Diversity, density, and Importance Value Index of mangroves in the Segara Anakan lagoon and its surrounding area, Cilacap Regency, Indonesia

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Abstract. Coastal mangrove forest habitats in the Segara Anakan Lagoon have become an important area for estuarine fisheries which should be preserved for sustainability. This study aims to analyze diversity, density, and the importance value index of the mangrove in the area. The method used was a plot and path (combination method). To conduct this study, the nine purposely sampled stations ranged from the western Segara Anakan Lagoon to the eastern mangrove area adjacent to the Donan River. The nine station was grouped into 3 (three areas) namely; Mangrove Eastern Area (river influence), Mangrove Middle Area, Mangrove Western Area (seawater influence. The results show the average mangrove density overall stations were dominated by seedlings with 39881 individuals/ha with fraction 75%, followed by saplings with 12311 individuals/ha (23%), and tree category with 711 individuals/ha (1%). Because of the average mangrove density of tree category less than 1000 trees/ha so, the mangrove forest in the Segara Anakan Lagoon and its surrounding area was categorized to be damaged. Meanwhile, the highest Importance Value Index (IVI) was at 221 for R. apiculata and at 220 for Sonneratia caseolaris for all stations.

Keywords: Importance Value Index; mangrove diversity; Segara Anakan Lagoon

1. Introduction

A mangrove forest is a forest that thrives in muddy habitat or grows on alluvial soils which border on the sea and which are still influenced by tides. It also has a wide range of ecosystem services [1], Physically, the structure of mangrove roots with their attached mud creates a barrier to seawater intrusion. Biologically, the structure attracts various juvenile fish. Global averages of primary food
sources to mangrove food webs are trees (leaf, wood, and root litter) 149 molC /m²/year macroalgae 110–118 molC/m²/year, and benthic microalgae 7–73 molC/m²/year [2]. Economically, For Indonesia, economic value of mangrove resource is estimated ranging from US $3,624.98 - US $26,734.61 per ha per year [3].

Indonesia is the largest mangrove-holding nation, containing between 26% and 29% of the global mangrove inventory with a deforestation rate of between 0.26% and 0.66% per year [4] due to various unsustainable forest uses. Story of the mangrove forest of Segara Anakan covered 35,000 ha in 1930. In 2013 only 3.716 hectares had remained from the original area [5]. Over the last 38 years (1978-2016), there has been major change in the Segara Anakan Lagoon [6]. Conversion of mangrove area primarily to rice fields and dryland agriculture [7]. Those changes as cause of mangrove loss which has implications for fish species abundance and fish reproduction [8] as well as for the livelihood of the local inhabitants [9]. The changes of the mangrove forests in the lagoon, continue with effects on mud crabs habitat and finally direct the discussion towards for decision on future mangrove management plan.

Therefore, the objective of the present study is to analyze the spatial diversity, density, IVI of the various categories of mangrove in different level of salinity spatially ranged from the West Plawangan Gate (more influenced by the freshwater discharge of the Citanduy River) to the East Plawangan Gate (more influenced by the seawater from the Indian Ocean). The benefit of this study is to provide a descriptive evaluation for sustainable mangrove-fisheries in the Segara Anakan Lagoon and its surrounding area.

2. Material and method

2.1. Study area

The study was conducted from 15 September 2017 to 20 April 2018 in the Segara Anakan Lagoon and its surrounding area, Cilacap Regency, Central Java Province of Indonesia. The nine purposely sampled stations ranged from the western Segara Anakan Lagoon to the eastern adjacent to the Donan River see figure 1. Mangrove ecosystem in Segara Anakan area has high aquatic resources and high economic value. It is nursery ground for fishes 23 families, 38 genus [10], and habitat macroinvertebrates e.g Scylla spp., polymesoda sp. Anthropogenic activities from upland results in a increase sediments along the area This condition will result in a decrease in water productivity and directly affect it conditions of the biota that live in the Segara Anakan area.

Study locations were assigned to three groups according to their water salinity: (1) Stations from I to III which are located close to the West Plawangan Gate and are more influenced by the freshwater discharge of the Citanduy River then the saltwater of the Indian Ocean, (2) stations IV to VII which are located central, most distant from both, the West Plawangan Gate and the East Plawangan Gate, and (3) stations VIII, IX which are much influenced by the seawater from the Indian Ocean [11].

2.2. Mangrove Growth Measurement

The study is based on two categorizations of the mangrove vegetation: (1) membership in the group of major mangrove species, minor mangrove species, or mangrove associates (as proposed by [12], and (2) membership of a tree in one of three life stages (seedling, sapling, tree). This could be the template formulation for the design of the survey:” three quadrat plots of decreasing size Plot A > Plot B > Plot C, compare figure 2, whereby each smaller plot is nested within the next larger one”, “tree attributes were measured in 10 m x 10 m plots Plot A, see figure 2. The height at which the diameter has been measured is also lacking. This is important. The standard is a height of 1.3 m (d1.30 or D1.30 or dbh or DBH). Seedlings, saplings are more often defined by the height criterion.

Measurements were as conducted following [13]. The measurements were using plot sized 10m x 10m (plot A, figure 2), in which there were two nested plots; one plot was a size of 5 m x 5 m (plot B), and another was a size of 2m x 2m (plot C) (figure 2). Plot A was for the tree category, Plot B was for the sapling category and Plot C was for the seedling category. These growth categories were used
to analyze mangrove vegetation [14] i.e., 1) The seedling category are individual trees < 1.5 cm in diameter, 2) The sapling category is comprised of individuals trees > 1.5 cm and to <10 cm in diameter, 3) The tree category is trees that have a diameter> 10 cm.

**Figure 1.** Location of the sampling stations situated in the mangrove forest of the Segara Anakan Lagoon and its surrounding area, Cilacap Regency, Central Java, Indonesia.

**Figure 2.** More details of the location, dimension and direction of the transects (Onrizal 2008).

### 2.3. Vegetation Analysis

The analysis of the mangrove vegetation is derived from tree/sapling/seedling data, the number of individuals their species membership, and their stem diameters. Further, the data was processed to obtain values for the density of a species, the relative density of a species, the dominance of species, and an Importance Value Index (IVI) for all mangrove species present [15].

\[
\text{Density((De) (individuals/ha))} = \frac{\text{Number of individuals belong to one species}}{\text{Sample area}}
\]  

(1)
Relative Density (RDe) = \frac{\text{Number of individuals belong to one species}}{\text{Total number of all individuals counted}} \times 100\% \quad (2)

Frequency (F) = \frac{\text{Number of plots where one species is found}}{\text{Total number of plots}} \quad (3)

Relative Frequency (RF) = \frac{\text{Frequency of one species}}{\text{Summed frequencies of all species}} \times 100\% \quad (4)

Basal area of individual = \pi \times (\frac{\text{DBH}^2}{4}) \times 144 \text{ [m}^2 \text{]} \quad (5)

Where \pi = 3.14, \text{DBH = diameter breast height (m)}

Dominance (Do) = \frac{\text{Basal area of one species}}{\text{Sample area}} \times \frac{m^2}{ha} \quad (6)

Relative Dominance (RDo) = \frac{\text{Dominance of one species}}{\text{Total dominance of all species}} \times 100\% \quad (7)

Importance Value Index (IVI) = RDe + RF + RDo \quad (8)

RDo is merely used in the calculation of species-specific IVI for trees with a diameter at breast height. For seedlings, small saplings or stem-less plants, such as Nypa fruticans, or the others (the group of mangrove minor and mangrove associates) are not taken into account.

3. Results

3.1. Number of the mangrove species

A total of 19 species belonging to 10 families was found in the mangrove vegetation, the categorization into major/minor mangrove species and mangrove associates. The group of major mangroves Avicennia alba Blume, A officinalis L, Bruguiera gymnorrhiza Lamk, Bruguiera parviflora Roxb, Ceriops tagal C.B. Rob, Ceriops decandra Griff, Rhizophora mucronata Poir, Rhizophora. Apiculata Blume, Sonneratia alba Griff, Sonneratia. caseolaris Engl, Lumnitzera racemosa Wild, Nypa fruticans Thunb; the group of minor mangrove species Acrostichum aureum, Xylocarpus moluccensis Lam, Xylocarpus. Granatum Koen, Aegiceras corniculatum Blanco, and the group of mangrove associates Derris trifoliata Lour, Acanthus ilicifolius L, Finlaysonia maritime Blume. The number of mangrove species tended to increase from Station I to Station VIII (figure 3).

![Figure 3. The number of mangrove species at individual stations in the Segara Anakan and its surrounding area.](image-url)
Besides that, presence of *Derris tripoliata* (shrub) was very abundance at mangrove areal of the Segara Anakan starting at Station I to Station VII, but at Station VIII and Station IX, they were not found.

### 3.2. Mangrove density in various categories

Density of mangrove for all stations can be seen in Figure 4. The density of seedlings was greater than both the saplings and the trees, except for Station IV where we did not find any seedlings. The average density across all stations was 39,881 individuals/ha (76%) for the seedling category, 12,311 individuals/ha (23%) for the sapling category, and 711 individuals/ha (1%) for the tree category.

![Figure 4](#)

**Figure 4.** Density of mangroves in different life stages at Station I – IX.

The highest density of the seedlings category was 57,600 individuals/ha (at Station III), and the lowest density was 26,133 individuals/ha (at Station II) while the highest density of the saplings was 23,733 individuals/ha (at Station I) and the lowest density was 4933 individuals/ha at (Station VI). The highest density of the tree category was 1500 individuals/ha (at Station III) and the lowest density of the trees was 67 individuals/ha (at Station IX).

### 3.3. Spatial variation of mangrove densities under different salinity

There were found 4 species namely *Sonneratia caseolaris*, *Rhizophora mucronata*, *Avicennia alba*, and *Nypa fruticans* at station 1. The highest densities among all the species were *Sonneratia caseolaris* with seedlings category 22,400 individuals/ha, saplings category 14,133 individuals/ha, and trees category 467 individuals/ha (figure 5).

![Figure 5](#)

**Figure 5.** Species-specific Densities (a) and Relative Densities (b) for different life stages at Station.

Four mangrove species (*Rhizophora mucronata*, *Avicennia alba*, *Nypa fruticans*, and *Sonneratia caseolaris*) were found at Station II. The densities of the seedling category, the sapling category, and the tree category were 26,133 individuals/ha (69.4%), 10,400 individuals/ha (27.6%), and 1133 individuals/ha (3%) respectively. In addition, *Rhizophora apiculata* was more dominant than the other
species for both, the seedlings and the saplings category, whereas *Nypa fruticans* were the most dominant species only for the tree category (figure 6).

![Figure 6](image6.png)

**Figure 6.** Species-specific Densities (a) and Relative Densities (b) for different life stages at Station II.

It found three species, namely *Avicennia alba*, *Nypa fruticans*, and *Sonneratia caseolaris* at Station III, which were fewer in number than at Stations I and II. Furthermore, the mangrove density for each category (the seedlings, the saplings and the trees) was 57,600 individuals/ha (73.2%), 19,600 individuals/ha (24.9%) and 1,500 individuals/ha (1.9%) respectively (figure 7).

![Figure 7](image7.png)

**Figure 7.** Species-specific Densities (a) and Relative Densities (b) for different life stages at Station III.

At Station IV, there was no species were detected for the seedling’s category, meanwhile one species for the sapling category (*Rhizophora mucronata* at 133 individuals/ha), and three species for the tree category (*Avicennia alba* at 67 individuals/ha, *Nypa fruticans* at 167 individuals/ha, and *Sonneratia caseolaris* at 200 individuals/ha). The relative densities can be seen in figure 8.

![Figure 8](image8.png)

**Figure 8.** Species-specific Densities (a) and Relative Densities (b) for different life stages at Station IV.
At Station V, was found eight species, consisting of five major mangrove species (Avicennia alba, Avicennia officinalis, Rhizophora apiculata, Nypa fruticans, Sonneratia caseolaris), one minor mangrove species (Aegiceras corniculatum), and two mangrove associates (Acanthus ilicifolius and Derris trifoliata). Besides, the density of individuals in each category was dominated by Nypa fruticans. The individual densities of mangrove species were 9813 individual/ha (the seedlings), 1306 individual/ha (the saplings), and 240 individual/ha (the trees) (figure 9).

We found 8 species at Station VI consisting of 6 species belonging to the group of major mangroves, namely Avicennia alba, Avicennia officinalis, Bruguiera parviflora, Bruguiera gymnorrhiza, Nypa fruticans, Sonneratia caseolaris, and 2 species belonging to the component of mangrove shrub, namely Derris trifoliata and Acanthus ilicifolius. In total, the mangrove density of each category was 36,800 individuals/ha, 4,933 individuals/ha, and 867 individuals/ha, respectively (figure 10).

At Station VII, there were found 5 major mangrove species which consist of (Bruguiera gymnorrhiza, Ceriops tagal, Ceriops decandra, Rhizophora apiculata, Lumnitzera racemosa) with Bruguiera gymnorrhiza having the highest density, both as the seedling (19,200 individuals/ha) and as the saplings (8,133 individuals/ha). Besides, at this Station, there were no trees (diameter of trees >10 cm) present. The relative density of Bruguiera gymnorrhiza was 43% (for the seedlings category) and 53% (for the saplings category) (figure 11). This relative density of Bruguiera gymnorrhiza shows dominance in this Station.

At Station VIII, we identified 8 species (B. gymnorrhiza, Ceriops tagal, Ceriops decandra, Rhizophora apiculata, Lumnitzera racemose, Rhizophora mucronata, Sonneratia alba, Nypa fruticans) with varying densities. The highest density was detected for Nypa fruticans at 19,733 individuals/ha (in the seedling category), and 467 individuals/ha (for the trees category). The highest density for the sampling was Rhizophora apiculata at 4,533 individuals/ha. The total density for the seedlings, the saplings and the trees respectively were 54,400 individuals/ha (81.3%), 11,733 individuals/ha (17.5%) and 800 individuals/ha (1.2%) (figure 12). The density of the trees found in this station was less than 1,000 trees/ha.

Figure 9. Species-specific Densities (a) and Relative Densities (b) for different life stages at Station V.

Figure 10. Species-specific Densities (a) and Relative Densities (b) for different life stages at Station VI.
The highest mangrove density was for *Rhizophora apiculata* for both the seedlings 32533 individuals/ha and the saplings 15200 individuals/ha at Station IX. In the tree category, we found similar *Nypa fruticans* at 33 individuals/ha and *Sonneratia alba* at 33 individuals/ha. Besides, the average seedling density was 10346 individuals/ha and the average sampling density was 3680 individuals/ha with the average tree density at 33 individuals/ha (figure 13).

![Figure 11](image1.png)
**Figure 11.** Species-specific Densities (a) and Relative Densities (b) for different life stages at Station VII.

![Figure 12](image2.png)
**Figure 12.** Species-specific Densities (a) and Relative Densities (b) for different life stages at Station VIII.

![Figure 13](image3.png)
**Figure 13.** Species-specific Densities (a) and Relative Densities (b) for different life stages at Station IX.

3.4. The Importance Value Index (IVI)

The Importance Value was different among stations. In table 1, the various Importance Values found in this study are given. At Station VII, there was no trees category and, thus, this station was not included in our evaluation. The highest IVI value was recorded for *Sonneratia caseolaris* at 220 (73.33%) and this species is distributed over 6 stations. The lowest IVI value was 30 (10%) for...
Sonneratia alba as well as for Sonneratia caseolaris. This shows that Sonneratia caseolaris was the best adapted among all species which we recorded in this study.

### Table 1. Species, Frequency Density (Ind/ha), Dominance (m²/ha), Relative Frequency, Relative Density, Relative Dominance, and IVI.

| Station | Species               | Relative Density (%) | Relative Frequency (%) | Relative Dominance (%) | IVI (0-300) |
|---------|-----------------------|----------------------|------------------------|------------------------|-------------|
| I       | Sonneratia caseolaris | 70                   | 50                     | 100                    | 220         |
| II      | Avicennia alba        | 9                    | 29                     | 30                     | 67          |
|         | Sonneratia caseolaris | 21                   | 29                     | 70                     | 120         |
| III     | Avicennia alba        | 0                    | 50                     | 0                      | 50          |
|         | Nypa fruticans        | 62                   | 50                     | 0                      | 112         |
|         | Sonneratia caseolaris | 38                   | 0                      | 0                      | 38          |
| IV      | Avicennia alba        | 15                   | 29                     | 36                     | 80          |
|         | Sonneratia caseolaris | 46                   | 43                     | 64                     | 153         |
| V       | Avicennia alba        | 6                    | 17                     | 34                     | 56          |
|         | Avicennia officinalis | 6                    | 17                     | 33                     | 55          |
|         | Sonneratia caseolaris | 6                    | 17                     | 33                     | 55          |
| VI      | Avicennia alba        | 19                   | 29                     | 55                     | 103         |
|         | Avicennia officinalis | 14                   | 29                     | 34                     | 77          |
|         | Sonneratia caseolaris | 5                    | 14                     | 11                     | 30          |
| VIII    | Rhizophora apiculata  | 29                   | 33                     | 60                     | 122         |
|         | Rhizophora mucronata  | 8                    | 17                     | 31                     | 56          |
|         | Sonneratia alba      | 4                    | 17                     | 9                      | 30          |
| IX      | Avicennia alba        | 9                    | 20                     | 11                     | 40          |
|         | Rhizophora apiculata  | 82                   | 60                     | 79                     | 221         |
|         | Sonneratia alba      | 9                    | 20                     | 10                     | 39          |

4. Discussion

In this study, there is an increase in the number of mangrove species significant toward the West Plawangan Gate especially within Stations VIII and XI where C. tagal and B. gymnorrhiza can be found. This study is almost similar to the findings of [6] and [17] that the eastern side of the Segara Anakan Lagoon (near The East Plawangan Gate) has a higher level of species richness of mangrove than the western side the Segara Anakan Lagoon (The West Plawangan Gate). The locations of Stations VIII and IX are far away from the freshwater inflow of the Citanduy River so that these stations are a higher salinity level which both these stations close to the West Palawangan Gate [11].

Furthermore, we found 19 species of mangrove. If comparing with previous study conducted in the Segara Anakan Lagoon (West Plawangan side) in 2015, there were 10 species which were dominated by A. marina, Avicennia alba, and Sonneratia caseolaris [18]. and also, in the 2012 study, found 10 species.

Meanwhile, Derris trifoliata is unseen these Station VIII and IX due to the effect of freshwater of the Citanduy River which has been decreasing, similar arguments were made by [19] that salinity is one of factor that determines the distribution of mangrove plants. This species belongs to the shrubs life-form and is highly invasive to cover areas that are planted mangrove trees. It was reported that the
highest population density was on the western side of Segara Anakan with 59% [20] The presence of this species is likely to be an indicator of the degradation of mangrove forests [21][22]

The average level of density in the seedling and the saplings in all stations, both these are considered a medium level (>2500 individuals/ha) but the trees are considered a low level (<1,000 individuals/ha), even at Station VII, the trees were not found in this study, this happens because of the distance to the nearest village. Despite that practice of illegal logging has decreased due to the recent switch to liquid petroleum gas usage (e.g. the IVI of heavily-logged species in the seedling category is higher than the IVI in the sapling category for the same specie), However, the recent study indicates a density level of the trees less than 1000 trees/ha [23], which the tree category is the role important relates to a large biomass production that

However, the number of saplings rose sharply when compared to previous studies in which the average density was 1823 individuals/ha [24]. The rise indicates that there still has been a high population increase in the Segara Anakan, Thus, there is a need for control at the seedlings and the saplings stage to achieve fully grown trees by involving the local community. Meanwhile, based on figure 13, the tree category at all stations is lower than for the seedlings and saplings except for those at Station IV. This situation indicates pressure on the tree category at all stations.[25]

The highest Importance Value Indices, namely 1) R. apiculata at 221 closers to the Indian Ocean at the west Plawangan are better adapted to a high salinity level [25] this result with similar findings of [26] who state that there are a gradual change of salinity level particularly in wet season. It is more increased salinity toward the western. 2) Sonneratia caseolaris at 220 closers to the Citanduy River. Although the IVI value of Sonneratia caseolaris is low, its presence at all observation stations is quite high which is from Station I to VI (67%),

Moreover, a high IVI value indicates an importance value. it represents the contribution of a species within the community. A species might have a high importance value within the community even though it possesses a low basal area, including the distance to the nearest village as an environmental factor in a gradient analysis and to apply the concept of relative stocking for the evaluation. Therefore, we suggest that Sonneratia caseolaris can be recommended for floral replantation of damaged areas.

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