# THE SPECIFIC ORDINATION AND CLUSTERING OF MANGROVE ECOSYSTEM IN SEGARA ANAKAN

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THE SPECIFIC ORDINATION AND CLUSTERING OF MANGROVE ECOSYSTEM IN SEGARA ANAKAN. Mangrove ecosystem has specific ordination and clustering following the adaptation toward the environment properties and species competition. This research had purpose to analysis a specific ordination using the relation between mangrove density and environmental properties. The research was carried out with a multidimensional system using density and environmental properties with similarity and Euclidian distance indexes. The results showed that West Segara Anakan (WSAL) had 6 ordination areas, and East Segara Anakan (ESAL) had 5 ordinations with a range density of 68-3373 trees/ha and 550-2975 trees/ha. Based on environmental properties, WSAL had nitrate, phosphate, pyrite, water and soil pH, and water salinity levels of 10.57-31.44 mg/lt, 8.44-22.89 mg/lt, 1.03-1.57 %, 5.60-7.78, 6.58-7.03, and 24.15-33.85 ppt, respectively. In ESAL, nitrate, phosphate, pyrite, water and soil pH, and water salinity were within the range of 19.72-28.98 mg/lt, 10.83-19.72 mg/lt, 1.28-2.91%, 6.35-7.05, 5.91-6.23, and 18.00-32.33 ppt. Furthermore, specific ordination showed that *Rhizophora stylosa*, *Rhizophora apiculata*, *Avicennia marina*, and *Nypa frutican* had the highest level of adaptation to grow and life in Segara Anakan Lagoon (both of WSAL and ESAL.

Keywords: Environment properties, mangrove clustering, mangrove density, mangrove ordination, Segara Anakan Lagoon

*ORDINASI DAN PENGELOMPOKAN YANG KHAS DARI EKOSISTEM MANGROVE DI SEGARA ANAKAN. Ekosistem mangrove memiliki ordinasi dan pengelompokan yang khas sebagai bentuk adaptasi dari karakteristik lingkungan dan kompetsisi antar jenis. Penelitian ini bertujuan untuk mengembangkan ordinasi spesifik menggunakan hubungan antara kerapatan mangrove dengan kondisi lingkungan. Penelitian dilakukan dengan sistem multidimensi menggunakan kerapatan dan karakteristik lingkungan dengan menggunakan indeks similaritas dan euclidian distance. Hasil penelitian menunjukkan bahwa Segara Anakan Barat (SAB) memiliki 6 wilayah ordonasi, dan Segara Anakan Timur (SAT) memiliki 5 wilayah ordonasi dengan kisaran kerapatan 68-3373 pohon/ha dan 550-2975 pohon/ha. Berdasarkan sifat lingkungan, SAB memiliki kadar nitrat, fosfat, pirit, pH air dan tanah, serta salinitas air masing-masing sebesar 10,57-31,44 mg/lt, 8,44-22,89 mg/lt, 1,03-1,57%, 5,60-7,78, 6,58-7,03, dan 24,15-33,85 ppt. Pada SAT, nitrat, fosfat, pirit, pH air dan tanah, serta salinitas air berada dalam kisaran 19,72-28,98 mg/lt, 10,83-19,72 mg/lt, 1,28-2,91%, 6,35-7,05, 5,91-6,23, dan 18,00-32,33 ppt. Selain itu, penahbisan spesifik menunjukkan bahwa* Avicennia marina*,* Rhizophora stylosa*,* Rhizophora apiculata*, dan* Nypa frutican *memiliki tingkat adaptasi tertinggi untuk tumbuh dan hidup di Laguna Segara Anakan (SAB dan SAT).*

*Kata kunci: Karakteristik lingkungan, pengelompokan mangrove, kerapatan mangrove, ordinasi mangrove, Laguna Segara Anakan*

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# I. INTRODUCTION

Segara Anakan Lagoon (SAL) is a semiclosed estuarine ecosystem that requires specific adaptation from mangrove vegetation as a dominant organism (Hilmi et al., 2021; 2022). The mangrove in Segara Anakan (SAL) must have ability to reduce the impact of salinity (water salinity between 0-40 ppt and soil salinity between 0-7,05 ppt), limited oxygen, muddy soil, and high organic matter (Cavalcante et al. 2021; Hilmi et al. 2021c). Specific adaptations of this vegetation to reduce impact of the environment is the ordination system, which represents as zonation and clustering pattern of the mangrove ecosystem. Furthermore, clustering and ordination pattern describe the adaptation and relationship between mangrove species with environment variables using the indicators of similarity, disimilarity, euclidian distance, and specific correlation among species (Haq et al. 2017; Hilmi et al. 2021c, 2022b). These concepts were developed using a dissimilarity index, which was analyzed with the Euclidian distance index (Haq et al. 2017; Hilmi et al. 2021c, 2022b). The cluster and ordination analyses also explain the multivariate analysis and hierarchical and non-hierarchical methods from the relation model of organisms with environmental properties.(Haq et al. 2017; Hilmi et al. 2021c, 2022b).

Based on previous reports, the dominant species in Segara Anakan Lagoon are Aegiceras *spp*. (*Aegiceras corniculatum*, and *A. floridum*) *Avicennia spp*. (*Avicennia alba*, *A. marina*, *A. officinalis*), *Bruguiera spp* (*Bruguiera gymnorrhiza*, *B. parviflora*, *B. sexangula*), *Callophylum inophylum*, and *Carbera manghas*. Furthermore, others include *Ceriops app* (*Ceriops decandra*, *C. Tagal* ), *Rhizophora spp* (*Rhizophora apiculata*, *R. mucronata*, *R. stylosa*,) *Sonneratia spp* (*Sonneratia alba*, *S. caseolaris*), *Tespia pulpunea*, *Terminalia cattapa*, *Xylocarpus spp*. (*Xylocarpus granatum*, *X. moluccensis*) (Koswara et al. 2017; Hilmi et al. 2021c, b). The distribution of mangrove species in SAL follows the environmental conditions of water and soil salinity, soil texture, water inundation, microorganism diversity, and disturbance (Halwany and Andriani 2015; Hilmi et al. 2017). The distribution of the mangrove species in SAL explains the irregular cluster and zonation. The mangrove zonation refresent the cluster of mangrove to illustrate the adaptation of species to reduce impact of disturbance (Toosi et al. 2022), and climate change, such as storms (Cameron et al. 2019; Branoff 2020; Wang et al. 2020), sea level rise (Latiefa et al. 2018; Cherry and Cherry 2020; Cahoon et al. 2021), seawater inundation (Bullock et al. 2017; Hilmi et al. 2021a, 2022a), sea tide, freshwater and seawater supply (Sufyan et al. 2017; Hilmi et al. 2022c), industrial activity, water pollution, and anthropogenic activity(de Almeida Duarte et al. 2017; Nour et al. 2019). Based on previous studies, clustering, and specific ordination can describe the ecological connectivity of the mangrove ecosystem (d'Acampora et al. 2018), which plays a role in coastal protection, abrasion prevention, sedimentation, nutrient cycling, and mangrove conservation (Doughty et al. 2016).

The mangrove ordination in SAL both of W-SAL and E-SAL also explains the valuable adaptation from the health status, density, diversity, and protecting endangered species (d'Acampora et al. 2018), vertical and horizontal stand structures (Sreelekshmi et al. 2018), as well as species ordination and zonation (Amjad et al. 2014). Ordination shows that vegetation structure is a combination of habitat, environmental conditions, and species distribution (Amjad et al. 2014). It also explains the ability of mangrove vegetation to efficiently use and manage natural resources, as well as the effective approach of utilizing environmental properties to support life and growth (Chen et al. 2015). A previous study stated that ordination and clustering are useful in identifying the relationship between environment properties with organism in an ecosystem, as well as the the index of species diversity, heterogenity. species richness and evenness as adaptation species to reduce impact of environmental gradients (Haq et al. 2017). Furthermore, mangrove ordination can be used to analysis and record species composition, species richness and species adaptation across edaphic, climatic, aquatic ecosystem and topographic variables, to life in the mangrove ecosystem (Haq et al. 2017).

Mangrove ordination in SAL also explains the species distribution, cluster, landscape, and zonation following the adaptation pattern to reduce the unstable environment, and potential disaster to support their continued growth and survival. The mangrove ordination in SAL is the concept of the stability and adaptation of species, which allows them to reduce the effects of unstable environmental properties (Yanuartanti et al. 2015; Hilmi et al. 2019d), conserve carbon (Hilmi et al. 2019b; Azman et al. 2021), lower heavy metal pollution (MacFarlane et al. 2003; Kibria et al. 2016; Zhang et al. 2019; Shi et al. 2020), mitigation of biodiversity loss (Khan et al. 2021) and prevent coastal disasters (Hilmi 2018; Pham et al. 2019; Nur and Hilmi 2021). Therefore, this research had propuse to analysis and develop a specific ordination using the relation between mangrove density and environmental properties in Segara Anakan Lagoon.

## II. MATERIALS AND METHODS

### A. Study Site

This study was conducted in Segara Anakan Lagoon (as a specific ecosystem at the southern coast of Central Java (S 7°39 – S 7°43/E 108°50 – E 109°00)) which is divided into Western and Eastern regions (Holtermann et al. 2009; Nordhaus et al. 2019). Furthermore, the lagoon is home to a mangrove ecosystem that is distributed along several rivers, including Kali Panas (water outlet of Pertamina), Donan (main rivers as outlet system of Holcim and Pertamina), Sapuregel (estuary of Pelawangan Timur), Kembang Kuning (estuary of Pelawangan Timur) (East Segara Anakan Lagoon/ESAL) as well as Citanduy (main river in W-SAL_, Cikonde, and Cibeureum (West Segara Anakan Lagoon/WSAL) (Hilmi et al. 2021b, c). According (Hilmi et al. 2021c) writes that Segara Anakan has soil texture had clay, loam, loamy clay, mud, mud clay, soil nitrate between 0.010-0.22%, soil pyrite between 1.03-3.10%, soil phosphate between 6.85-17.65%,, soil salinity between 0-7.05, and water salinity between 0-40 ppt, soil pH between 5.7-6.92, water pH between 5.6-7.07,. The study site can be shown in Figure 1 and Table 1.

Table 1 shows that West and Segara Anakan have 22 and 20 stations, respectively, with each station containing 5-10 sampling plots. The plots were developed based on the abundance or density of mangrove species, which were dominated by *Rhizophora apiculata*, *R. mucronata*, *R. stylosa*, *Nypa frutican* and *Avicennia marina* (Hilmi, et al., 2021; 2022).

Table 1. The distribution of sample stations in Segara Anakan Lagoon

| West Segara Anakan | | | | East Segara Anakan | | | |
|---|---|---|---|---|---|---|---|
| Stations | number station | Coordinate | | Stations | number station | Coordinate | |
| | | Latitude (S) | Longitude (E) | | | Latitude (S) | Longitude (E) |
| River of Ujung Gagak | 1 station | 07°40'13" | 108°48'43" | Donan | 2 stations | 070 40' 33,98" | 108 59' 56,90" |
| River of Lorogan | 1 station | 07°40'44" | 108°48'30" | Donan Kalipanas | 1 station | 070 42' 10,17" | 108 59' 23,75" |
| River of Majingklak | 1 station | 07°40'32" | 108°48'1" | Donan Pertamina | 1 station | 070 41' 15,49" | 108 59' 43,22" |
| River of Mauara Cawitali | 1 station | 07°41'46" | 108°47'41" | Kembang Kuning 1 | 3 stations | 070 43' 12,88" | 108 55' 42,21" |
| River of Kebuyutan | 1 station | 07°41'13" | 108°47'45" | Kembang Kuning 2 | 4 stations | 070 42' 25,31" | 108 54' 53,56" |
| River of Batu Macan | 1 station | 07°41'38" | 108°47'46" | Muara pelawangan Timur 1 | 1 station | 070 43' 48,07" | 108 59' 10,78" |
| River of Jongor | 1 station | 07°40'23" | 108°48'20" | Muara pelawangan timur 2 | 1 station | 070 43' 20,95" | 108 58' 07,45" |
| River of Muara Legok | 1 station | 07°39'48" | 108°48'13" | Sapuregel 1 | 1 station | 070 42' 54,20" | 108 57' 42,07" |
| River of Kayu Mati | 1 station | 07°39'5" | 108°48'27" | Sapuregel 2 | 2 stations | 070 41' 53,33" | 108 57' 37,81" |

| West Segara Anakan | | | | East Segara Anakan | | | |
|---|---|---|---|---|---|---|---|
| Stations | number station | Coordinate | | Stations | number station | Coordinate | |
| | | Latitude (S) | Longitude (E) | | | Latitude (S) | Longitude (E) |
| River of Langkap | 1 station | 07°38'48" | 108°48'44" | Sleko | 1 station | 070 42' 46,06" | 108 59' 29,10" |
| River of Karang Braja | 1 station | 07°40'59" | 108°48'47" | Tritih | 6 stations | 070 40' 22,17" | 109 0' 33,98" |
| River of Klaces | 1 station | 07°41'5" | 108°49'47" | | | | |
| River of Inti Ujung Gagak | 1 station | 07°40'34" | 108°49'47" | | | | |
| River of Muara Bagian | 1 station | 07°40'58" | 108°51'42" | | | | |
| River of Muara Masigitsela | 1 station | 07°41'24" | 108°50'46" | | | | |
| River of Pertigaan Ujung Alang | 1 station | 07°41'44 | 108°51'39" | | | | |
| River of Ujung Alang | 1 station | 07°42'0" | 108°51'42" | | | | |
| River of Dermaga Ujung Alang | 1 station | 07°42'6" | 108°51'53" | | | | |

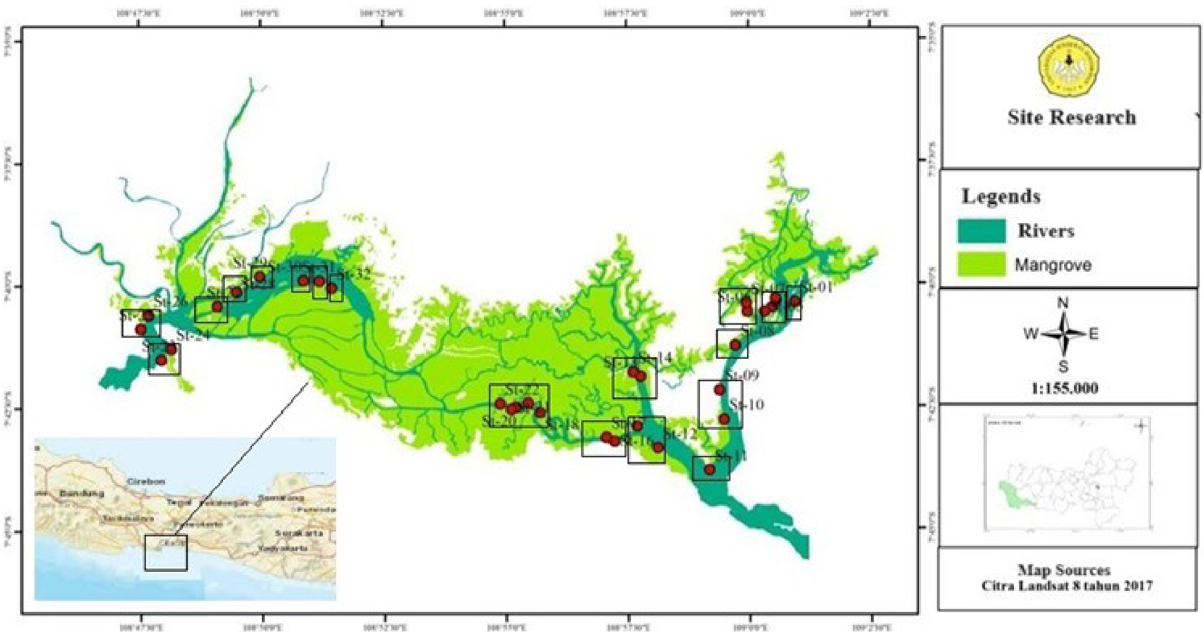


Figure 1. The research site

## B. Sampling Techniques

This study used a two-stage cluster sampling method (Hilmi et al. 2017, 2021c), where the lagoon was divided into two clusters in the first stage, namely West and East Segara Anakan. In the second stage, West and East Segara Anakan (consisted 42 stations) (Hilmi et al. 2017, 2021d; Ismail et al. 2018) were further divided into 22 and 20 stations (following the characteristics of the mangrove ecosystem), respectively. Each station contains 5-10 sampling plots (size plot : 10 m x 10 m) following the species density soil and water salinity.

## C. Study Procedures

**Mangrove density**. was measured using a quadrant and line transect with a sampling plot size of 10mx10m. The measurement was carried out on mangrove trees with a diameter of >4 cm (Hilmi et al. 2019c). Furthermore, the data obtained were analyzed using the vegetation analysis equation (Hilmi 2018; Xiong et al. 2018; Cooray et al. 2021), namely density $= \frac{Trees\ number\ of\ mangrove\ speies}{area}$. Mangrove density was then categorized with system analysis(Hilmi et al. 2019a).

**Environment Properties**. The analysis of environmental properties includes (a) the analysis of water and soil salinity (ppt) using the conductive-photometric method/Hand Refractometer (APHA, 2005; 2012), (b) the analysis of soil and water pH using the Potentiometric method/pH meter (APHA, 2005; 2012); (c) the analysis of Nitrate (NO) (mg 100 g) using the Brucine method (APHA, 2005; 2012), (d) the analysis of Phosphate (PO) (mg 100 g ) using the ascorbic acid method (APHA, 2005; 2012); and (e) the analysis of pyrite (%) using the Calorymeter method.

## D. Data Analysis

### *Mangrove density*

The mangrove density was analyzed by equation: mangrove density = $\frac{total\ number\ of\ mangrove\ trees\ from\ each\ species}{total\ area\ (m^2\ or\ ha)}$ (Umroh et al. 2016; Hilmi et al. 2021c). The mangrove density was used to determine the degradation and stability of mangrove (Hilmi et al. 2020).

### *Mangrove Ordination*

Mangrove ordination was analyzed using the dissimilarity index, euclidian distance index, and vegetation analysis (Haq et al. 2017). Furthermore, the stages involved the calculation of (1) IS (Similarity Index) using the equation, IS = $\frac{2W}{A+B}$ x 100 (w = the smallest individual value from the two stations; A = the sum of total individuals from station A; and B = the sum of total individuals from station B), (2) ID (index dissimilarity) with the formula, ID = 100 – IS, (3) ordination X using the equation X = $\frac{L^2+(dA)^2-(dB)^2}{2L}$, with (L = ID between AX and BX, dA = ID value from station A, dB = ID value from station B, (4) e2 value using the formula e2 = dA2 – X2 (5) ordination Y with the equation Y = $\frac{L^2+(dA)^2-(dB)^2}{2L}$.

### *The Specific Clustering of Mangrove Area and Density of Mangrove Species*

The Specific Clustering of the mangrove area and mangrove species was determined using the mangrove species density (Hilmi et al. 2021c, b). The results obtained were visualized using scatter analysis. The clustering analysis had the option to analyze clusters using mangrove area or mangrove species following the grade of tree density in this ecosystem.

## III. RESULTS AND DISCUSSION

### 1. Mangrove Clustering and Ordination in Segara Anakan

Ordination and clustering of mangrove areas in Segara Anakan Lagoon are presented in Figures 2 and 3. The data showed that the ecosystem in the area can be divided into two big clusters, namely West and East Segara Anakan, with 6 and 5 ordination classes, respectively. Ordination class in the WSAL cluster were estuary of Bagan and Klaces (ordo 1), Pertigaan Sudiro, Ujung Alang Port (ordo 2), Kayu Mati, Langkap (ordo 3), Legok, Pertigaan Ujung Alang, Ujung Alang River, Kali Semak, Estuary of Cawitali, Estuary of Masikitsela, Batu Macan (ordo 4), Majingklak, Karang Braja, Ujung Gagak, Lorongan, (ordo 5), Core of Ujung Gagak, Jongor, Kebuyutan (ordo 6). The characteristics of mangrove ordination explain the similarity of mangrove species and mangrove density. The data in Figure 2 showed that the Estuary of Bagan and Kalces have a high similarity of species distribution and species density. The Estuary of Bagan and Klaces have a high distance with the core of Ujung Gagak and Kebuyutan. Meanwhile, Estuary of Pelawangan Timur 2, Tritih (ordo 1), Kembang Kuning 1, Kembang Kuning 2 (ordo 2), Sapuregerl 1, Sapuregel 2, Pertamina Donan (ordo 3), Kalipanans Donan, Sleko (ordo 4) and Donan dan Estuary Pelawangan Timur 1 (ordo 5) were found in the ESAL cluster.

The clustering showed the similarity of mangrove species dominant and similarity of environmental properties. For example, the estuary of Bagan and Klaces have similarities of species dominant, that are *Sonneratia caseolaris*, *Rhizophora mucronata*, *Aegiceras corniculatum*, *Ceriops tagal*, and similarity of soil nitrate, soil phosphate , soil pyrite, pH (water and soil) and

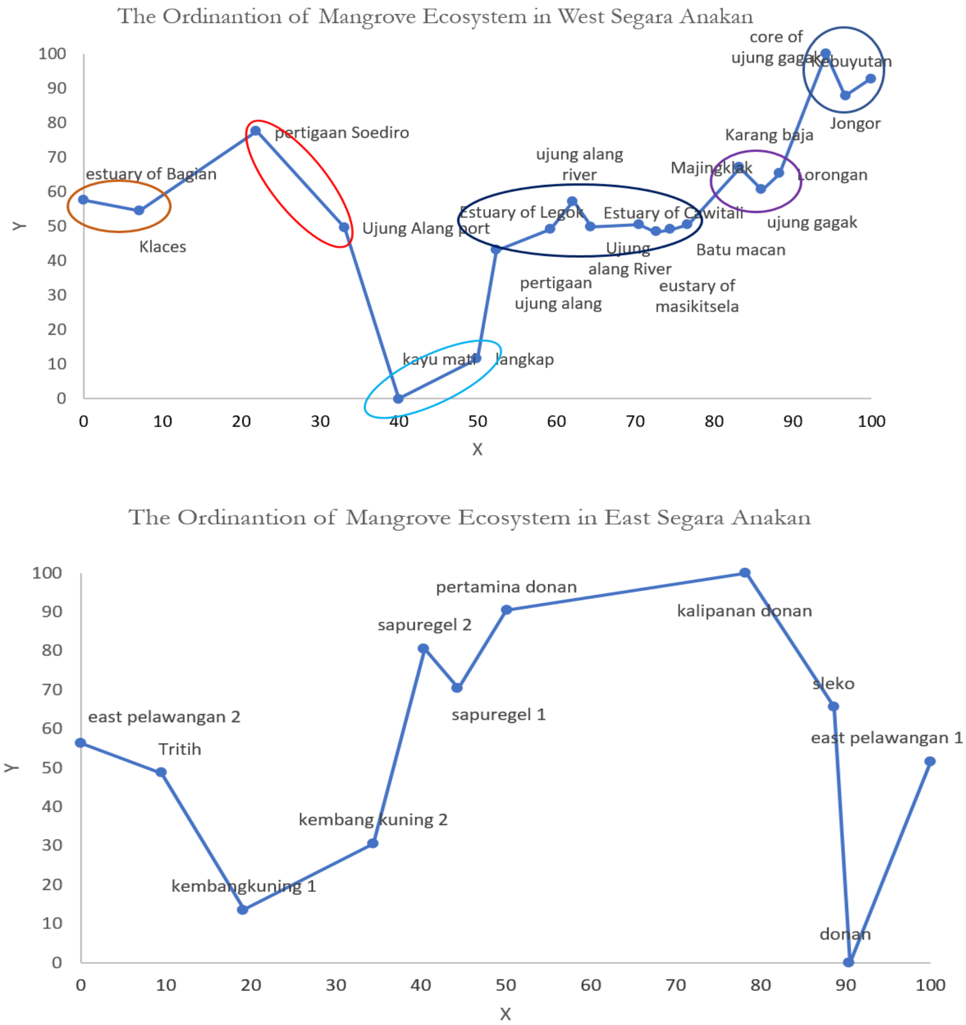


Figure 2. The ordination of the mangrove area in Segara Anakan Lagoon

salinity (water and soil). The other condition, in East Segara Anakan also gave data that Estuary of Pelawangan Timur 2, Tritih has similarity of mangrove species that are *Avicennia marina*, *A. alba*, *Rhizophora apiculata*, *R. mucronata*, *R. Stylosa*, *Sonneratia caseolaris*, *S. alba*, *Nypa frutican*, *Bruguiera sexangula*, *Aegiceras corniculatum* and similarity of environmental properties.

Ordination of mangrove areas in SAL were influenced by several factors, including species distribution and dominance, environmental properties, mangrove association (Barreto et al. 2016; Datta and Deb 2017), species competition (Masuda et al. 2017; Bathmann et al. 2021), solar energy, nutrient, mineral, and water (Amjad et al. 2014; Sreelekshmi et al. 2018; Xiong et al. 2018). Furthermore, the existence of *Rhizophora mucronata*, *R. apiculata*, *R. stylosa*, *Sonneratia caseolaris*, *Avicennia marina*, and *Nypa frutican* supported the development of mangrove ordination, clustering and zonation.

## 2. Ordination and Mangrove Clustering Based on Environmental Properties

Table 2 provides an overview of mangrove clustering in Segara Anakan. Clustering in this region was developed by several factors, including environmental properties, such as phosphate, pyrite, pH, and salinity. The data showed that West Segara Anakan had nitrate, phosphate, pyrite, water pH, soil pH, and salinity range of 10.57-31.44 mg/l, 8.44-22.89


Note : A. the lagoon and mangrove ecosystems in WSAL, B = The lagoon and mangrove ecosystems in ESAL, C= The beach ecosystem in WSAL, D = the sedimentation factor in the mangrove ecosystem,25

Figure 3. The viewing ordination of the research location in Segara Anakan Lagoon

mg/l, 1.03-1.57 %, 5.60-7.78, 6.58-7.03, and 24.15-33.85 ppt, respectively. Meanwhile, East Segara Anakan had nitrate, phosphate, pyrite, water pH, soil pH, and water salinity range of 19.72-28,98 mg/l, 10.83-19.72 mg/l, 1.28-2,91 %, 6.35-7.07, 5.91 – 6.23, and 18.00-32.33 ppt, respectively.

The environmental properties in the study location showed that soil pH, soil salinity, and phosphate have a significant correlation (but only have a score between 0.15-0.22/ weak correlation) with vegetation life and growth. These properties were also crucial factors that supported the development of mangrove species association and clustering (Datta and Deb 2017). But in Segara Anakan Cilacap voth of WSAL and ESAL are not clear clustering and zonation pattern, because the distribution of environment properties haven't specific clustering. Basically, the ordination, clustering, and zonation also are influenced by the distance from the ocean and wind buffers area, mangrove canopy cover, the height of vegetation above the soil surface, water inundation, tidal inundation, pollution, and the mangrove degradation (Osland et al. 2019; Hilmi et al. 2022c). Similar to this condition, Radabaugh et al. (2020) also highlighted the critical role of soil properties in the strengthening of species in fringe mangrove and basin forests.

Similar to Segara Anakan, Sullivan et al. (2021) also reported that the salinity and $NO_2$ levels in mangrove swamps were 25.24–28.33 ppt and 0.006-0.011 mg/L. In Myanmar, The water salinity ranged from 14.4±3.0-28.8±0.5 PSU (Win et al. 2019). The water salinity and $NO_2$ give a high impact on the mangrove ecosystem because of the reduction of N assimilation rate for $NO_3^-$ and $NH_4^+$ as well as inhibit the association enzyme (Shiau et al.

Table 2. The ordination of environment properties in Segara Anakan Lagoon

| Ordi-nation | mangrove area | mangrove density | | Environment properties | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Soil Nitrate | Soil Phosphate | Soil Pyrite | pH | | Water salinity |
| | | trees/ha | | mg/l | mg/l | ( % ) | Water | Soil | (ppt) |
| | | min | max | | | | | | |
| West Segar Anakan | | | | | | | | | |
| 1 | estuaty of bagian and klaces | 145-176 | 633-1300 | 10,57-20,86 | 10,67-18,22 | 1,12-1,41 | 7,40-7,65 | 6,67-6,99 | 28,85-31,15 |
| 2 | pertigaan sudiro, ujung alang port, | 68-363 | 599-1899 | 13,43-22,86 | 11,38-21,78 | 1,03-1,39 | 7,50-7.78 | 6,58-6,93 | 30,15-31,85 |
| 3 | kayu mati, langkap | 83-279 | 800-1567 | 14,06-26,86 | 16,22-22,89 | 1,20-1,34 | 7,40-7,60 | 6,60-6,72 | 26,85-30,85 |
| 4 | estuary of legok, pertigaan ujung alang, Ujung Alang River, Kali Semak, Estuary of Cawitali, Estuary of Masikitsela, Batu macan | 47-600 | 600-3373 | 12,00-28,57 | 12,00-21,33 | 1,04-1,38 | 5,90-6,12 | 6,58-6,83 | 25,65-33,15 |
| 5 | Majingklak, Karang Braja, Ujung Gagak, Lorongan, | 10-422 | 433-2167 | 16,86-31,44 | 12,44-21,56 | 1,26-1,57 | 5,60-5,72 | 6,67-7,03 | 24,15-29,85 |
| 6 | Core of Ujung Gagak, Jongor, Kebuyutan | 79-732 | 832-3367 | 17,47-24,57 | 8,44-18,04 | 1,24-1,49 | 5,60-5,72 | 6,56-6,68 | 27,65-33,85 |
| East Segara Anakan | | | | | | | | | |
| 1 | Estuary of Pelawangan Timur 2, Tritih | 631-919 | 2150-2553 | 19,77-28,91 | 13,24-17,33 | 1,38-2,89 | 6,67-7,07 | 6,01-6,20 | 25,33-31,00 |
| 2 | Kembang Ku ning 1, Kembang Kuning 2 | 550-810 | 1425-1833 | 21,08-28,63 | 10,83-19,72 | 1,63-2,88 | 6,70-6,90 | 6,00-6,09 | 28,00-30,00 |
| 3 | Sapuregerl 1, Sapuregel 2, Pertamina Donan | 630-880 | 1933-2800 | 23,61-28,73 | 16,45-19,22 | 1,83-2,82 | 6,35-6,97 | 5,94-6,23 | 28,33-31,00 |
| 4 | Kalipanans donan, Sleko | 702-850 | 2763-2975 | 20,82-27,12 | 16,55-18,91 | 1,28-2,91 | 6,76-6,83 | 5,91-6,03 | 18,00-28,67 |
| 5 | Donan dan Estuary Pelawangan Timur 1 | 680-792 | 2208-2756 | 19,72-28,98 | 13,14-17,33 | 1,40-2,89 | 6,54-7,05 | 6,03-6,22 | 18,00-32,33 |

2017b, a; Wang et al. 2018). Mangrove species must have the adaptation patterns to eliminate the ieffect of environmental conditions, including water salinity that can affect fine root function (Ahmed et al. 2021), as well as develop a relationship with microbial respiration activity (Davies et al. 2017).

Other properties, the distributions of pyrite percent of soil in Segara Anakan between 1.28-2,91 % more than the potential of pyrit from (Ding et al. 2014) between 1.0770.41 wt% and 0.6270.32 wt% also give impact to support clustering pattern of mangrove species. Basically, pyrite existed in three forms, including framboidal aggregates, minute crystals, and large solitary crystals. The observation showed that the dominant forms were minute crystals (<2 pm) and framboidal aggregates (Ding et al. 2014). Ding et al. (2014) writes that this condition give influence for the distribution of mangrove species, such as *Bruguiera cylinderica*, *Kendelia candel*, *Sonneratia apetala*, *Nypa fruitican*, *Xylocarpus granatum*, *Avicennia alba*, *Cerbera odollam*, *Erythrina indica*, *Heritiera littoralis*, *Kendelia candel*, *Rhizophora apiculata*, *Sonneratia caseolaris*, *Sapium indicum*, *Brownlowia tersa*.

## 3. Mangrove Ordination and Clustering Using the Indicator of Mangrove Density

Mangrove clustering and ordination based on the indicator of species density are presented in Table 3. Species density data showed that *Rhizophora stylosa*, *R. apiculata*, *Avicennia marina* and *Nypa frutican* were the dominant species. The second dominant were *Avicennia alba*, *Rhizophora mucronata*, *Sonneartia alba*, *S. caseolaris*, and *Bruguiera gymnorrhiza*, and co-dominant

Table 3. The mangrove ordination based on species density in Segara Anakan Lagoon

| Ordination | Stations | Mangrove species | Mangrove density | |
|---|---|---|---|---|
| | | | Density | Class density (Hilmi et al. 2020) |
| | | West Segara Anakan | | |
| 1 | estuaty of bagian and Klaces | *Sonneratia caseolaris, Rhizophora mucronata, Aegiceras corniculatum, Ceriops tagal* | 145-1300 | very rare- rare |
| 2 | pertigaan sudiro, ujung alang port, | *Avicennia marina, Avicennia officinalis, Ceriops tagal, Bruguiera gymnorrhiza, Rhizophora apiculata, Rhizophora mucronata, Sonneratia caseolaris,.* | 68-1899 | very rare-moderate |
| 3 | kayu mati, langkap | *Avicennia alba, Avicennia marina, Sonneratia caseolaris* | 83-1567 | very rare- rare |
| 4 | estuary of legok, pertigaan ujung alang, Ujung Alang River, Kali Semak, Estuary of Cawitali, Estuary of Masikitsela, Batu macan | *Aegiceras corniculatum, Aegiceras florisum, Avicennia officinalis, Avicennia alba , Avicennia marina, Ceriops tagal, Sonneratia caseolaris, Sonneratia alba,, Xylocarpus granatum* | 47-3373 | very rare-very dense |
| 5 | Majingklak, Karang Braja, Ujung Gagak, Lorongan, | *Avicennia alba, Avicennia marina, Rhizophora stylosa,, Sonneratia caseolaris, Sonneratia alba, Xylocarpus granatum* | 10-2167 | very rare-moderate |
| 6 | Core of Ujung Gagak, Jongor, Kebuyutan | *Avicennia marina, Aegiceras corniculatum, Bruguiera gymnorrhiza, Ceriops tagal, Rhizophora mucronata, Sonneratia alba* | 79-3367 | very rare-very dense |
| | | *East Segara Anakan* | | |
| 1 | Estuary of Pelawangan Timur 2, Tritih | *Avicennia marina, Avicennia alba, Aegiceras corniculatum, Bruguiera sexangula, Nypa frutican,, Rhizophora apiculata, Rhizophora mucronata, Rhizophora Stylosa, Sonneratia caseolaris, Sonneratia alba,* | 631-2553 | rare-dense |
| 2 | Kembang Kuning 1, Kembang Kuning 2 | *Avicennia marina, , Bruguiera gymnorrhiza, Aegiceras corniculatum, Ceriops tagal, Ceriops tagal, Excoecaria agallocha, Hibiscus tiliaceus, Nypa frutican,, Rhizophora apiculata, Rhizophora mucronata, Rhizophora Stylosa, Xylocarpus granatum,* | 550-1833 | rare-moderate |
| 3 | Sapuregerl 1, Sapuregel 2, Pertamina Donan | *Aegiceras corniculatum, Bruguiera gymnorrhiza, Ceriops tagal, Ceriops tagal, Heritiera litoralis, Nypa frutican , Rhizophora apiculata,Rhizophora mucronata, Rhizophora Stylosa,* | 630-2800 | rare-dense |
| 4 | Kalipanans donan, Sleko | *Avicennia marina, Avicennia alba, Aegiceras corniculatum,, Bruguiera gymnorrhiza, Bruguiera sexangula, Ceriops tagal, Rhizophora apiculata, Rhizophora mucronata, Rhizophora Stylosa, Sonneratia alba, Nypa frutican,* | 702-2975 | rare-dense |
| 5 | Donan dan Estuary Pelawangan Timur 1 | *Avicennia marina, Avicennia alba, Aegiceras corniculatum,, Bruguiera gymnorrhiza, Bruguiera sexangula, Ceriops tagal, Nypa frutican,, Rhizophora apiculata, Rhizophora mucronata, Sonneratia caseolaris, Sonneratia alba,* | 680-2756 | rare-dense |

were followed by *Bruguiera sexangula*, *Ceriops tagal*, *Ceriops decandra*, *Aegiceras corniculatum* and *Xylocarpus granatum*. Furthermore, the recessive species included *Heritiera littoralis*, *Hibiscus tiliaceus*, *Excoecaria agallocha*, *Avicennia officinalis*, and *Xylocarpus mollucensis*.

The mangrove distribution using the ordination system has a different pattern from Sreelekshmi et al. (2018) who noted that the Southwest Coast of India has been dominated by *Avicennia marina*, *A. alba*, *Avicennia officinalis*, *Acrostichum aureum*. *Aegiceras corniculatum*, *Bruguiera sexangula*, *B. cylindrica*, *Ceriops tagal*, *Kandelia candel*, *Lumnitzera racemosa*, *Excoecaria agallocha*, *E. indica*, *Bruguiera gymnorrhiza*, *Rhizophora mucronata*, *R. Apiculata*, *Sonneratia alba* and *S. caseolaris*, Cooray et al. (2021a) reported that Rekawa Lagoon had been dominated by *Lumnitzera racemosa* (32.6%), *Avicennia marina* (21.0%), *Ceriops tagal* (15.4%) and *Excoecaria agallocha* (11.1%), while Excoecaria agallocha (34.7%), *Rhizophora apiculata* (23.3%), and *Rhizophora mucronata*

(15.2%) dominated the other area in Rekwa Lagoon. Furthermore, Puttalam-Kalpitiya was dominated by *Avicennia marina* (83.8%), and the Batticaloa Lagoon was dominated by *Excoecaria agallocha* (71.7%). Different conditions were also shown by the mangrove dominant in Negombo Lagoon which was dominated by *Avicennia marina* (42.1%), *Rhizophora mucronata* (21.1%), and *Lumnitzera racemosa* (19.2%)

The ordination analysis using the Principal Component Analysis (PCA) aims to determine specific locations dominated by certain and dominant species (Chen et al. 2015). Datta and Deb (2017) reported that mangrove in Indian Sunderbans has extensive mixed plantations, such as *Avicennia marina*, *Ceriops tagal*, and *Excoecaria agallocha* (dominant species). The co-dominant group comprised *Xylocarpus varieties*, *Nypa fruticans*, *Phoenix paludosa*, and *Aegiceras corniculatum*. Meanwhile, the recessive group consisted of *Avicennia alba*, *Ceriops tagal*, *Excoecaria agallocha*, and *Bruguiera gymnorhiza* (Datta and Deb 2017). The other area, Myanmar has different clusters and ordination which was dominated by *Bruguiera cylinderica*, *Kendelia candel*, *Sonneratia apetala*, *Nypa fruitican*, *Xylocarpus granatum*, *Avicennia alba*, *Cerbera odollam*, *Erythrina indica*, *Heritiera littoralis*, *Rhizophora apiculata*, *Sonneratia caseolaris*, *Sapium indicum*, and *Brownlowia tersa*.

## 4. The Spesific Clustering of Mangrove Species

### *The Specific Clustering of Mangrove Area*

The specific clustering of mangroves in SAL is presented in Figure 4. The data showed that the ESAL had nine clusters of mangrove species density, but, the WSAL had six clusters. The different clustering of mangrove areas in East and West Segara Anakan described the mangrove ability to grow and live in specific environments because these areas have different oceanography (Karl and Church 2017), salinity (Junaidi et al. 2022), soil texture, sea tide, sea current, sedimentation (Sari et al. 2016; Hilmi et al. 2021d), and water pollution (Costa-Böddeker et al. 2020; Chai et al. 2020). West Segara Anakan had higher sediment potency, water salinity, sea tide, and sea current, but its water pollutant was lower compared to East Segara Anakan. Various environmental conditions served as trigger factors for the survival and growth of different species. the different conditions also affected the activity of mangrove species to develop zonation, cluster, association, and ordination.

The mangrove area in ESAL had a specific cluster of mangrove areas that was lower than WSAL. The specific cluster of mangrove area in ESAL had 6 clusters, while in WSAL had 9 clusters. The different numbers of clusters were influenced by the different dominant species, the characteristics of water and soil salinity, water inundation, and potential sedimentation (Sari 2016; Hilmi et al. 2021a). The specific ordination of mangrove areas also explains the adaptation pattern of mangrove species to reduce the effects of environmental conditions in Segara Anakan.

The clustering of mangrove area can be divided into (1) East Segara Anakan is developed by *Aegiceras corniculatum* (species cluster 1), *Avicennia alba* and *Avicennia marina* (species cluster 2), *Bruguiera sexangular*, *B. parviflora* and *B. gymnorrhiza* (species cluster 3), *Ceriops tagal* and *Ceriops decandra* (species cluster 4), *Excoecaria agallocha-Heritiera litoralis* (species cluster 5), *Nypa frutican-Rhizophora apiculata* (species cluster 6), *Rhizophora mucronata-Rhizophora stylosa* (species cluster 7), *Sonneratia caseolaris-Sonneratia alba* (species cluster 8) and *Xylocarpus granatum-Xylocarpus molucensis* (species cluster 9). (2) West Segara Anakan is developed by *Aegiceras corniculatum* (species cluster 1), *Avicennia alba-Avicennia marina* (species cluster 2), *Bruguiera gymnorrhiza* and *Ceriops tagal* (species cluster 3), *Rhizophora apiculata*, *R. mucronate* and *R. stylosa* (species cluster 4), *Sonneratia caseolaris-Sonneratia alba* (species cluster 5) and *Xylocarpus granatum-Xylocarpus molucensis* (species cluster 6).

Species clusters show similar adaptations, requirements for environmental factors such

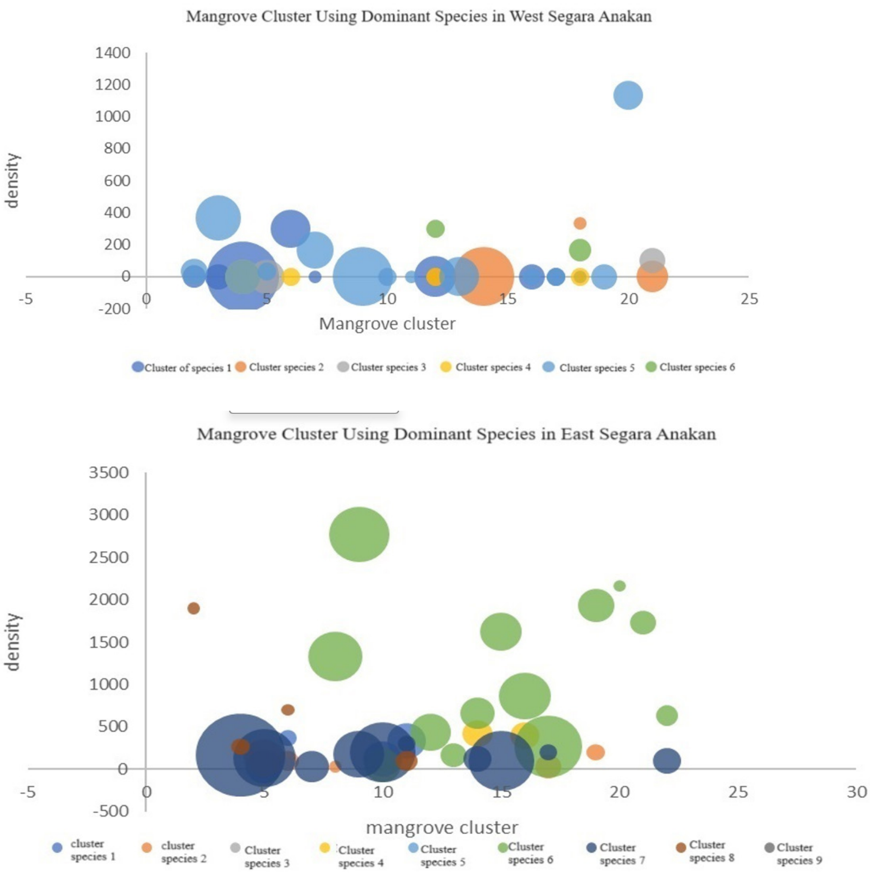


Figure 4. The specific clustering of mangrove areas in Segara Anakan

as salinity, pH, soil fertility, pyrite (Kayalvizhi and Kathiresan 2019; Bomer et al. 2020; Khan et al. 2021), growth ability, and mangrove affinity (Hilmi et al. 2021c; Marlianingrum et al. 2021). Species clusters also explain mangrove succession and mangrove zonation, indicating mangrove regeneration in Segara Anakan Lagoon.

***The specific clustering of mangrove species***

Specific clustering of mangrove species using species density in Segara Anakan Lagoon is shown in Figure 5. The data in Figure 5 showed that the mangrove species density ranged from <100–400 trees/ha (cluster 1/very rare), 600–800 trees/ha (cluster 2/rare), 800–1000 trees/ha (cluster 3/rare) and >1000 trees/ha (cluster 4/moderate). The Segara Anakan was dominated by the rare category, namely 100-400 trees/ha. The dominance and density of mangrove species were influenced by mangrove damage, delayed mortality, and early recovery (Radabaugh et al. 2020). Species density and species distribution in Segara Anakan were different from those in the Mekong Area of Vietnam, which was dominated by *Avicennia*, *Aegiceras corniculatum*, and *Nypa fruticans*, followed by *Sonneratia* and *Nypa frutican* as second and third dominants, respectively (Bullock et al. 2017). East Segara Anakan had dominant species *Nypa frutican* between 433-2775 trees/ha, *Rhizophora apiculata* with a density between 275 – 1.067 trees/ha, and Rhizophora mucronata with 233 – 1633 trees/ha. But West Segara Anakan was dominated by Sonneratia caseolaris with 133 – 700 trees/ha), Sonneratia alba with 100 – 1133 trees/ha, and Avicennia marina with 100 – 1000 trees/ha.

The number and species density of mangrove ecosystems in ESAL was larger

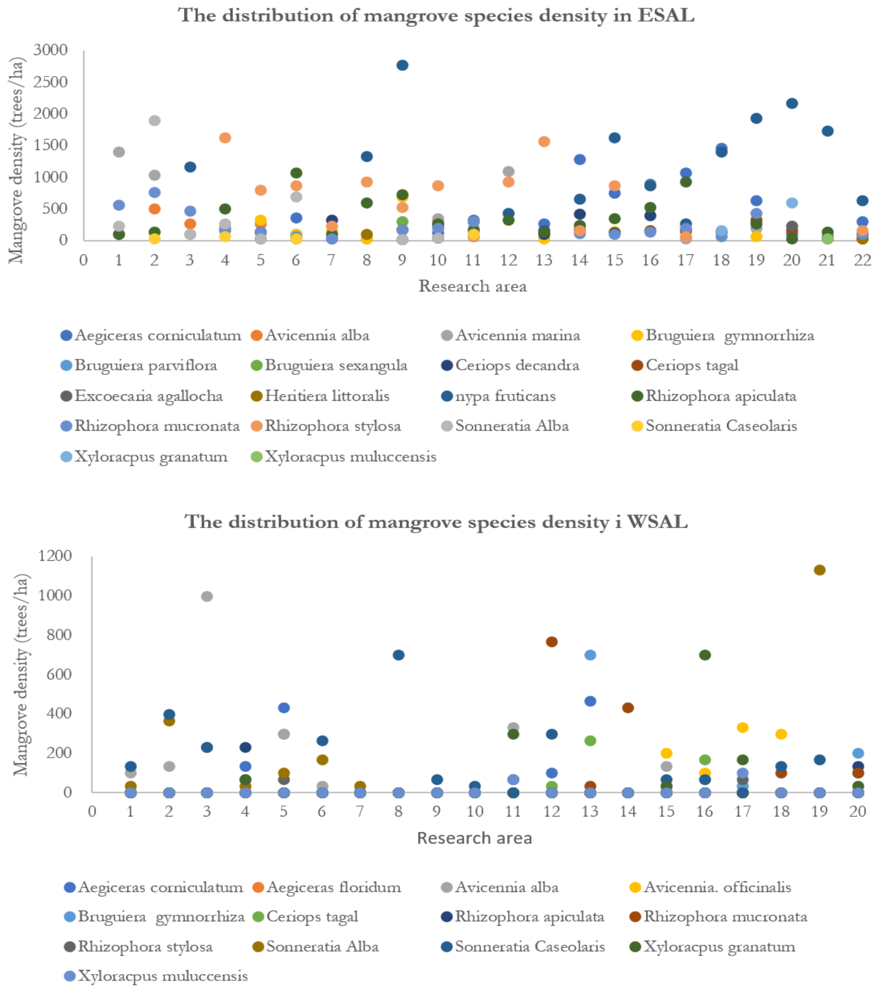


Figure 5. The clustering distribution of species density in Segara Anakan Lagoon

than that in WSAL. The data also explained that *Avicennia marina*, *Nypa frutican*, *Rhizophora styllosa* and *Rhizophora apiculate* were dominant species, in both WSAL or ESAL The clustering and ordination of mangrove species reflected the ability of mangrove species to live and growth in the specific environment properties in WSAL and ESAL.

## IV. CONCLUSION

Mangrove ordination and clustering in Segara Anakan explain the relationship between species density, water quality, and soil quality, which represented a specific adaptation pattern to life and growth in the lagoon ecosystem. *Avicennia marina*, *Nypa frutican*, *Rhizophora mucronata*, *Rhizophora apiculata*, *Rhizophora stylosa* and *Sonneratia caseolaris* as dominant species which supported the development of mangrove ordination, clustering, and zonation. The ordination of the mangrove ecosystem in WSAL has 6 ordos, but the mangrove ecosystem in ESAL has only 5 ordos. The specific ordination of mangrove species is dominated by trees density ranging from <100–400 trees/ha (very rare).

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