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COLONIZATION OF MANGROVE FOREST AT ABANDONED SHRIMP-POND OF SEGARA ANAKAN-CILACAP

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ABSTRACT

During the 1996 to 1997, large areas of mangrove forest in the Segara Anakan were cleared and converted into intensive shrimp-ponds. After one to two years, these shrimp-ponds failed and were abandoned. These abandoned ponds created large gap areas and canopy gaps, which were colonized by mangrove shrub and liana. The Segara Anakan mangrove also experienced heavy siltation, and there were tree cuttings from the remnant of the mangrove trees. This research aimed to study the colonization of mangrove vegetation at the abandoned-shrimp pond. Vegetation data were collected using rectangular plots of 25 m x 25 m with 4 replicates. The water qualities were also studied. The results revealed that the mangrove forests were composed of two layers: canopy tree and floor-vegetation. The gap areas triggered the pioneer species of mangrove shrubs and liana, Acanthus ilicifolius and Derris heterophylla, to colonize and dominate 100% of the mangrove forest floor. The mangrove trees consisted of natural and planted tree species. The natural trees were Sonneratia alba, Avicennia alba, and saplings of Aegiceras corniculatum, which varied between 56 – 136, 4, and 4 individuals per ha, respectively. The planted trees were Rhizophora apiculata, which amounted to 4 – 12 individuals per ha, at the island of the ponds. These trees and saplings were entangled by the liana mangrove, which disturbed their growth. The A. ilicifolius and D. heterophylla prevented the mangrove tree propagules to grow, and they colonized and characterized those abandoned shrimp-ponds, which threatened the Segara Anakan mangrove ecosystem.

Keywords: ***Canopy gap, Mangrove tree, Acanthus, Derris***

ABSTRAK

Pada tahun 1996-1997, hutan bakau di Segara Anakan dalam skala luas ditebang dan diubah fungsinya menjadi tambak udang. Tambak udang tersebut tidak produktif dan ditinggalkan sebagai tambak rusak. Tambak rusak tersebut menciptakan gap area yang luas dan dikatagorikan sebagai usikan besar, kemudian dikoloni oleh semak, dan liana semak bakau. Di samping itu, tambak udang rusak, hutan bakau Segara Anakan juga mengalami sedimentasi yang tinggi dan penebangan sisa pohon bakau. Penelitian ini mempelajari kolonisasi hutan bakau di tambak udang rusak. Pada setiap lokasi, data vegetasi dikoleksi dengan kuadrat plot 25 meter x 25 meter dengan ulangan 4 kali, dan juga dipelajari kualitas perairannya. Hasil mengungkapkan bahwa hutan bakau di tambak udang rusak disusun oleh dua lapisan hutan, lapisan kanopi pohon penyusun hutan, dan vegetasi lantai semak, dan liana bakau. Gap area yang luas sebagai usikan besar terhadap ekosistem hutan bakau, telah memicu semak dan liana semak bakau, *Acanthus ilicifolius* dan *Derris heterophylla* mengkoloni dan mendominasi lantai hutan bakau. Pohon bakaunya sangat jarang dan disusun oleh spesies *seedling* pohon yang ditanam dan tumbuhan alami. Pohon yang tumbuh alami adalah *Sonneratia alba, Avicennia alba,* dan sapling *Aegiceras corniculatum* berturut-turut 56-136; 4; dan 4 individu per-ha. Pohon yang ditanam di plataran tambak adalah *Rhizophora apiculata*, 4-12 individu per-ha. Pohon tersebut dililit oleh liana bakau dan telah menganggu pertumbuhannya *Acanthus ilicifolius* dan *D. heterophylla* mencegah propagule pohon bakau untuk tumbuh berkembang. Semak dan liana semak bakau mendominasi dan mencirikan hutan bakau rusak, dan telah mengancam keberlanjutan ekosistem hutan bakau Segara Anakan.

Kata Kunci: ***Gap kanopi, Pohon bakau, Acanthus, Derris***

INTRODUCTION

The mangrove of Segara Anakan (SA) is the largest area of remnant mangrove in Java. During the 1996 to 1997 large areas of mangrove forests were cleared and converted to intensive shrimp-ponds at alarming scale. However these shrimp-ponds were failure and abandoned which left the large-gap areas and threatened the mangrove ecosystem services (Djohan 2007; Djohan 2012). A healthy mangrove-forest was highly productive ecosystem, which were dominant along many tropical and subtropical coastlines. Their productivities were very high, and provided ecosystem services for many species with ecological and economical values in mangrove ecosystem itself and sea scape fisheries. This mangrove-ecosystem served as nursery grounds for economic values of larvae of shrimp, crabs and fishes. and ecological values-organism, such as fiddler crabs (Odum 1971; Ronnback 1999; Ronnback and Primavera 2000; Nagelkerken et al. 2008; Barbier and Cox 2004).However at the SA mangrove ecosystem, these services were in questioned due to the loss of large amount of mangrove trees.

At the SA, beside the large areas of mangrove forest conversion to the intensive and extensive shrimp-ponds, the mangrove ecosystem of SA was also experienced heavy siltation, 4.5 tons per year (Napitupulu and Ramu 1982). Since 1980 up to present, the SA estuary was filled up by sediment and created a lot of newly-formed lands and pro-grading coastlines. It means that the newly-formed and pro-grading lands were a good habitat for mangrove-tree forest to develop. But it did not happen, due to the selective mangrove-tree cutting. People from out site the SA cut the commercial values trees, *Bruguiera* spp. and *Rhizophora* spp. (Sunaryo 1982; Djohan 2007). This caused the mangrove trees as sources of the propagules were rare.

More over at SA between the 1996 to 1997 large areas of mangrove forest were land clearing and reclaimed to extensive and intensive-shrimp ponds. This mangrove reclamation to the shrimp ponds was carried out by the outsiders and supported by the villagers of SA. The mangrove forest clearance caused the economic mangrove-tree propagules became not available. Since then, the people from other area also cut down the non-economic value trees such as *Avicennia* spp., and *Sonneratia* sp. (Djohan 2007). Big disturbance played crucial rule in various forest ecosystems. They represented major shaping forces in forest succession and spatio-temporal processes (Vogt et al. 2014).

Djohan (2012) reported that in 2007 the SA mangrove was disturbed ecosystem. The mangrove dynamics were dictated by the available of mangrove tree-propagules. There were 12 species of mangrove trees, *Sonneratia alba*, *S. caseolaris*, *Avicennia alba*, *Rhizophora apiculata*, *R. mucronata,Bruguiera gymnorhiza*, *B. parpiflora*, *Aegiceras corniculatum*, *Xylocarpus molluccensis*, *X. granatum*, *Heritiera litoralis*, *Nypa fruticans*, and also 3 species of the mangrove floor vegetation, *Acanthus ilicifolius, Derris heterophylla, Finlaysonia obovata, Acrosticum aureum,* and one species of aquatic macrophyte, *Cyperus malaccensis.* The mangrove ecosystem was occupied by shrubs and liana mangroves, *Acanthus ilicifolius* and *Derris heterophylla,* which was covered the area almost 100%. The mangrove tree dominance were *Avicennia alba* and *Sonneratiaalba* in consecutively 485 and 203 individuals per ha. The combinations of the mangrove land-clearance, highly sedimentation, mangrove-tree cuttings, and climate change worsen the SA mangrove ecosystem. In the 2007, the salinities of the waters varied seasonally, between hypo-saline during the rainy season, and hyper-saline in dry season. Thus at the SA estuary, the salinities did not response to the tide-period daily.

The shrimp productions were the primary aquaculture activities, which were responsible for the loss of mangrove trees in many tropical countries. It happened also at the SA mangrove ecosystem. Moreover, the conversions of the mangroves forests by shrimp ponds were irreversible. Without careful ecosystem restoration and manual replanting efforts, mangroves did not regenerate even in abandoned shrimp-ponds areas (Barbier and Cox 2004).

In the SA, the abandoned shrimp-pond created a large gap area, which triggered the colonization of pioneer mangrove floor-species, *A. ilicifolius*, and *D. heterophylla*, which had r and K strategies. These species out competed to the mangrove tree seedling to grow (Djohan 2007). In the 2001 at SA, the rehabilitations of mangrove tree species efforts were established at the island of the abandoned shrimp-ponds of this research area by SACDP, a government conservation project. The seedling of mangrove trees, *R. apiculata, R. mucronata,* and *Bruguiera gymnorhiza,* were planted at the abandoned shrimp-ponds with distance of 1 meter. The project only planted the seedling of the mangrove trees, but they did not take care of the planted seedlings to grow (Parmin of Desa Motean 2007: Pers. Comm.).

The large areas of abandoned shrimp-ponds immediately were colonized by mangrove floor species, since the natural tree-propagules were not available especially *Rhizophora* spp, and *Bruguiera* spp. Therefore in this abandoned shrimp-pond, the research addressed the questions: (1) How was the forest profile? (2) What were kinds of the growth form and species present? (3) How were their densities, and which one was dominance? (4) How were the conditions of water qualities of the stream inflow, shrimp pond canal and island included salinity, dissolved oxygen (DO), pH, air temperature, and moisture. The purpose of this research was to study the colonization of mangrove vegetation at the abandoned shrimp-pond. This research was part of the long-term study in attempt to reconstruct the abandoned shrimp-ponds with the mangrove trees as a model for the sustainable ecosystem.

Methods

The research was carried out at two abandoned shrimp-ponds, TaTi (East pond) and TaBa (West pond) on February 2008. These abandoned shrimp-ponds were at the fringing mangrove of Nusa Kambangan, which were adjacent to Motean village (Figure 1). The size of each abandoned pond was 50 m x 100 m. These abandoned shrimp-ponds consisted of stream inflow, shrimp pond canal, and island also canal outflow. Mangrove shrubs and liana *A. ilicifolius* and *D. heterophylla* dominated the ponds. In the 2001, the government conservation project planted the tree seedling on the island of the ponds, *R. apiculata, R. mucronata,* and *B. gymnorhiza*. But unfortunately, they left them in the nature to grow without cared.

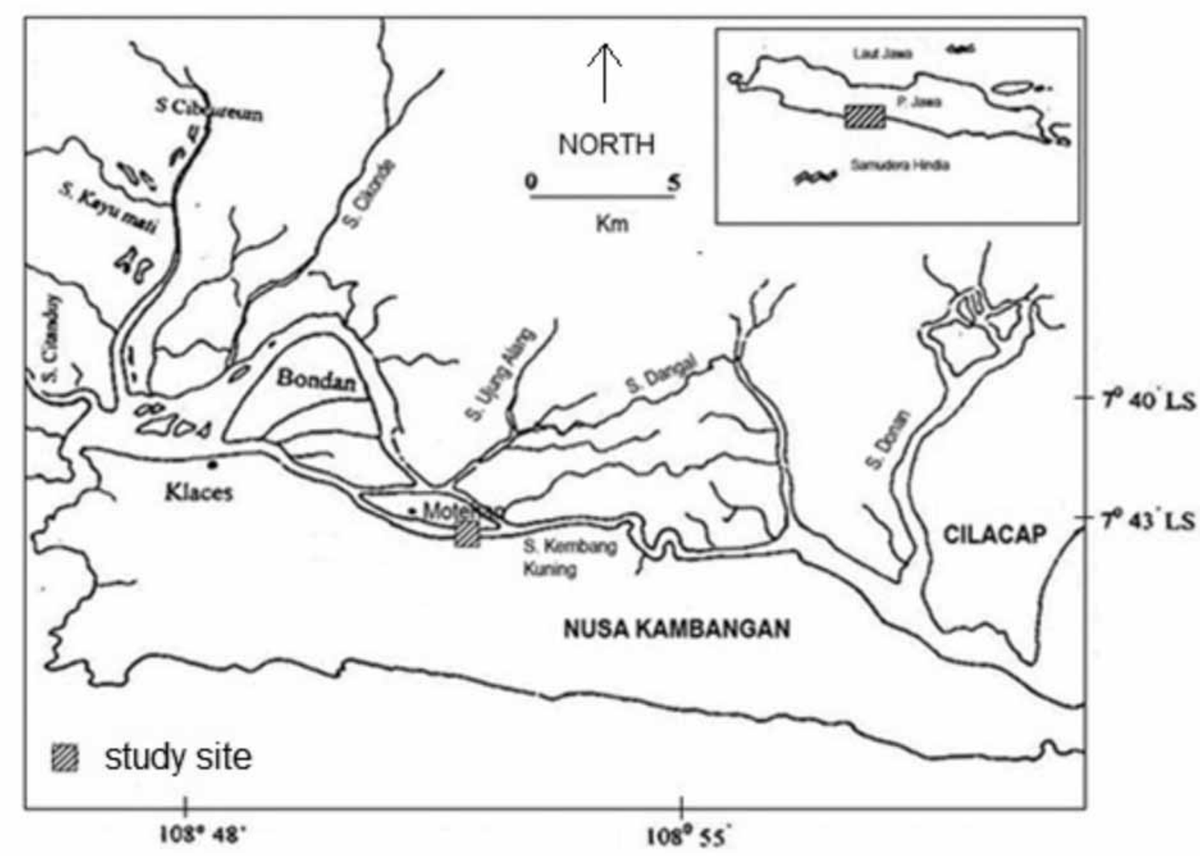


Figure 1.
The Abandoned Shrimp-Pond Studied Area was at Fringing Mangrove of Nusa Kambangan, and next to Motean village.

Data Collections

On each pond of TaTi and TaBa, the vegetation data were collected using quadrate plot of 25 m x 25 m with 4 replicates. The parameter measures

were: the vertical forest-layers; growth forms of the vegetation; number of species; number of individual of each species, tree height, and tree canopy coverage. The forest profile was constructed using Oldeman Method at all replicate-quadrate plots, TaTi 1-4, and TaBa 1-4. The water qualities were also measured from canal of abandoned ponds and river inflow. At each plot, the parameter measures were salinity using Hand-refracto meter, pH, DO of water shrimp-pond canal and river inflow using Micro-Winkler Methods, temperature, and moisture with 5 replicates.

Data Analyses

Data were performed and analyzed in area of 0.25 ha at TaTi (East pond) and TaBa (West pond) and in also in 1 ha. The mangrove profiles were constructed at all replicate plots of 25 m x 25 m. Then the colonization of mangrove-species trends was analyzed at both the abandoned shrimp-ponds.

RESULTS AND DICUSSIONS

The results revealed that the mangrove forest-profiles were composed of two layers of forests, canopy-tree layer and floor vegetation-layer at both of the abandoned

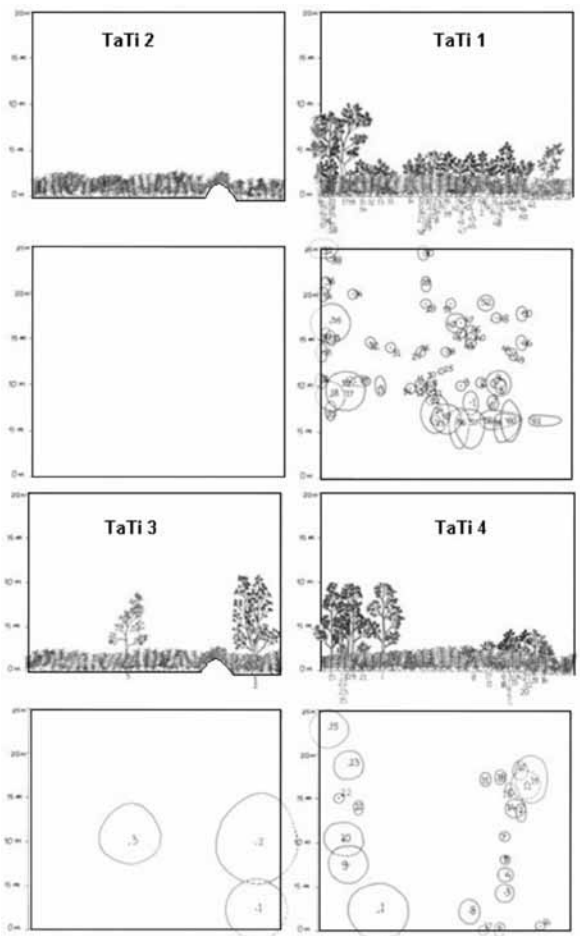


Figure 2.
The Mangrove Profile at The Abandoned Shrimp-Ponds from Front and Back Settings at TaTi.

Explanation: The projection of vegetation only for mangrove tree and sapling coverage. The TaTi 2 and TaTi 3 had levees, which was dominated by non-mangrove shrub species, *Wedelia marina*. The forest profiles were composed of two layers, except at the TaTi 1. The first layer was consisted of mangrove tree and sapling canopies. The second layer was dominated by floor mangrove vegetation. The forest floor vegetation was covered by 100% of *A. ilicifolius* and *D. heterophylla*. The mangrove forest trees were dominated by naturally growth of *Sonneratia alba*.

Shrimp-ponds of TaTi and TaBa at all quadrate plots (Figure 2-3). But, the TaTi-2 only had one layer of forest floor-vegetation. The abandoned shrimp-ponds created large gap-areas, and were considered as big disturbance to the SA mangrove ecosystem, due to their large number of abandoned shrimp-ponds. These large gap-areas had triggered the pioneer species of mangrove shrubs and liana, *Acanthus ilicifolius* and *Derris heterophylla*, developed and colonized almost 100% of the mangrove forest floor at both the abandoned- shrimp ponds. Both of these species were out competed to the seedlings of mangrove trees. Therefore, the seedlings of the mangrove tree were not found at those abandoned shrimp-ponds (Figure 4a-b).

Growth form and Abundance of Species

The forest at the abandoned ponds, were composed only by 4 growth forms. These growth forms were mangrove trees, saplings, shrubs and liana. However, the plot of TaTi 2, only had 2 growth forms of shrubs and liana (Figure 4). At the forest profiles with two layers, the first layer was composed by mangrove trees and saplings. The second layers were dominated by mangrove shrubs and mangrove liana (Figure 2-4). The mangrove trees were rare and consisted of natural and planted tree species, but the shrubs and liana at the forest floor grew naturally. The natural-tree species were composed of *Sonneratia alba*, and *Avicennia alba*. The planted tree was *Rhizophora apiculata* and *Bruguiera gymnorhiza*. The number individual of *Rhizophora* were 4 and 12 trees per ha at TaTi and TaBa inconsecutively, which were 5.88 and 7.89% of the total trees in the ponds.

The Tree-Sapling Canopy and Tree Height

The coverage of tree-sapling canopies varied between abandoned-shrimp ponds. Total canopy trees-sapling at TaTi1 were 13.47% per-ha, and their coverage at the shrimp-ponds were between 0 to 70.71%. However at TaBa, the total tree coverage was 42.72%, and also their coverage varied between 14.28 to 79.02% (Figure 2; Figure 3; Figure 5a). Even though at TaBa1 had very high coverage of canopy, but its forest floor was still occupied by 100% of *A. ilicifolius*, and *D. heterophylla*. The liana *D. heterophylla* grew on the trunk of the mangrove tree and sapling, and entangled, which had disturbed the growth of the mangrove tree-sapling. The mangrove tree heights varied between shrimp pond and tree species: 5.0 to 9.0 meter (Figure 2; Figure 3; Figure 5b). The saplings heights were 1.5 to 4.0 meter. The variation of tree height responded to the soil and water conditions.

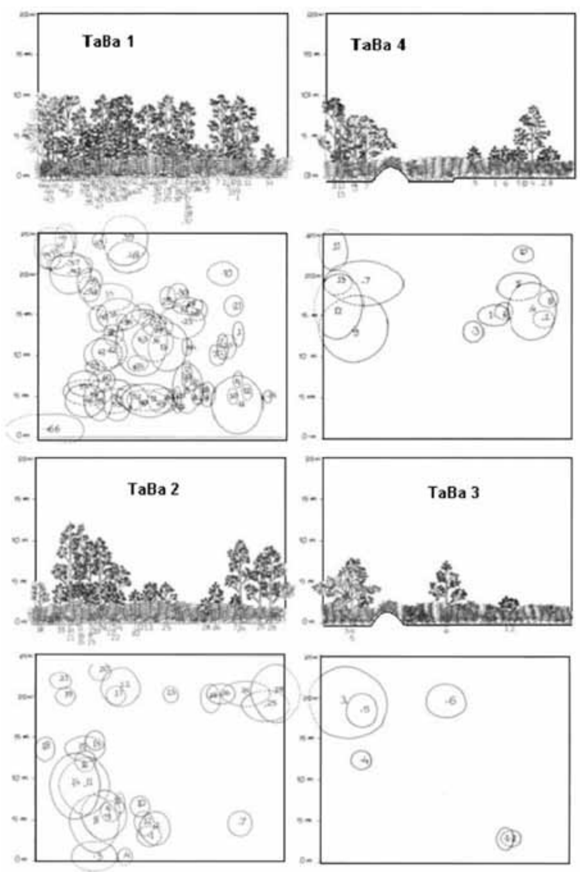


Figure 3.
The Mangrove Profile at The Abandoned Shrimp-Ponds from Front and Back Site Settings at TaBa.

Explanation: The projection of forest layers were only for tree and sapling coverage. The TaBa 3 and 4 had levees, which was dominated by non-mangrove species, *Wedelia marina*. The projection of forest layers were only for tree and sapling coverage. The profiles were composed of two layers of forests. The first layer was consisted of mangrove-tree and sapling canopies. The second layer was dominated by floor vegetation, which was covered by 100% of *A. ilicifolius* and *D. heterophylla*.

The *Sonneratia alba* trees dominated both of the abandoned ponds 56 and 136 trees per ha inconsecutively with 83.35 and 89.47% of the total trees (Figurer 4a). The survival of planted tree-seedlings from the 2002 conservation project grew to the mangrove trees were only 1% of the planted seedling. The conservation project did not take care of the planted mangrove-seedlings to grow and develop; they just left these planted seedlings to the nature. These unfortunate planted-seedlings were loss competition to the mangrove shrubs and liana, *A. ilicifolius* and *D. heterophylla*. As mentioned before, the total of tree canopy-coverage at TaTi and TaBa between 10-40%. Thus the abandoned shrimp-ponds created large gap areas, which caused big disturbance and threatened to the sustainable of mangrove ecosystem at SA. Rejmanek (1984) reported that a simulation of a single big disturbance of spruce forest in Krknose Mountains of Czechoslovakia led to loss of two-third of three Growth forms, grasses and shrubs, within 40 years, and the spruce trees dominated the area. Therefore the big disturbance at the mangrove forest ecosystem had threatened the biodiversity of mangrove species at the SA.

It is interesting to note that abandoned shrimp-pond at TaBa had more mangrove trees than TaTi, 152 individual per ha compared to 68 trees per ha (Fig 3-4; Figure 4a). Even though the number of the mangrove trees was abundant, but both the abandoned ponds did not have the seedling trees. As mentioned before, the seedling trees cannot develop in the abandoned shrimp-pond due to the colonization of the forest floor with the mangrove shrub and liana of *A. ilicifolius* and *D. heterophylla*. Their present disturbed the mangrove tree-propagules to develop. Therefore in the SA, without careful ecosystem rehabilitation efforts of the abandoned shrimp-ponds, mangroves trees would not regenerate in mangrove gap area and even in the abandoned shrimp-ponds.

The *Avicennia alba* was the natural tree which clumped in the shrimp-pond canals with number of individuals were 4 trees per ha at each pond (Figure 4a). Their presents were very rare due to: (1) Very rare of the natural trees as the source of propagules. During the mangrove land-clearing, all the mangrove trees were removed for the area. Therefore the remnant mangrove forest did not have enough the source of the tree propagules; (2) The outsider people of the SA also cut the non-economic value of the mangrove tree, *Avicennia*, and *Sonneratia* ; (3) The seedling mangrove-trees loss competition to the mangrove shrubs and liana, *Acanthus ilicifolius* and *Derris.*

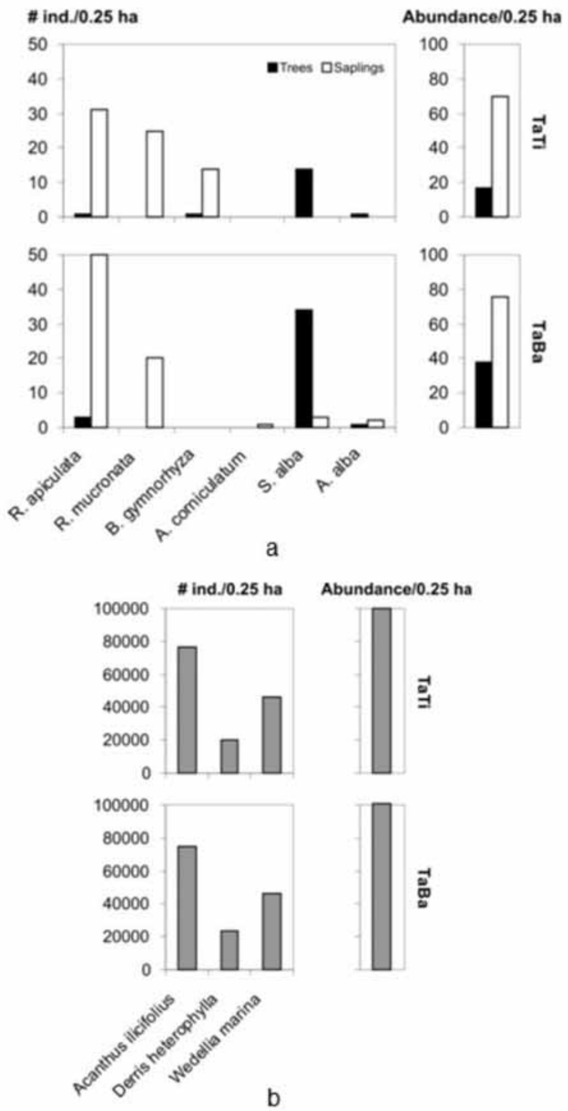
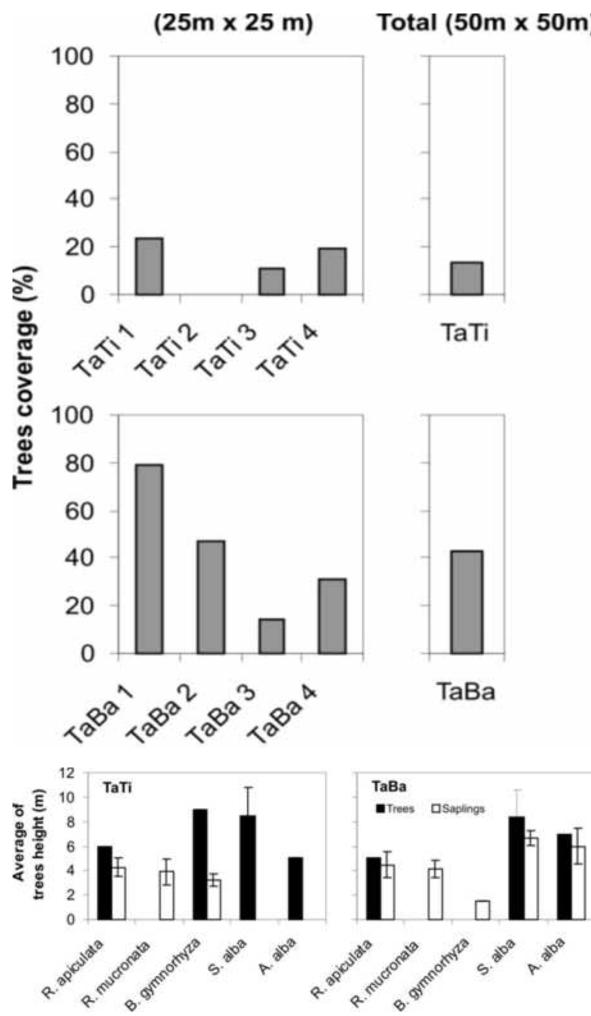


Figure 4.
a. Densities of each Species the Mangrove Tree and its Abundance at TaTi and TaBa per 0.25 ha; b. Density Mangrove Floor Vegetation, and there were no Chance ofthe Mangrove Tree-seedlings to Developed because They Lost Competition to the Mangrove Shrubs and Liana *heterophylla.*

Explanation: Both of these species had r and K strategies, which mean they reproduce and grow quickly through seed, and also they have long live. In contrast, the mangrove tree-seedlings grow slowly, even though they have long-live, but they loss competition to the mangrove shrubs, *A. ilicifolius,* especially for the light. More over the mangrove trees and saplings were colonized by the mangrove liana, *D. heterophylla*. This liana grew and entangled the tree trunks, which was disturbed the mangrove tree to grow.

The species of sapling were composed of *R. apiculata*, *R. mucronata*, *Avicennia alba*, and *Aegiceras corniculatum.* With the exception to the sapling of *A. alba* and *A. corniculatum which grew naturally*. All the saplings of the mangrove trees were planted. Even though the conservation project had planted the mangrove-tree seedling



a. b.

Figure 5
a. The Tree Canopy-Coverage at all Quadrate Plots of Both the Abandoned Shrimp-Ponds of TaTi 1-4 and TaBa 1-4; b. The Height Average of The Mangrove Trees and Saplings at Both

the Abandoned Shrimp-Ponds, TaTi and TaBa with distance of 1 m x 1 m, but this reforestation project was unsuccessful.

Explanation: Thus the mangrove tree and saplings were the survival of the project plantation, and they grew entangled with the mangrove liana, *D. heterophylla*, which was disturbed their growth.

The abundance of *Rhizopora* saplings at TaTi and TaBa were 224 and 280 individual per 1 ha, which were consisted of 80% and 92% of the total saplings inconsecutively. The heights of saplings varied 3-4 meter (Figure 4a; Fig 5). But the saplings of *A. corniculatum* were found only at TaBa, 4 individual per ha, and they grew naturally. In contrast, the saplings of *Rhizophora mucronata* were only found at TaTi. The trees and saplings of *Bruguiera gymnorhiza* were only found at TaTi. The survival saplings of the planted-tree seedling were about 25%. However these saplings were colonized by mangrove liana, *D. heterophylla*. This liana entangled the sapling and trunks and disturbed their metabolic activities, such as photosynthesis. Therefore the future of these planted saplings were also threatened the future mangrove trees of Segara Anakan ecosystem.

As mentioned before, both the trees and sapling of *R. apiculata*, *R. mucronata*, and *B. gymnorhiza* were planted. It is interesting to note that the seedling of mangrove trees were absent at both ponds. The absent of the seedling of mangrove trees due to the colonization 100 % of mangrove forest-floor with the mangrove shrubs and mangrove liana which have species ecologically r and K strategies. The saplings of mangrove trees at both abandoned ponds were considered higher than the mangrove trees. Naturally, the mangrove saplings were the future mangrove trees. However at the abandoned shrimp ponds of SA, due to the abundance of mangrove shrubs and mangrove liana with had coverage almost 100%, without human efforts in reforestation, the growth of the future trees would be disturbed by both of those mangrove shrubs and liana. It means that the both abandoned ponds will be colonized by 100 % of mangrove shrubs and liana. Thus, the future mangrove trees at the Segara Anakan ecosystem were questioned, and threatened.

Mangrove-Forest Floor

The second layer of forest at the abandoned shrimp-ponds were dominated by mangrove shrubs and mangrove liana, *A. ilicifolius* and *D. heterophylla*. Beside that at the levees of the pond werecolonized by *Wedelia marina*. The *W. marina* is a shrubs and was not a mangrove species. If the *W. mariana* was not considered, therefore the mangrove forest floor at TaTi will be dominated by 100% by mangrove shrub and liana, *A. ilicifolius* and *D. heterophylla* of 306,475 and 80,737 individual per ha, with 79% and 21% total coverage of both species. At TaBa those both species were colonized by 298,804 and 92,794 per ha with 76% and 24% of the total coverage. Thus both abandoned shrimp-ponds were colonized by mangrove shrubs. If the *W. marina* was included which was not mangrove-shrub species, the coverage of the ponds was between 186,240 and 186,240 individual per ha.

The levees of the ponds were dominated by a shrub, *Wedelia marina*, which was not a mangrove species. The *W. marina* developed on the levee, which was not influenced by the tides. Thus the levee was not inundated and always dry. The forest floor vegetation both *A. ilicifolius* and *D. heterophylla* prevented the mangrove tree-propagules to grow, and they characterized these abandoned shrimp-ponds. At both of the abandoned ponds, there were no chances of the mangrove tree-seedlings to develop. Because they loss the competition to the mangrove shrubs and liana.

The Water Quality

Waters at the abandoned shrimp-ponds during high and low tides did not move easily due to the colonization forest floor with the *A. ilicifolius* and *D. heterophylla*. Thus in the shrimp-pond canals and the forest floors, the waters were inundated and not flowing, which created the anaerobic conditions, and caused the dissolved oxygen (DO) was very low, between 1.6 – 1.7 mg perliter compared to the stream inflow, 6 mg per liter (Tabel 1). The low concentration of DO was not good to the aquatic communities such as shrimp, fish, and crab larvae in the abandoned shrimp-ponds, which reflected that waters in this abandoned ponds were not in good conditions. These bad conditions were due to the abundance of the mangrove shrubs, which disturbed the tide movements, which also caused the dispersal of the mangrove-tree propagules failed to teach the abandoned shrimp-ponds. The water levels during high tides were between 15 and 29 cm and the stream inflow was 170 cm. Shallow

Tabel 1. The Water Qualities at Both Abandoned Shrimp-Ponds and Stream Inflow.

Parameter	TaTi	TaTi	Stream
Salinity at high tide (‰)	15	15	14
Water level (cm)	29	15	170
Canal DO (mg/l)	1.6	1.75	6
Water pH	6.65	6.95	6.9
Soil canal pH	3.63	3.65	
Soil island pH	3.5	3.78	
Air moisture (%)	27	90	
Air temperature (^{o}C))	31	31	
Soil temperture (^{o}C)	27	28.5	
Water temperature (^{o}C)	28.5	29	

water in the canal were also due the sediment filled the canals. The pH was between 6.65 and 6.95, but the soil pH was very low between 3.5 and 3.8 and caused by the low DO. The water salinities during high tides were 15 ‰ in the canals and 14 ‰ in the stream inflow.

CONCLUSIONS

The mangrove forest profile at abandoned shrimp-ponds consisted of two layer forest: (1) Mangrove tree layer was occupied by the natural tree layer of *Sonneratia alba*, and the planted tree species of sapling of *Rhizophora apiculata*whichhad low survival rate; (2) Mangrove floor vegetation layer was dominated by 100% of mangrove shrub and liana: *Acanthus ilicifolius*, and *Derris heterophylla*, which were prevented the propagule and tree-seedlings of the mangrove species to grow and develop. The *A. ilicifolius* and *D. heterophylla* colonized and characterized the mangrove of Segara Anakan. The Large areas of the abandoned shrimp-ponds were responsible for the loss of the mangrove trees and threatened the sustainable of the Segara Anakan mangrove ecosystem.

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