged from 7.3±2.4 ind.100m$^{-2}$ to 34.0±2.6 ind.100m$^{-2}$ in Wundi and Meos Mangguandi, respectively. The highest regeneration was found in Pai which had the densest sapling and seedling stand at 22.3±7.1 ind.100m$^{-2}$ and 75.3 ind.100m$^{-2}$, respectively. It was different significantly with other sites. On the other hand, Pasi had the lowest regeneration levels (Table 1). Low density was consistently found in a rock-gravel sand substrate.

Table 1. The substrate, species INP, diameter-density; and height.

| Island | Substrate Description* | Dominant Species** | Species Number | $d_{tot}$ (ind.100 m$^{-2}$) | $d_{tree}$ (ind.100 m$^{-2}$) | $d_{sap}$ (ind.100 m$^{-2}$) | $d_{sed}$ (ind.100 m$^{-2}$) |
|--------|------------------------|-------------------|----------------|----------------------------|----------------------------|-----------------------------|-----------------------------|
| Auki   | MS                     | BG                | 4              | 16.8±3.3$^{ab}$             | 10.0±1.4$^{a}$             | 6.8±2.2$^{a}$               | 68.3                        |
| Wundi  | RGS                    | SA                | 4              | 11.3±3.5$^{a}$             | 7.3±2.4$^{a}$              | 4.0±2.1$^{a}$               | 8.0                         |
| Padaidori | MS                 | RA                | 6              | 12.2±1.6$^{a}$             | 9.8±1.7$^{a}$              | 2.3±0.7$^{a}$               | 4.8                         |
| Pasi   | RGS                    | SA                | 1              | 26.0±8.5$^{ab}$            | 24.7±7.2$^{bc}$            | 1.3±1.3$^{a}$               | 2.0                         |
| Pai    | SM                     | BG                | 4              | 34.7±13.4$^{b}$            | 12.3±6.4$^{a}$             | 22.3±7.1$^{b}$              | 75.3                        |
| Meos   | SM                     | BG                | 1              | 37.3±1.5$^{b}$             | 34.0±2.6$^{c}$             | 3.3±1.2$^{a}$               | 54.3                        |
| Owi    | RGS                    | SA                | 1              | 11.6±2.4$^{a}$             | 9.5±1.1$^{a}$              | 2.1±1.6$^{a}$               | 5.8                         |
| Total  |                        |                   | 11             | 21.4±4.2                   | 15.4±3.8                   | 6.0±2.8                     | 31.2±12.5                   |

* MS=Muddy sand; RGS=Rock-Gravel Sand; SM=Sandy Mud
** BG=Brugueira gymnorrhiza; SA=Sonneratia alba; RA=Rhizophora apiculata
Mangrove in Biak’s small islands had a large size according to trunk diameter and tree height (Figure 3). The diameter average of mangrove in all sites was 16.6±1.9 cm, while their height means was 16.5±1.2 m. Mangrove in Auki had the tallest mangrove stands at 19.9±1.8 m, which had only a significant difference with Wundi (ANOVA: F=2.432; Sig. 0.04). The lowest average of mangrove diameter was found in Meos Mangguandi by 10.9±1.5 cm, which had no significant difference with other sites (ANOVA: F=1.113, Sig. 0.37).

As many as 11 species were found in all sites, where Padaidori was dominant and occupied by six species (Figure 4). Three sites, Owi, Pasi, and Meos Mangguandi, were a monospecies site that was only grown by a single species. There were two dominant species in Biak’s small islands, *Brugueira gymnorrhiza* (INP=115.97%) and *Sonneratia alba* (INP=140.07%).

**Figure 3.** Height (m)-left; and tree trunk diameter (cm)-right of mangrove in all sites (Islands: AU=Auki; WU=Wundi; PD=Padaidori; PS=Pasi; PI=Pai; MM=Meos Mangguandi; OW=Owi; All=total)

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**Figure 4.** Important Value Index (IVI) of mangrove species among sites (Islands: AU=Auki; WU=Wundi; PD=Padaidori; PS=Pasi; PI=Pai; MM=Meos Mangguandi; OW=Owi; All=total)
Initial correlation analysis found that canopy coverage was influenced by substrate type (Spearman rho = 0.195*; N=124; Sig (2-tailed)=0.03). Finer and higher organic substrate tend to have denser mangrove canopy. The later analysis was used substrate as a filter, which found the correlation between coverage and the other community data shown in Table 2. Coverage had a significant correlation to tree height, which was related to its diameter. The density and diameter have a significant negative relation both in total and tree level.

Table 2. Spearman rank among mangrove vegetative parameters in Papua small islands

|       | $D_{tot}$ | $d_{tot}$ | $d_t$ | $D_t$ | $h$ (m) |
|-------|-----------|-----------|-------|-------|---------|
| $C$ (%) | -0.08     | 0.12      | 0.08  | -0.03 | 0.32*   |
| $D_{tot}$ | 1         | -0.65***  | -0.46**| 0.92***| 0.29*   |
| $d_{tot}$ | -0.65***  | 1         | 0.81***| -0.61***| -0.10   |
| $d_t$   | -0.46**   | 0.81***   | 1     | -0.56***| -0.05   |
| $D_t$   | 0.92***   | -0.61***  | -0.56***| 1     | 0.32*   |

The substrate type was highly related to mangrove species composition. Rock-gravel-sand was frequently occupied by *Sonneratia alba*, which dominantly grows in higher salinity environment. On the other hand, higher organic sediments were grown by mixed species, which are *Rhizophora*, *Ceriops*, and *Brugueira* (Figure 1). MDS ordination showed that Pasi and Owi, which had monospecies mangrove, *S. alba*, were attached to each other’s. Those sites were similar to Padaidori and Wundi’s mangroves related to their rocky sand substrate domination. In contrast, the finer substrate sites Meos, Pai, and Auki, were highly correlated to *Brugueira gymnorrhiza* domination (Figure 3).

Figure 5. MDS ordination among sites based on the importance value index (IVi) of mangrove species.

4. Discussion
Canopy coverage was categorized as a densely covered mangrove on average (≥75%), while some sites were in moderate (<75%) [17]. A pristine mangrove forest relatively has a dense canopy
coverage. This study had a similar percentage compared with the mangrove canopy coverage in Raja Ampat (84.73%) [18]; Bunaken Nasional Park (79.64%) [19]; Manado (76.98%) [20]; and Wondama (82.46%) [21]. Crown diameter had a strong relationship with tree height which was also correlated with diameter [22]. Tree height and diameter size representing habitus are varied among mangrove species; hence the canopy coverage was also influenced by dominated species in the area. In pristine condition, Sonneratia-dominated forest tended to has a lower canopy coverage than a dense Rhizophora.

Papuan small islands in Biak regency were categorized into a dense mangrove forest based on the mean of tree density which was upper than 15 tree.100m-2. A previous study found a lower tree density at 7.77 tree.100m-2 in Wondama Gulf, Papua [21]. It was similar to mangrove forest in Ternate and Tidore which had 12.75 tree.100m-2 of tree density [23]. Mangrove density has a significant correlation with trunk diameter. Their relation tended to be a negative correlation. Once a mangrove forest was low in tree density, trunk diameter size would be larger [21][24][25].

In terms of small islands, the morphological size of mangrove stands in Biak was relatively large compared with some previous studies. A pristine site of mangrove Papua, in Wondama Gulf, mangrove diameter was reaching 19.77± 6.55 cm on average, while was 78.59 cm for the maximum size of tree21. However, the small island mangroves which were located nearby Sorong city had lower diameter size (10.96 cm) and higher density (28.6 trees .100m-2) [26]. On the other hand, small islands in regencies of western Indonesia tended to have a smaller size of trunk diameter, for instance, Bintan’s (11.42 cm) [27], Natuna (10.90 cm) [28], Batam’s (7.55 cm) [29], Sabang’s (12.01 cm) [30], Kepulauan Seribu’s (10.47 cm) [31]. The mangrove tree height had a similar pattern compared with other studies. In addition, mangrove diameter and height had a significant positive correlation, hence the taller mangrove would be had a larger diameter size [32].

Species distribution of mangrove has been influenced by many factors such as salinity, substrate type, and habitat geo-morphology [33]. Salinity is the main factor for zonation forms in mangrove forests [34]. Small islands with a narrow mangrove habitat and low freshwater input tend to have a high salinity environment. Hence, only salt-tolerant species could be grown. Sonneratia alba preferred to grow in a higher salinity and hard substrate. On the other hand, B. gymnorrhiza was grown optimally in the finer muddy substrate and lower salinity in the landward zone.

5. Conclusion
Even the mangrove growth in the risky Pacific Ocean, Papuan small island’s mangroves in Biak Numfor regency were in excellent condition since they had a dense canopy coverage, high tree density, and large size of stands. Mangrove species distribution was highly related to the substrate type and habitat.

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