THE MONITORING OF MANGROVE VEGETATION COMMUNITY STRUCTURE IN SEGARA ANAKAN CILACAP FOR THE PERIOD OF 2009 AND 2015

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ABSTRACT

Over-exploitation and land-use conversion into aquaculture ponds have damaged the mangrove ecosystem. The extreme environment condition resulting in sedimentation led to the reduction of lagoon area and eventually of mangrove vegetation community. It was, therefore, necessary to conduct sustainable mangrove management through the monitoring system. Changes in the mangrove community were monitored periodically by evaluating width changes and land cover distribution. This study aimed to monitor the structure of mangrove community and changes occurring for the period of 2009 and 2015 by applying the purposive sampling method. The samples were mangrove vegetation community at several different locations. The samples were taken from nine stations with three replicates. There were 14 species of mangrove from six families. Mangrove trees were mostly found in the western area, while mangrove sapling and seedling mostly found in the east. Most of the stations showed a moderate level of diversity index and good productivity except station four. Mangrove forest in Segara Anakan had significant changes from 2009 up to 2015 due to the reduction of mangrove diversity.

KEY WORDS: Segara Anakan, Mangrove, Monitoring, Vegetation community

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INTRODUCTION

Mangrove, according to Steenis (1978), is forest vegetation that grows in the tidal zone. Nybakken (1993) defined mangrove forests as a general term to describe a tropical coast community dominated by some unique tree species or shrubs capable of growing in salt waters. Indonesia has 43 true mangrove species consisted of 24 families, 41 genera, and 75 species with only 26 species have tree habitus (Soekardjo, 1993).

Mangrove forest areas commonly spread throughout the Indonesian coast. They grow in tidal areas that flood the river along the coast (Tarigan, 2008). Segara Anakan Lagoon, Cilacap, located on the southern shore, is the largest mangrove area in Java created through the protection of Nusakambangan Island from sea waves and freshwater input of the Citanduy River (Setyawan *et al.*, 2003). Geographically, Segara Anakan Lagoon is on coordinates 7°35–7°50' Southern Latitude and 108°45'–109°01' Eastern Longitude. Based on Badan Pengelola Kawasan Segara Anakan (BPKSA), the lagoon area was 6.450 ha in 1903, and decline to 6,060 ha in 1,939 (390 ha in 36 years). It, again, was down to 4,290 ha in 1971, then reached 2,906 ha in 1984. In the next decade, the area decreased to 1,331–1,575 ha followed by a further decrease of 834 ha after 11 years (2005). Thus, in 21 years, 2,072 ha disappeared (98.6 ha per year) (Sukardi, 2010).

Human activities interfere Segara Anakan area from year to year. Unsustainable land use of urban areas and forest degradation of the upper river regions resulted in high erosion rates in rivers flowing into the lagoon. The sedimentation causes the lagoon to shallow and narrow. Besides, mangrove forest in Segara Anakan also experiences enormous environmental pressures due to illegal logging, which decreases the area of mangrove forest. People that live around the mangrove forest do illegal logging for economic reasons such as opening the land for fisheries, agriculture, settlements, building materials, and raw materials for charcoal industry (Sukardi, 2010). These disturbances change the mangrove community structure of Segara Anakan Cilacap. The rate of changes in mangrove vegetation structure should be periodically monitored as an initial step to record the presence and abundance of mangrove and to analyze the effect of increasing human activity. The monitoring provides accurate and continuous information on mangrove distribution in Segara Anakan.

This research evaluated the condition of mangrove vegetation in Segara Anakan Cilacap with emphasis on the changes of mangrove vegetation community structure in 2015. The goals were to record the community structure of mangrove vegetation and its change in Segara Anakan Cilacap for the period of 2009 and 2015.

METHODS

The observation had been done for six months (March–August 2015) in mangrove forest area in Segara Anakan Cilacap (Figure 1). The species identification was carried out in Laboratory of International Tropical Marine and Earth Sciences (ITMEL), Universitas Jenderal Soedirman, and soil analysis was in Laboratory of Mycology, Faculty of Biology, Universitas Jenderal Soedirman.

The tools required were GPS, boat, machete, meter roll, camera, soil tester, stationery, plastic bag, cutter, trace paper, hand-refractosalinometer, analytical scale, measuring tape, thermometer, and laptop. The materials were mangrove vegetation in Segara Anakan. The survey method with purposive sampling technique was applied, and the sampling plot selection was based on the recorded locations in 2009 study covering nine stations.

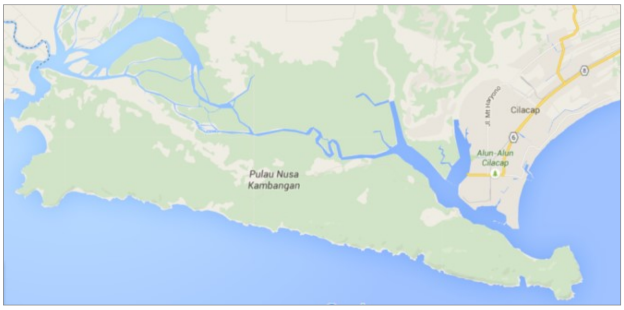

Figure 1. Sampling location (Source: Google map 2015)

The dependent variable was mangrove vegetation community recorded of the year of 2009 and 2015, and the independent variable was the change of environmental factors. The parameters measured consisted of the number of species, the number of individuals per species, diameter of the tree trunk measured at breast height, and environmental factors including water and air temperature, water salinity, soil pH and moisture, water, and soil organic matter content.

Every observation station was divided into three plots separated 50 meters from each other where the mangrove vegetation was recorded. Trees with a diameter more than 10 cm were sampled in 10 x 10 m plot, sapling with a diameter of 1–10 cm used 5 x 5 m plot, seedlings and herbs were from 1 x 1 m plot. The measurement of mangrove vegetation was conducted by recording the data of species richness, species individual number, and diameter breast height (DBH) of the tree trunk. The vegetation was categorized into three; tree with a diameter more than 10 cm and 1.5 m height, and sapling with a diameter less than 10 cm and more than 1.5 m height (Ningsih, 2008). The formula followed was:

$$\text{DBH} = \frac{\text{trunk diameter}}{3.14}$$

The evaluated environmental factors measured around the sampling point included water and air temperature, soil pH, salinity, and soil moisture. They were measured by submerging the device into the water then recorded the obtained values. The air temperature was measured with a thermometer hang around the sampling point. Water salinity was taken with hand-refractosalinometer by dripping water samples on hand-refractosalinometer glass. Soil pH was recorded with soil tester by placing a soil tester into the ground, and recorded the pH after it showed a constant value. Soil moisture was taken by immersing the soil tester on the substrate for 10 minutes (APHA, 1985). Soil texture was identified by pipetting method. The soil water content was measured by drying soil samples in an oven at 40°C for three days. The weight difference between the initial and the dried soil sample was the water content. Organic matter content measured by furnacing soil sample for four hours at 400°C, the weight loss of dry soil from combustion process was the organic material.

The mangrove vegetation community structure was analyzed with importance value based on Mueller-Dombois & Ellenberg (1974) as follow:

$$\text{Density} = \frac{\text{number of a species}}{\text{total area sampled}}$$

$$\text{Relative Density (RD)} = \frac{\text{density of a species}}{\text{total density of all species}} \text{x } 100\%$$

$$\text{Frequency} = \frac{\text{area of plots in which a species occurs}}{\text{total area sampled}}$$

$$\text{Relative Frequency (RF)} = \frac{\text{frequency of a species}}{\text{total frequency of all species}} \text{x } 100\%$$

$$\text{Dominance} = \frac{\text{total basal area of a species}}{\text{total area sampled}}$$

$$\text{Relative Dominance (RD)} = \frac{\text{dominance of a species}}{\text{total dominance of all species}} \text{x } 100\%$$

Importance Value Index (trees and sapling):

= RD + RFR + RD

Importance Value Index (seedlings):

= RD + RF

Shannon Index (English *et al*., 1994):

$$\text{SI} = -\sum \text{IV}_\text{i}/\text{IV x ln}(\text{IV}_\text{i}/\text{IV})$$

Where,
SI = Shannon Index
IV_i = Importance Value of a species i (*Importance Value*)
IV = Total Importance Value of all species (*Importance Value*)

The value of species diversity index according to Shannon was described as follow:

SI > 3 = high diversity.
1 ≤ SI ≤ 3 = moderate diversity.
SI < 1 = low diversity.

Bray-Curtis Similarity Index:

$$\text{IS} = \frac{2\text{c}}{\text{a} + \text{b}} \text{x } 100\%$$

Where,
IS = *Index of similarity*
a = Species number in location a
b = Species number in location b
c = Species number in location a and b

Pelu (1991) grouped the value of similarity index into:

0–25% = no similarity
26–50% = low similarity
51–75% = medium similarity
76–95% = high similarity
96–100% = similar

The analysis of changes in mangrove vegetation communities in 2009 and 2015 was conducted with descriptive analysis by comparing mangrove vegetation communities in 2009 with 2015.

RESULT AND DISCUSSION

We observed 14 species from seven families of mangrove. They were *Aegiceras corniculatum*, *Avicennia alba*, *Avicennia marina*, *Bruguiera gymnorrhiza*, *Bruguiera sexangula*, *Ceriops decandra*, *Ceriops tagal*, *Rhizophora apiculata*, *Rhizophora mucronata*, *Sonneratia alba*, *Sonneratia caseolaris*, *Xylocarpus granatum*, *Xylocarpus moluccensis*, and *Nypa fruticans*. Three shrubby herbs from 2 families were recorded, *Acanthus ebracteatus*, *Acanthus ilicifolius*, and *Derris trifoliate*. According to Sugiarto & Ekariyono (1996), diversity of mangrove plants depended on the water salinity and the flooded area. Thus the species grown in the particular field were affected by water logging and salinity fluctuation.

Setyawan *et al.*, (2002) added that physical changes in mangrove forests caused changes in mangrove habitat.

Five mangrove species of tree category included *A. alba*, *A. marina*, *S. alba*, *S. caseolaris*, and *X. granatum*. Sapling category consisted of 14 species i.e. *A. corniculatum*, *A. alba*, *A. marina*, *B. gymnorrhiza*, *B. sexangula*, *C. decandra*, *C. tagal*, *R. apiculata*, *R. mucronata*, *S. alba*, *S. caseolaris*, *X. granatum*, *X. moluccensis*, and *Nypa fruticans*. Nine species of seedlings category were *A. corniculatum*, *A. alba*, *B. gymnorrhiza*, *B. sexangula*, *C. decandra*, *C. tagal*, *R. apiculata*, *S. alba*, and *N. fruticans*.

Species of tree categories included *A. alba*, *A. marina*, *S. alba*, *S. caseolaris*, and *X. granatum*, and their number of individuals was presented in Figure 2. *A. marina* inhabited station 1 (salinity of 26.5‰), and *A. alba* mostly lived in station 9 (salinity of 30‰). The salinity in these stations was higher than that of the others. This condition was supported by Chapman (1975) that *Avicennia* spp. was a pioneer species that lived towards the sea, and tolerated high salinity (up to 35‰). It was a genus that grew in a wider range of salinity tolerance compared to the other genera. Logging activity for the needs of daily firewood, production of small coconut sugar industry, and fish processing caused the low abundance of trees mangrove species.

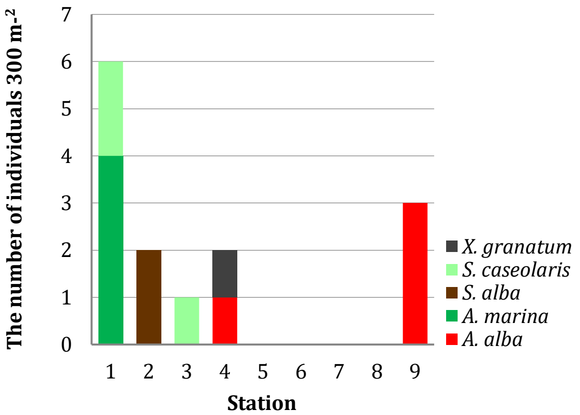

Figure 2. The number of individuals of each major mangrove tree species in every station

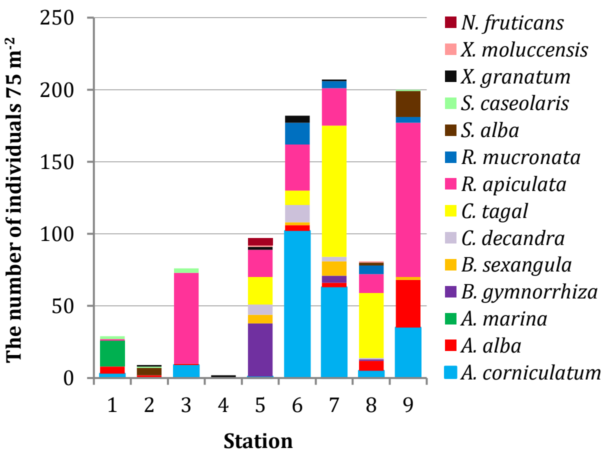

Figure 3. The number of individuals of each mangrove species sapling category in every station

Sapling mangrove species, *R. apiculata* and *A. corniculatum* grew in all stations, except station 2 and 4 (Figure 3). Their presence was caused by the muddy substrate susceptible for *Rhizopora* growth (Setyawan *et al.*, 2002). Bengen (2001) reported that *Rhizopora* grew in delicate substrate had the specific life cycle and wider dispersion.

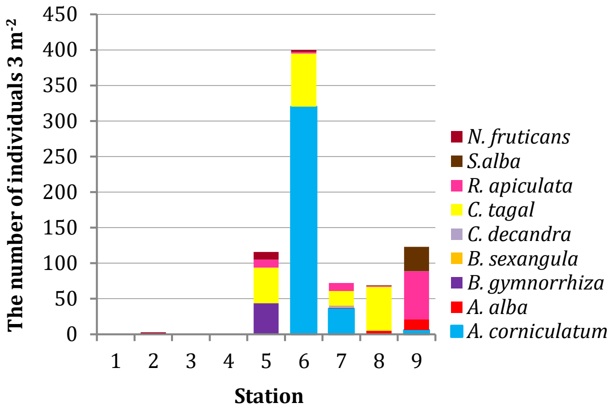

Figure 4. The number of individuals mangrove seedling species in every station

Mangrove vegetation structure for seedlings category consisted of 783 individuals (Figure 4). Station 6 showed the highest abundance. The most dominant species in this station was *A. corniculatum* with total 320 individuals. *B. sexangula* was the least species grew with the only one individual in station 7. This finding was consistent with Noor *et al.*, (1999). Even though *A. corniculatum* does not have aerial roots, it has a high tolerance to various soil type (substrate).

Table 1. Importance Value Index

No.	Spesies	Importance Value Index (%)		
		Trees	Saplings	Seedlings
1	*A. corniculatum*	-	42.118	17.863
2	*A. alba*	**80.931**	30.732	12.118
3	*A. marina*	62.412	8.857	-
4	*B. gymnorrhiza*	-	19.496	25.542
5	*B. sexangula*	-	11.400	**3.709**
6	*C. decandra*	-	7.160	3.970
7	*C. tagal*	-	36.711	**51.967**
8	*R. apiculata*	-	**88.733**	47.898
9	*R. mucronata*	-	11.597	-
10	*S. alba*	58.990	14.458	19.483
11	*S. caseolaris*	78.398	11.350	-
12	*X. granatum*	**19.269**	8.509	-
13	*X. moluccensis*	-	**2.735**	-
14	*N. fruticans*	-	6.143	-

The highest importance value index for the tree was *Avicennia alba* (80.931%), for saplings was *R. apiculata* (88.733%), and *C. tagal* (51.967%) represented seedlings category. These findings indicated that *A. alba* dominated the area. Ewusie (1980) reported similar results along Malaysian coast, *Avicennia* and *Sonneratia* dominated the mangrove. Soeroyo & Suyarso (1996) also observed that *Avicennia* and *Sonneratia* dominated muddy substrate of sediment in Birik Bay, South Sumatra. According to Noor *et al.*, (1999), the abundance of *R. apiculata* corresponded to mangrove zonation structure. This species was middle zone mangrove plant which influenced by tidal waves 2–3 times a day with two hours flooding duration. *C. tagal* was a mangrove species able to tolerate and grow in high salinity and poor nutrient substrate (Gordon, 1993).

Table 2. Shannon Index (SI)

Station	***Shannon Index* per station in 2015**
1	1.24
2	1.01
3	1.12
4	0.68
5	1.76
6	1.83
7	**1.85**
8	**1.85**
9	1.61

Importance value index can be used to analyze the effect of disturbance on the environment, determine the successive stages and the stability of plant community in the certain location (Odum, 1983). Shannon Index (Table 2) of all stations ranged between 0.68 and 1.85. The highest value (1.85) was in station 7 and 8 indicating moderate diversity and productivity of the sites. A community with high diversity value reflects a community of having many species. In contrast, low diversity value represents low species number accompanied by dominant species (Silulu *et al.*, 2013).

Station 4 and 9 demonstrated the highest similarity with percent similarity index of 37.5%. According to Pelu (1991), however, similarity index between 26 and 50% suggested of having a low similarity of species composition between two habitats. Thus, even though, station 4 and 9 showed the highest similarity, their species composition similarity was low.

Bray-Curtis similarity analysis revealed that station 6 and 7 had the highest similarity (57.22%), which possibly because these two stations were close to each other. According to Irwanto (2007), the higher the similarity index, the greater the uniformity of vegetation composition between two habitats. His statement supported the results that both stations had a moderate similarity that fell between the range of 51-75%. Station 1, 2 and 4 had a low percentage (< 25%), suggesting that species composition of these stations differed. This difference might be because the small species number found in these stations.

Station 5 and 8 had the highest similarity index of 55.13%, indicating that both showed a moderate level of species composition similarity. Similarity index of station 1, 2, 3, 4, 6, and 9 was in the range of 0–24.39% suggesting of differences in their species composition. The differences were most likely was due to environmental and anthropogenic factors.

Mangrove species of Segara Anakan observed in 2009 (Hinrichs *et al.*, 2009) were different with those in 2015 (Table 3). There were seven species absent in 2015, consisting of *Finlaysonia obovata*, *Avicennia officinalis*, *Lumnitzera littorea*, *Scaveola taccpresent*, *Hibiscus tiliaceus*, *Ficus* sp., and *Bruguiera parviflora*. Not all of mangrove species was dispersed to a specific region.

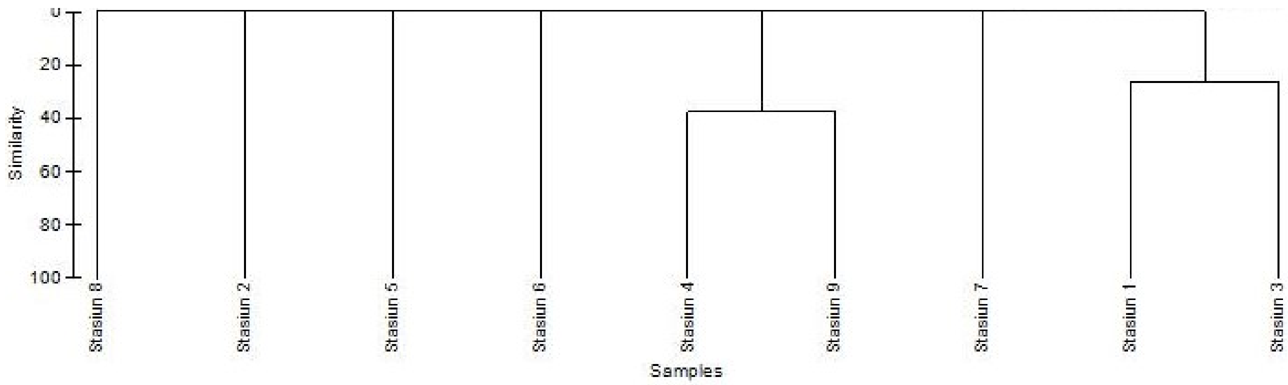

Figure 5. Dendrogram of similarity index of mangrove based on trees category between stations

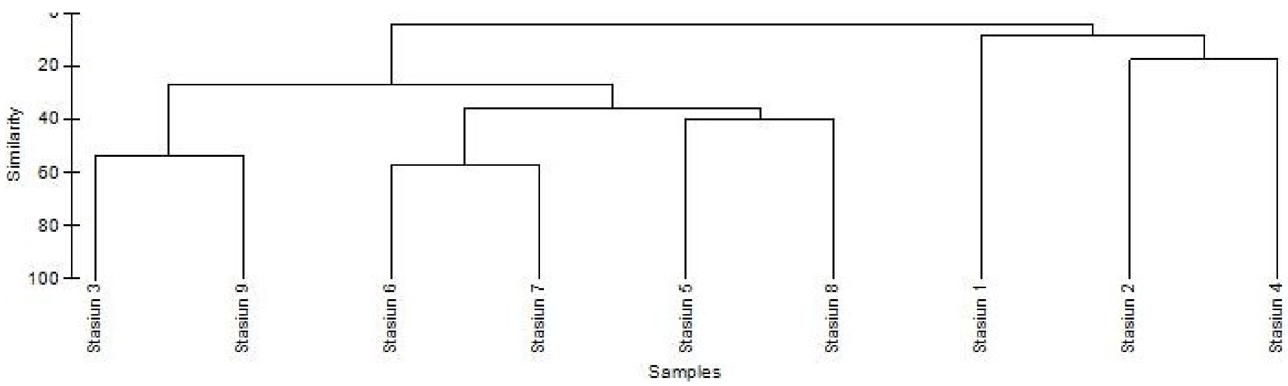

Figure 6. Dendrogram of mangrove similarity based on saplings category between stations

Table 3. Mangrove Species and Herb Species in Segara Anakan Cilacap

Families	Species	(Hinrichs *et al*., 2009)	Tahun 2015
Asclepipresentceae	*Finlaysonia obovata*	Present	Absent
Avicenniaceae	*Avicennia alba*	Present	Present
	Avicennia marina	Present	Present
	Avicennia officinalis	Present	Absent
Combretaceae	*Lumnitzera littorea*	Present	Absent
Goodeniaceae	*Scaveola taccpresent*	Present	Absent
Malvaceae	*Hibiscus tiliaceus*	Present	Absent
Meliaceae	*Xylocarpus granatum*	Present	Present
	Xylocarpus moluccensis	Present	Present
Moraceae	*Ficus* sp.	Present	Absent
Myrsinaceae	*Aegiceras corniculatum*	Present	Present
Palmae	*Nypa fruticans*	Present	Present
Rhizophoraceae	*Bruguiera gymnorrhiza*	Present	Present
	Bruguiera parviflora	Present	Absent
	Bruguiera sexangula	Present	Present
	Ceriops decandra	Present	Present
	Ceriops tagal	Present	Present
	Rhizophora apiculata	Present	Present
	Rhizophora mucronata	Present	Present
Sonneratiaceae	*Sonneratia Alba*	Present	Present
	Sonneratia caseolaris	Present	Present
	Tumbuhan Bawah		
Acanthaceae	*Acanthus ebracteatus*	Present	Present
	Acanthus ilicifolius	Present	Present
Leguminosae	*Derris trifoliata*	Present	Present

Table 4. Density and Base Area of each Station in 2009

Station	Total density (Ind.m^{-2})	Trees density (%)	Total base area (m^2)	Trees base area (%)
1	0.328 ± 0.301	56.85	10.480 ± 11.340	98.34
2	0.270 ± 0.254	**73.46**	9.154 ± 9.214	98.07
3	1.530 ± 1.415	51.42	19.310 ± 12790	94.64
4	0.472 ± 0.455	79.51	14.020 ± 10.000	**98.65**
5	1.138 ± 0.761	65.89	10.890 ± 7.055	91.98
6	**2.288 ± 1.420**	64.46	**19.420 ± 11.360**	92.02
7	0.788 ± 0.798	43.34	4.374 ± 5.210	82.40
8	0.732 ± 0.698	22.78	3.608 ± 4.612	83.46
9	1.303 ± 0.699	16.62	7.760 ± 11.260	79.27

Table 5. Density and Base Area of each Station in 2015

Stasiun	Total density (Ind.m^{-2})	Trees density (%)	Total base area (m^2)	Trees base area (%)
1	0.184 ± 0.231	17.09	0.479 ± 0.719	17.47
2	0.064 ± 0.080	**18.92**	**2.154 ± 5.498**	**87.74**
3	0.508 ± 0.714	1.17	0.438 ± 2.162	56.77
4	0.017 ± 0.015	70	1.680 ± 1.905	85.62
5	0.659 ± 0.932	0	0.135 ± 0.104	0
6	1.254 ± 1.773	0	0.102 ± 0.099	0
7	1.380 ± 1.952	0	0.065 ± 0.069	0
8	0.540 ± 0.763	0	0.052 ± 0.039	0
9	**1.339 ± 1.879**	1.48	0.142 ± 0.161	10.24

Species composition and characteristic of mangrove forest depended on several factors, such as climate, coastal land shape, tidal wave distance, freshwater availability, and soil type. According to Nybakken (1993), declining of mangrove diversity was due to increasing habitat change rates from a fish nursery, logging, sedimentation, reclamation, and pollution.

Table 4 and 5 showed a comparison of density and basal area for each station in 2009 and 2015. A significant difference was in the decrease of total density, tree density, total basal area, and basal tree area of almost all stations in 2015. These data suggested that the vegetation density in each site underwent species abundance decrease. In 2009, the highest total density was in station 6 (2.288 ± 1.420 individuals.m^{-2}) with relatively large percentage of tree density (64.46%). According to Parwati (2001), the mangrove forest in Segara Anakan faced continual total area decline. Also, the change of density level occurred because of excessive land conversion.

Total basal area also influenced total density of mangrove species. In 2009, it was wider than that observed in 2015 especially station 6 with an area of 19.420 ± 11.360 and basal tree area of 92.02%, indicating tree species of mangrove were more likely to be found than the sapling species. Mangrove tree species were more abundant in 2009 than in 2015 with the absence of some species that in turn lowering the base area value.

The highest diversity in 2009 was in station 5 with Shannon Index of 2.33, and the lowest was in station 1 with 1.29 (Table 6). In 2009, all stations showed the moderate level of diversity and relatively good productivity, while in 2015, the values decreased in station 1, 2, 3, 4, 5, 8 and 9.

The reduction of mangrove diversity in station 4 seemed very significant. In 2009, the value was 1.65 (moderate diversity), but in 2015 it decreased to 0.68 (low diversity). This decrease might be caused by the land use change to fish nursery by surrounding people, and environmental stress that triggered the growth of associative mangrove Acanthus sp. and Derris trifoliata in the unused lands.

Table 6. Comparison of Shannon Index between stations in 2009 and 2015

Station	Shannon Index (Hinrichs *et al*., 2009)	Shannon Index in 2015
1	1.29	1.24
2	1.47	1.01
3	1.53	1.12
4	1.65	0.68
5	**2.33**	1.76
6	1.53	1.83
7	1.65	**1.85**
8	2.16	**1.85**
9	1.91	1.61

CONCLUSION

There were 14 mangrove species from 9 genera and 6 families observed in Segara Anakan Cilacap. Tree category was more abundant in the West region, sapling and seedling categories were abundant in the East region. Community structure of mangrove vegetation had changed significantly from 2009 to 2015 shown by the reduction of mangrove vegetation diversity that necessarily be managed properly.

These findings were hopefully be used as useful information to recognize the change in mangrove forest Segara Anakan, and as a reference for the government and society to manage and preserve the mangrove forest ecosystem.

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