Assessment of Natural Regeneration of Mangrove Species at Tsunami Affected Areas in Indonesia and Malaysia

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Abstract. Indian Ocean tsunami caused extensive damage on human life and coastal environments, including fragmented mangroves prior to 2004 tsunami. The natural regeneration of mangrove woody species was assessed in four tidal coasts of Aceh and Peninsular Malaysia during August 2015 to August 2016. A total of 23 mangrove woody species was recorded and they having good ability in term of natural regeneration at tsunami affected areas. The North coast of Aceh was recorded as richest mangrove with 22 species, followed by East coast of Aceh (17 species) and Peninsular Malaysia coast (13 species). In addition, the poorest mangrove was found in West coast of Aceh (7 species). Some species, such as Rhizophora apiculata, R. mucronata, Nypa fruticans, Scaevola taccada and Sonneratia caseolaris are found growing well in all sites. In contrast, Bruguiera cylindrica is only found in West coast of Peninsular Malaysia as same as Ceriops tagal, Phoenix paludosa and Sonneratia ovata are only found in North coast of Aceh. To date, some areas of natural regenerated mangrove were ruined by negative activities, such as illegal cutting and encroachment. Therefore, public consultations and community participations were needed to develop and conserve the important natural assets.

1. Introduction

Mangrove is a unique and vital ecosystem, distributed in inter-tidal areas between the sea and the land in tropical and subtropical areas of the world between approximately 30° N and 30° S latitude. The importance of mangrove in maintaining crucial ecosystem functions such as nutrient filtering, supporting estuarine fisheries[1, 2] and providing storm buffer has become more evident after the tsunami that ravaged parts of Asia and Africa in December 2004[3-13]. Unfortunately, mangrove ecosystem has been degrading over time.[14-21] Dahdouh-Guebas[6] stated that degradation of mangroves occurred at many sites in Indian Ocean coastal areas and were badly affected by the tsunami tragedy. Apparently, the most affected area was Aceh in Northern Sumatra, Indonesia and followed by west coast of Peninsular Malaysia.

Indonesia possesses more mangroves, in terms of number of species[22] and areas[20, 23], than other countries arguably making it the most important mangrove habitat in the world. The latest extensive inventory gathered by Giri et al.[20] for 2000 and Hamilton & Casey[23] for 2015 found that the Indonesia has more than 20% of world mangroves. However, prior to the 2004 tsunami, mangroves in the Aceh and Peninsular Malaysia are already disturbed by human activities and converted into developed areas, such as aquaculture ponds, settlement areas, tourism areas and others. Subsequently, the study of mangrove vegetation in Aceh coast prior to tsunami is very limited.[24] Whitten *et al.*[25] provided information and accounts on ecology of Sumatra, however the facts related to the ecology of Northern Sumatra coastal vegetation was lacking. Therefore, the ecology of coastal vegetation in the areas prior to tsunami is unknown

According to Onrizal and Mansor[24], Northern Sumatra coastal studies increased after the tsunami catastrophic; however most of them are about coastal geo-morphological studies focusing on earthquake and tsunami. Onrizal and Mansor[24] reported the status of coastal vegetation ecology immediately after the 2004 tsunami. However, the recovery status of coastal vegetation, including mangrove species at both Aceh and Peninsular Malaysia are not published, yet. Therefore, this study is to assess and overview the recovery of mangrove woody species at 11 and 12 years after the 2004 tsunami in Aceh and Peninsular Malaysia coasts.

2. Materials and Methods

2.1. Study site

Three coastal regions of northern tip of Aceh and one coastal region of northwest coast of Peninsular Malaysia were focused in this study. West coast of Aceh is extending south to Ujung Pulot and north to Lhok Nga about 25 km, North coast of Aceh is extending west to Lam Badeuk and west to Neuhen about 25 km and East coast of Aceh is extending north to Ujung Batee and south to Kuala Unga about 20 km. In addition, the northwest of Peninsular Malaysia is extending north to Kuala Perlis and south to Kuala Kedah about 25 km.

2.2. Methods

A serial intensive assessment was conducted from August 2015 to August 2016 in entire coast lines of above-mentioned regions to provide an overview of the mangrove woody species list of natural regeneration and their status at affected area by the 2004 tsunami. Plant specimens were collected whenever identification was not possible in the field. The identification of the species was done based upon Tomlinson[26] and Giesen et al.[27] Nomenclatures of the identified species were standardized using The International Plant Names Index[28], The Plant List[29], Slik[30] and Slik and Webb[31]. IUCN statuses were taken from the IUCN Red List of Threatened Species, Version 2016.2.[32]

3. Results

A total of 23 species of mangroves belonging to nine families and 15 genera were recorded in all study sites (Table 1). The woody species list is dominated by tree (82.6%), followed by palm (13.0%) and shrub (4.3%). According to IUCN Red List, two species is recorded as near threatened (NT), i.e. *Phonix paludosa* (palm) and *Sonneratia ovata* (tree). Subsequently, others species are recorded as least concern (LC).

Table 1 also shows that some species, such as *Rhizophora apiculata*, *R. mucronata*, *Nypa fruticans*, *Scaevola taccada* and *Sonneratia caseolaris* are found growing well in all sites. It means, the species is higher level of resiliency compared to other species after tsunami catastrophes. In contrast, *Bruguiera cylindrica* is limited distribution and only found in West coast of Peninsular Malaysia as same as *Ceriops tagal*, *Phoenix paludosa* and *Sonneratia ovata* are only distributed in North coast of Aceh.

The North coast of Aceh is recorded as richness ecosystem comprises 95.7% of all woody species. The second richness ecosystem is East coast of Aceh comprises 73.9% of all woody species, followed by West coast of Peninsular Malaysia (56.5% of all woody species). Subsequently, the West coast of Aceh is recorded as poorest ecosystem in term of species richness which the areas is only found 7 species or 30.4% (Table 1).

Of nine families in all study sites, Rhizophoraceae is recorded as richness family and has the maximum richness in taxa at both genus and species level which the family comprises 7 species belonging to 3 genera. The second richness family is Lythraceae comprises 4 species and 2 genera. In addition, four families, i.e. Combretaceae, Euphorbiaceae, Goodeniaceae and Meliaceae are recorded as the poorest family which comprises only 1 species (Table 1 and Figure 1).

4. Discussions

The observed mangrove woody species of both Aceh (22 species) and Peninsular Malaysia (13 species) is lower than the record by Spalding et al.[22], Latif and Faridah-Hanum[33] and Kusmana.[34] Malaysia has 38 exclusive, 57 non-exclusive and nine associate mangrove species[33], while Indonesia has 52 species of trees, 21 species of shrubs, seven species of palms and many species of other plant habit.[34] The species loss is predicted as combine impact of human and natural disturbance, such as conversion and heavy harvesting of mangroves as well as tsunami and earthquake catastrophes occurred in the areas. As well know that the mangrove ecosystems are threatened globally due to their widespread resources which are utilized for human use and disturbed by natural catastrophes.

Table 1. List of mangrove woody species observed from the natural regeneration at 11 or 12 years after tsunami with their IUCN status

Family	Genus	Species	Habit	Status	Site				F
					WA	NA	EA	WP	(%)
Acanthaceae	*Avicennia*	*alba*	Tree	LC	0	1	1	1	75
		marina	Tree	LC	0	1	1	1	75
		officinalis	Tree	LC	0	1	1	1	75
Arecaceae	*Borassus*	*flabellifer*	Palm	LC	1	1	1	0	75
	Nypa	*fruticans*	Palm	LC	1	1	1	1	100
	Phonix	*paludosa*	Palm	NT	0	1	0	0	25
Combretaceae	*Lumnitzera*	*littorea*	Tree	LC	0	1	1	1	75
Euphorbiaceae	*Excoecaria*	*agallocha*	Tree	LC	0	1	1	1	75
Goodeniaceae	*Scaevola*	*taccada*	Shrub	LC	1	1	1	1	100
Lythraceae	*Pemphis*	*acidula*	Tree	LC	0	1	0	0	25
	Sonneratia	*alba*	Tree	LC	0	1	1	0	50
		caseolaris	Tree	LC	1	1	1	1	100
		ovata	Tree	NT	0	1	0	0	25
Malvaceae	*Heritiera*	*littoralis*	Tree	LC	0	1	1	0	50
	Hibiscus	*tiliaceus*	Tree	LC	1	1	1	0	75
Meliaceae	*Xylocarpus*	*granatum*	Tree	LC	0	1	1	1	75
Rhizophoraceae	*Bruguiera*	*cylindrica*	Tree	LC	0	0	0	1	25
		gymnorrhiza	Tree	LC	0	1	1	0	50
		sexangula	Tree	LC	0	1	0	1	50
	Ceriops	*tagal*	Tree	LC	0	1	0	0	25
	Rhizophora	*apiculata*	Tree	LC	1	1	1	1	100

Table 1. Cont.

	mucronata	Tree	LC	1	1	1	1	100
	stylosa	Tree	LC	0	1	1	0	50
	Total			7	22	17	13	
	Percentage			30.4	95.7	73.9	56.5	

Note: WA = West coast of Aceh, NA = North coast of Aceh, EA = East coast of Aceh, WP = West coast of Peninsular Malaysia, 0 = absent, 1 = present.

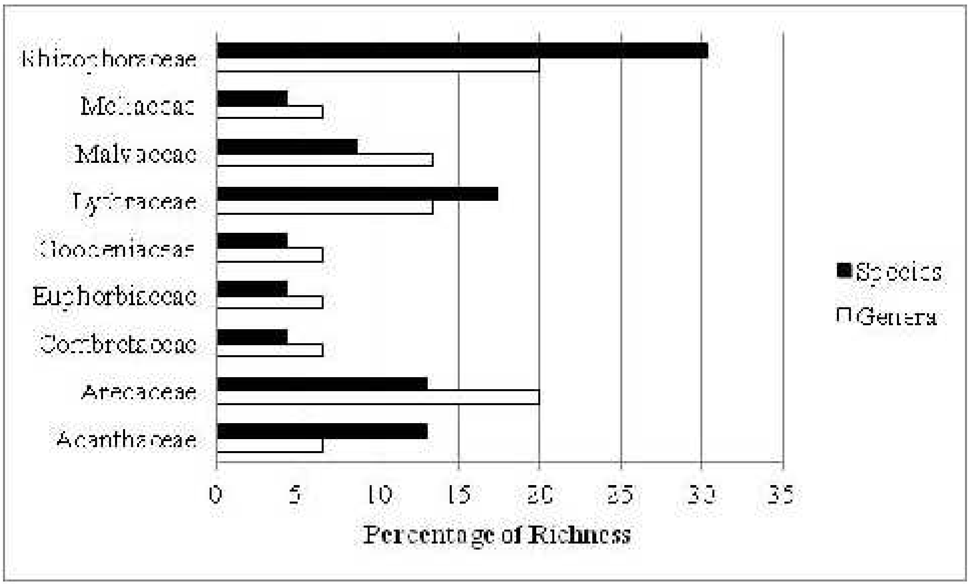

Figure 1. Graphical representation of the percentage of richness in genera and species of mangrove families in all study sites at 11 and 12 years after the tsunami.

Rhizophoraceae, such as *Rhizophora apiculata*, *R. mucronata* and *R. stylosa* are found high resiliency after the tsunami disturbance as well as *Nypa fruticans* and *Sonneratia caseolaris*. According to some publication[35-39], the species have also high level of persistent and resilient in other sites where they were affected by tsunami. Cochard et al.[40] stated that the resilience of a mangrove ecosystem is likely to be influenced by factors such rates of tree regeneration and seedling recruitment, and renewed sedimentation reversing soil losses during the hazardous event. Based on field survey, the previous species have higher rates of natural regeneration and seedling recruitment compared to others species.

Until 12 years after tsunami, the recorded of mangrove woody species in Aceh coast (22 species) is higher than recorded by Onrizal and Mansor[24] for the immediately after tsunami (2005) in the same sites in Aceh, i.e. only 7 species. Of 12 years after tsunami catastrophes, the mangrove woody species increased more than 300% compared than the immediately after tsunami. It means that the natural re-colonization of mangrove woody species is high recovery and growing well in affected areas of Aceh coast by the 2004 tsunami. Therefore, the natural regeneration is needed to maintain and conserve.

5. Conclusions

Of 12 years after tsunami, the recovery of mangrove woody species at affected area by the 2004 tsunami in Aceh and Peninsular Malaysia inter-tidal coasts is running well. A total of 23 mangrove woody species was recorded and they having good ability in term of natural regeneration at tsunami affected areas. North coast of Aceh was recorded as richness ecosystem which has 22 mangrove woody species. The second richness ecosystem was East coast of Aceh (17 species), followed by West coast of Peninsular Malaysia (13 species) and West coast of Aceh (7species).

However, based on field observation, some activities have potentially competed and threaten the sustainable of new mangroves both as result of natural regeneration and planted mangroves, such as illegal cutting and conversion to other land uses in the coastal areas. Therefore, maintenance of mangrove is needed to continue. Government and coastal communities are often aware of particular protection afforded by mangroves in coastal areas and an integrated mangrove management system that includes utilization of the materials produced by the mangrove forests and community participation on one side and awareness program in the other side are needed. To propose and to achieve a sustainable and long lasting vegetation bioshield, to conserve the biodiversity and to maintenance the production capacity are required.

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