Advances in Environmental Biology

2019 June; 13(6): pages 13-20
DOI: 10.22587/aeb.2019.13.6.3

Original Article
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Production Ratio of Seedlings and Density Status of Mangrove Ecosystem in Coastal Areas of Indonesia

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Received date: 15 April 2019, **Accepted date:** 25 June 2019, **Online date:** 29 June 2019

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Abstract

The propagation process of mangrove naturally occurs through a reproduction system. There are four methods of mangrove reproduction namely: vivipary, crypto vivipary, natural germination, and vegetative propagation taking place naturally every year. Study analysis of mangrove community structure was aimed to analyze the distribution and status of the mangrove ecosystem in Indonesia, and to analyze the production ratio of each mangrove species in Indonesia. These analyses were conducted by examining 105 articles relating to the community structure. From those articles, 55 articles were chosen to contain data regarding mangrove density in the categories of tree and seedling which represent 75 coastal areas in Indonesia. Results of the analysis indicate that there are 10 species of mangrove dominantly in Indonesia namely *Bruguiera cylindrica, Bruguiera gymnorhiza, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, Sonneratia alba, Xylocarpus granatum, Avicennia alba, Avicennia marina*, and *Ceriops tagal*. These species are found with a status in the rare category. The high and lowest average density of mangrove species are *Rhizophora apiculata* and *Bruguiera cylindrica* with 1293.40 trees/ha and 99.97 trees/ha, respectively. Further, the three dominant mangrove species in Indonesia, are *Rhizophora apiculata* for eastern areas, *Ceriops tagal*, *Rhizophora mucronata*, with densities of 1664.80 trees/ha, 1194.67 trees/ha, and 1485,29 trees/ha, respectively. The highest and the lowest seedling production ratio in Indonesia are *Rhizophora stylosa* (2.40) and *Ceriops tagal* (1.45). While, the highest ratio of mangrove seedling for eastern, central and western coastal areas in Indonesia are *Bruguiera gymnorhiza* (1.89), *Rhizophora stylosa* (3.12), and *Rhizophora mucronata* (3.06), respectively. Furthermore, the ratio of mangrove seedling is able to be influenced by vegetation pattern and ecosystem community structure, including mangrove species dominance in the coastal areas of Indonesia.

Keywords: mangrove ecosystem status, seedling production ratio, Indonesian coastal areas

INTRODUCTION

Mangroves are trees and scrubs living in the mangrove habitats or a group of different plants that are different one another, however, possessing similarity of morphological and physiological adaptation on the habitat which are affected by tides where mangroves are going to be inundated by seawater during a high tide and getting free of inundation during a low tide [27]. In some recent decades, mangrove ecosystem undergoes degradation due to exploitations and land-use changes or development in the coastal areas [9, 14, 21, 45, 22] that needs to be propagated it either rehabilitation or natural propagation.

A propagating process of mangrove naturally takes place through the reproduction system. [10] stated that there are four methods of mangrove reproduction, namely vivipary, crypto-vivipary, natural germination, and vegetative propagation. The reproduction of mangrove in vivipary occurs in around two until three months every year [66]. The reproduction time in every species is relatively different and influenced by the environmental condition, which is the main habitat of mangrove [33]. For instance, [14] found that the flowering process of species *Avicennia marina* happens in every six months in Papua New Guinea, Australia, and New Zealand. The needed times from the flowering process to be fertilization are both in the range of 2-3 months for tropical areas and 10 months for temperate areas. However, commonly time-consuming from the fertilization process to be a

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new individual or seedling of mangroves comes about once a year and the distribution of these plants is highly affected by tides and seawater current in its surrounding environment [11]. [62] stated that the number of produced mangrove seedlings is defined by several trees; for example, total production of seedlings in Bangladesh exceeds 27,750 individuals/hectare.

A comparison between the numbers of trees and seedlings is called a production ratio. This ratio plays a vital role in determining species dominance in a certain ecosystem. Furthermore, according to [15], and [39] that a distribution pattern of mangrove seedlings is significant also in specifying the structure dynamic of mangrove communities in a certain ecosystem. The researches regarding the community structures of mangroves and its density had been abundantly conducted in variously coastal areas starting from western parts to eastern parts of Indonesia. Nevertheless, among these researches, there is not any study yet analyzing the magnitude ratio of seedling production in every mangrove species in Indonesia. Hence, this paper is going to review all papers related with mangrove community structures with aiming (1) to analyze the spatial distribution of mangrove species in Indonesia, (2) analyze ecosystem status of mangrove in Indonesia, and (3) analyze the production ratio of seedling for each mangrove species in Indonesia.

MATERIAL AND METHODS

First Methods: Selection of literature

The gathered kinds of literature were related to mangrove community structures gaining from various sources as many as 105 literature. Furthermore, 50 documentary were selected containing data regarding mangrove density in the categories of tree and seedling (Table 1). The chosen literature exhibited 75 coastal areas of Indonesia inhabiting dominant species in the mangrove ecosystems. The coastal areas, according to these kinds of literature were then segregated based on the Indonesian territorial zones namely eastern part including Papua, Maluku, Nusa Tenggara, and Halmahera; central part consisting of Sulawesi, Kalimantan, and Bali; and west parts composing of Java and Sumatera.

Table 1: List of literature review related to mangrove community structure

Wilayah Timur	Wilayah Tengah	Wilayah Barat
[72], [46], [19], [51], [52] [74], [37], [1], [24], [8], [41], [58], [34], [43], [70], [76]	[35], [12], [30], [6], [25], [53], [57], [36], [49], [61], [29], [60], [73], [7]	[3], [12], [68], [48], [23], [40], [75], [26], [54], [50], [56], [32], [63], [4], [42], [64], [2], [5], [44], [18]

Second Methods: Data Analysis

1 - Analysis of Mangrove Distribution (2008 -2018)

The analysis of mangrove spatial distribution in the coastal areas of Indonesia was conducted using a quantitatively descriptive method and was specified for species possessing data of mangrove density with the category of tree and seedling. This was carried out due to these species are dominant mangrove species in the coastal areas of Indonesia. This method referred to the data quantification from the reviewing result of all related papers.

2 - Analysis of Mangrove Ecosystem Density Status (2008 – 2018)

The analysis of mangrove ecosystem density status in Indonesia was carried using a quantitatively descriptive method by enacting some criteria of assessment, namely very rare, rare, medium, dense, and very dense. These assessment criteria were going to be symbolized using colors like the following table.

Table 2: The assessment criteria for mangrove ecosystem status

Density (tree/ha)	Color	Criteria/ status
< 500		Very rare
>500 – 1000		Rare
>1000 – 1500		Medium
>1500 – 2000		Dense
>2000		Very dense

3 - Analysis of the Seedling Production Ratio

The analysis of the production ratio of seedling was yielded by comparing the density of seedling and trees. The production ratio for the seedling is formulated as follows.

Ratio (r) = $\frac{Ks}{Kp}$ ..... (1); Where: Ks = Seedling density (Ind/ha),

RESULTS

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Mangrove Distribution in Indo – Australia Areas .

Table 3: True mangrove distribution in Indo-Australian Areas [59]

Species	India	Bangladesh	Vietnam	Indonesia	Papua New Guinea	Australia
Acanthus ebracteatus	+		+	+		+
Acanthus ilicifolius	+	+	+	+	+	+
Aegialitis annulata				+	+	+
Aegulitis retundifolia	+	+				
Aegiceras corniculatum	+	+	+	+	+	+
Avicennia alba			+	+		
Avicennia eucalyptifolia	+	+	+	+	+	
Avicennia marina	+	+	+	+	+	+
Avicennia officinalis	+	+	+	+	+	
Bruguiera cylindrica	+		+	+	+	
Bruguiera exaristata				+	+	+
Bruguiera gymnorrhiza	+	+	+	+	+	+
Bruguiera hainesii				+	+	
Bruguiera parviflora	+		+	+	+	+
Bruguiera sexangula			+	+	+	+
Campnosperma schultzii				+	+	+
Ceriops decandra	+	+	+	+	+	+
Ceriops tagal	+		+	+	+	+
Cynometra ramiflora	+	+		+	+	
Excoecaria agallocha	+	+	+	+	+	+
Heritiera litoralis			+	+	+	
Kandelia candel	+	+	+	+		
Lumnitzera littorea	+		+	+	+	+
Lumnitzera recemosa	+	+	+	+	+	+
Nypa fruticans	+		+	+	+	+
Osbornia octodonta				+	+	+
Phoenix paludosa	+	+	+	+		
Rhizophora apiculata	+		+	+	+	+
Rhizophora lamarckii				+	+	
Rhizophora mucronata	+	+	+	+	+	+
Rhizophora stylosa			+	+	+	+
Scyphiphora hydrophyllacea	+		+	+		+
Sonneratia alba	+		+	+	+	+
Sonneratia caseolaris	+	+	+	+	+	+
Sonneratia ovata			+	+	+	
Xylocarpus granatum	+	+	+	+	+	+
Xylocarpus mekongensis		+		+		+
Xylocarpus moluccensis			+	+	+	

Mangrove Ecosystem Distribution in Indonesia (2008 – 2018)

Based on analyzing of the literature study, during in years of 2008 to 2018, mangrove ecosystems in the coastal areas in Indonesia are dominated by *Bruguiera cylindrica*, *Bruguiera Gymnophiona*, *Rhizophora apiculata*, *Rhizophora mucronata*, *Rhizophora stylosa*, *Sonneratia alba*, *Xylocarpus granatum*, *Avicennia alba*, *Avicennia marina*, and *Ceriops tagal*. These mangrove species spread in three-zone parts of Indonesia with different dominance and densities.

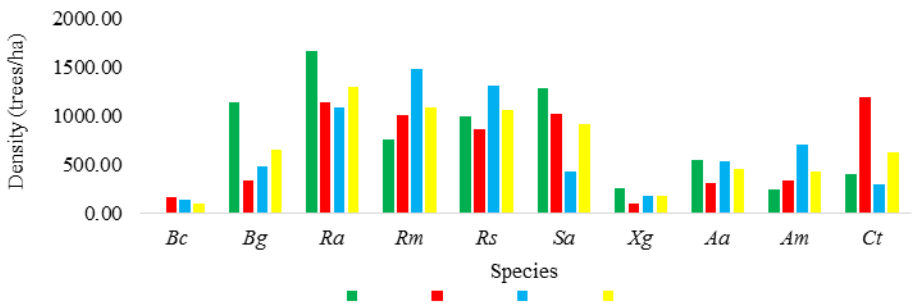

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Fig. 1: Density Distribution of Mangrove in the Coasal Areas of Indonesia (Tree Category). *Bc = Bruguiera cylindrica, Ra = Rhizophora apiculata, Rm = Rhizophora mucronata, Rs = Rhizophora stylosa, Sa = Sonneratia alba, Xg = Xylocarpus granatum, Aa = Avicennia alba, Am = Avicennia marina, Ct = Ceriops tagal*

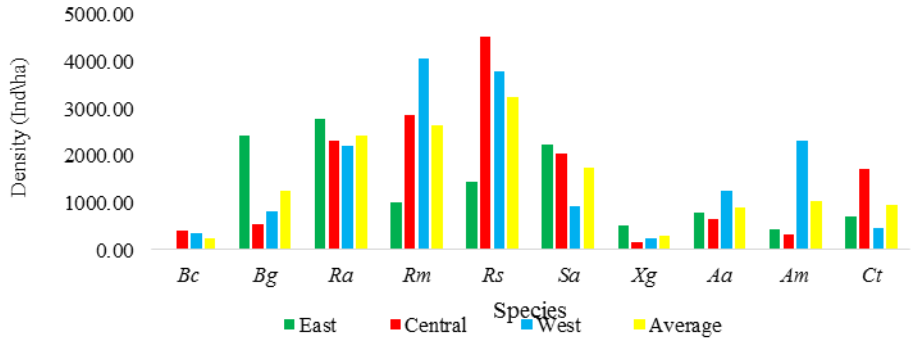

Fig. 2: Density Distribution of Mangroves in the Coastal Areas of Indonesia (Seedling Category). *Bc = Bruguiera cylindrica, Ra = Rhizophora apiculata, Rm = Rhizophora mucronata, Rs = Rhizophora stylosa, Sa = Sonneratia alba, Xg = Xylocarpus granatum, Aa = Avicennia alba, Am = Avicennia marina, Ct = Ceriops tagal*

Density Status of Mangrove in Indonesia

The analysis results on the density status of the mangrove ecosystem in the coastal areas of Indonesia that has been provided in Table 4 exhibits that commonly mangrove ecosystem in Indonesia is in an orange zone or rare category namely the density in a range of >500 – 1000 trees/ha.

Table 4: Density status of mangrove in the coastal areas of Indonesia

Species	Coastal areas			
	East	Central	West	Average
Bruguiera cylindrica	0,00	163,50	136,40	99,97
Bruguiera gymnogrhiza	1139,17	342,92	480,00	654,03
Rhizophora apiculata	1664,80	1134,18	1081,22	1293,40
Rhizophora mucronata	756,63	1008,92	1485,29	1083,61
Rhizophora stylosa	997,50	869,63	1310,40	1059,18
Sonneratia alba	1287,69	1021,65	427,06	912,13
Xylocarpus granatum	262,33	101,80	177,40	180,51
Avicennia alba	549,67	307,86	529,88	462,47
Avicennia marina	244,33	338,43	705,25	429,34
Ceriops tagal	404,50	1194,67	299,50	632,89
Average	730,66	648,35	663,24	680,75

Annotation: Red= Very Rare (<500 trees/ha), Orange = Rare (>500 – 1000 trees/ha), Yellow= Medium (>1000 – 1500 trees/ha), Green= Solid (>1500 – 2000 trees/ha), Blue= Very Solid (>2000 trees/ha).

Production Ratio of Mangrove Seedlings

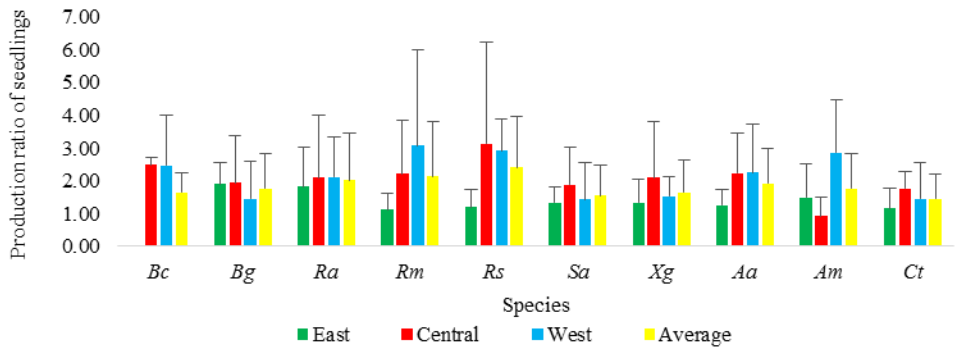

Fig. 3: Production ratio of Mangrove Seedling in the Coastal Areas of Indonesia. *Bc = Bruguiera cylindrica, Ra = Rhizophora apiculata, Rm = Rhizophora mucronata, Rs = Rhizophora stylosa, Sa = Sonneratia alba, Xg = Xylocarpus granatum, Aa = Avicennia alba, Am = Avicennia marina, Ct = Ceriops tagal*

DISCUSSION

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General Description of Mangrove Ecosystems in Indonesia

According to [47], so far in Indonesia, there are 202 mangrove species recorded consisting by 89 species of tree, 5 species of palm, 19 species of liana, 44 species of ground herbs, 44 species of epiphyte, and 1 species of fern. From these amounts, 43 species are true mangrove species and others are associated with mangrove species. Among those true mangroves, 33 of them are species of either tree or scrub habitus both sizes, big and small.

Referring to [59], all over the world, there are 60 true mangrove plants recorded and some of the major species for this type are only in Indonesia, especially Indo-Australian countries (Table 3). This signifies that the mangrove diversity in Indonesia is very high spreading in all islands from Sabang to Merauke [47]. Furthermore, mangroves in Indonesia are more varied than in other countries. In Indonesia, it is able to be discovered the stands of *Avicennia marina* with a range of 1-2 m height in the continuously inundated beaches until mix stands of *Bruguiera-Rhizophora* with more than 30 m height. On open shores, *Avicennia alba* and *Sonneratia alba* are able to be found, while in along river banks with lower salinity are abundantly uncovered species of palm *Nypa fruticans* and *Sonneratia caseolaris*.

The results of the literature study indicate that in 10 recent years, mangrove ecosystems in Indonesia are more dominated by family species of Bruguieraceae, Rhizophoraceae, Achantaceae, Lythraceae, and Meliaceae. Mangroves from these families are spread with varied density in all three zone parts of Indonesia. Lowering the number of mangroves in Indonesia both species and density is highly affected by the logging activities destructively and land conversion to be fish ponds starting from 1840 and exceeding its usage peak on post-2000s [28]. Further, [28] reported that since 1960s mangrove ecosystems in Indonesia especially Java and Sumatera experienced degradation as many as 200.000 ha and 800.000 ha in 30 years or an amount of 6667 ha/year and 26.667 ha/year, respectively

Mangrove Ecosystem Distribution in Indonesia (2008 – 2018)

Figure 1 signifies that *Bruguiera cylindrical* and *Xylocarpus granatum* are two mangrove species with the lowest density in terms of tree category than other species found in the coastal areas of Indonesia namely 99.97 trees/ha and 180.51 trees/ha, respectively. These species are rarely discovered in the eastern part and only a few are found in the central and western part of Indonesian coastal areas. The highest densities of mangrove species are *Rhizophora apiculata, Rhizophora mucronata*, and *Rhizophora stylosa* with a density value of 1293.40 trees/ha, 1083.61 trees/ha, and 1059.18 trees/ha, respectively. These species are found in all part zone areas with each density range of 1081.22 – 1664.80 trees/ha, 756.63 – 1485.29 trees/ha, and 869.63 – 1310.40 trees/ha.

Contrarily, mangrove species in the category of the seedling are dominated by *Rhizophora stylosa*, *Rhizophora mucronata*, and *Rhizophora apiculata* with their densities are 3252.88 trees/ha, 2636.27 trees/ha, and 2439.94 trees/ha, respectively. While two species, *Bruguiera cylindrica* and *Xylocarpus granatum*, are distinguished as the lowest density namely 248.63 trees/ha and 308.64 trees/ha, respectively (Figure2).

Density Status of Mangrove in Indonesia

An approximately average of mangrove density in three (east, central, and west) coastal areas of Indonesia are 730.66 trees/ha, 648.35 trees/ha, and 663.24 trees/ha, respectively. On eastern coastal areas of Indonesia possess four mangrove species with a very rare category namely *Bruguiera cylindrica, Xylocarpus granatum, Avicennia marina*, and *Ceriops tagal*, three species in the rare category namely *Rhizophora mucronata, Rhizophora stylosa*, and *Avicennia alba*, two species in the medium category such as *Bruguiera gymnorhiza* and *Sonneratia alba*, and one species in the solid category namely *Rhizophora apiculata*.

Further, central and western coastal areas of Indonesia have five species in each with the category rare namely *Bruguiera cylindrica, Bruguiera gymnorhiza, Xylocarpus granatum, Avicennia alba*, and *Avicennia marina* for central Indonesia, and *Bruguiera cylindrica, Bruguiera gymnorhiza, Sonneratia alba, Xylocarpus granatum,* and *Ceriops tagal* for west Indonesia. The low status of mangrove density in the coastal areas of Indonesia might be caused by raising the land-use conversion activity to be fish ponds and logging activity actively [28].

In terms of mangrove status above, mangrove ecosystem in the coastal areas of eastern Indonesia is still relatively good compared with two parts, central and western parts. The coastal areas in eastern Indonesia have mangrove with high density, especially in areas such as Kupang, Maluku, and Raja Ampat. The species dominant of these coastal tree areas are *Rhizophora apiculata, Rhizophora mucronata*, and *Rhizophora stylosa*. Nevertheless, mangrove ecosystem status in each coastal areas of Indonesia has to be increased through conservation and rehabilitation efforts to the gathered functions and benefits are going to become more maximal and sustainable.

Production Ratio of Mangrove Seedlings

The production ratio of mangrove seedling refers to a comparison of mangrove tree number per hectare on the number of seedlings resulted naturally through the fertilization process within a year. Figure 3 signifies that mangrove species with the highest and the lowest production ratio of seedling in Indonesia are *Rhizophora stylosa* and *Ceriops tagal,* namely 2.40 and 1.45, respectively. The mangrove species such as *Bruguiera gymnorhiza* in eastern Indonesia, *Rhizophora stylosa* in central Indonesia, and *Rhizophora mucronata* western Indonesia are species with the highest productivity of seedlings compared with other species, respectively. The production ratios of these mangrove species are 1.89 for *Bruguiera gymnorhiza*, 3.12 for *Rhizophora stylosa*, and 3.06 for *Rhizophora mucronata*. Furthermore, mangrove species with the lowest production ratios are *Bruguiera cylindrica* for eastern Indonesia (0,00), *Avicennia marina* for central Indonesia (0.92), and *Sonneratia alba* for western Indonesia (1.43).

In general, the high and low productivity of mangrove seedlings are able to be affected by the water quality including nutrient input which becomes a supporting factor for mangrove life in the ecosystem. The production ratio of mangrove seedlings can

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influence vegetation pattern and community structure of the mangrove ecosystem. Mangrove species with the highest production ratio is going to be the dominant species in a certain mangrove ecosystem

CONCLUSION

Commonly the mangrove ecosystems in the coastal areas of Indonesia are dominated by species such as *Bruguiera cylindrica, Bruguiera gymnoghiza, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, Sonneratia alba, Xylocarpus granatum, Avicennia alba, Avicennia marina*, and *Ceriops tagal*. The density status of mangrove in the east, central and west coastal areas of Indonesia are in orange zones, namely in the rare category. This is due to mangrove use activity in forms of logging and land conversion as fish ponds occurring in along coastal areas of Indonesia especially during 1980s to 2000s.

Species with the highest production ratio of mangrove seedlings *Bruguiera gymnorhiza* (eastern Indonesia), *Rhizophora stylosa* (central Indonesia), and *Rhizophora mucronata* (western Indonesia). Based on the density values and production ratios of mangrove seedlings, in a time span of 20 years, mangrove species such as *Rhizophora apiculata* and *Bruguiera gymnorhiza* will become the dominant species in coastal areas of eastern Indonesia, *Rhizophora stylosa* and *Rhizophora apiculata* are going to be the dominant species in the coastal areas of central Indonesia, and *Rhizophora mucronata* and *Rhizophora stylosa* will grow into the dominant species in the coastal areas of western Indonesia. Overall, two species that will be come up to be the dominant species of mangrove are *Rhizophora stylosa* and *Rhizophora mucronata*.

ACKNOWLEDGEMENT

The author would like to express the highest gratitude to the Indonesian Endowment Fund for Education (LPDP) as the main sponsor of this research so that the research could be conducted successfully.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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Citation: Rahman *et al.*, 2019. Production Ratio of Seedlings and Density Status of Mangrove Ecosystem in Coastal Areas of Indonesia. Advances in Environmental Biology 13(6): 13-20. DOI:10.22587/aeb.2019.13.6.3

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