The role of forest restoration in conserving mangrove plant at the eastern coast of North Sumatra

O Onrizal1*, R Amelia1, M Arif1, R Agustini1, K Amri1, G N Simamora1, J M Saragih1, R K Saragih1, N Sulistiyono1 and M Mansor2

1Faculty of Forestry, Universitas Sumatera Utara, Medan, Sumatera Utara, Indonesia.
2School of Biological Sciences, Universiti Sains Malaysia, Penang, Malaysia.

E-mail: *onrizal@usu.ac.id

Abstract. Mangrove forests are wetland resources in coastal areas that important role in supporting of life. However, in recent decades, many mangrove forests have been degraded or lost, mainly due to the conversion of mangroves into ponds. Mangrove restoration activities on ex-pond lands have begun in recent years on the eastern coast of North Sumatra. This study aimed to measure the recovery of mangrove species through restoration activities on ex-pond lands and to know the composition of the restored mangrove forests at the eastern coast of North Sumatra. A total of 30 sample plots, each plot size of 10m by 10m, have been established at each age of mangrove stands (5-9 years) and secondary forests. All trees with the diameter (DBH) ≥ 2 cm in the sample plot were identified and measured the DBH. Overall, there were 14 mangrove species in all sample plots, equivalent to 42.42% of all true mangrove plants found in Indonesia. This result indicated that mangrove restoration has succeeded in restoring mangrove species diversity. Therefore, the mangrove restoration on ex-pond land needs to be promoted in an effort to restore various mangrove functions for community and coastal resources resilience.

1. Introduction
Mangrove forests naturally grow on tropical and sub-tropical coasts [1-2] that support a variety of ecosystem services, including fisheries production [3], nutrient cycles [4-5], soil formation [6], timber production [7], breeding grounds of fish and other marine and estuarine biota [8-9] as well as ecotourism [10], carbon storage [6, 11] and coastal protector from tsunami [12-15] and storm [16-17]. Indonesian mangroves contributed about 30% of global mangrove areas [1]. In the last three decades, forest degradation and loss due to anthropogenic factors have increased significantly [1, 18-19]. The remaining mangrove forests are threatened due to clear-cutting, land conversion, hydrological changes and chemical/pollutant spills [18-20]. Therefore, the appropriate management of mangroves needs to be applied both local and global scale.

Until the end of the 1960s, Indonesia had lost more than 200,000 hectares of mangrove forests. Due to the government policy is to expand the ponds in the 1980s that it triggered the loss of mangrove area as much as 800,000 ha in just 30 years [18]. Meanwhile, around 60% of the mangrove forest on the east coast of North Sumatra was lost in the period 1977-2006, mainly due to the conversion of mangroves to pond land [21].

The loss and degradation of mangrove forests could reduce the productivity of mangroves in supporting coastal ecosystems that will cause various environmental problems such as floods, seawater
instructions, coastal abrasion as well as decreased volume and diversity of fish species caught [3]. Mangrove restoration efforts on unproductive ponds or ex-pond land have been carried out in several areas on the east coast of North Sumatra since the late 2000s. This study aimed to measure the recovery of mangrove species due to mangrove restoration activities and to determine the species composition at various ages of mangrove forest stands resulting from restoration on ex-pond land in the eastern coast of North Sumatra.

2. Materials and methods

2.1. Study sites and period

This study occurred at restored mangrove forest on ex-pond land and secondary mangrove forests at Percut Sei Tuan District, Deli Serdang Regency of the eastern coast of North Sumatra (Figure 1). The field research was conducted from June to November 2016.

![Figure 1. Research site of mangrove forests at the eastern coast of North Sumatra](image)

2.2. Method

Vegetation analysis was conducted at 30 sample plots, each size 10m by 10m that established at each restored mangrove stand (5-9 years) as well as secondary forests. The selection of plot sample within forest according was carried out systematic sampling with random start method. The distance between sample plots in each mangrove stand was 10 m. Each tree in the sample plot is grouped according to the growth stage, namely 1) saplings stage that are 2.0-9.9 cm in diameter (DBH) and 2) trees stage that is ≥ 10 cm in DBH. Each individual contained in each plot was identified, and its diameter (DBH) was measured, total tree height (TH) was estimated [14].
Distribution of mangrove tree species was shown based on regeneration stages in each forest stand. Importance value Index (IVi) was calculated for each sampling sites based on stem density, basal area, and frequency [14, 22] to determine the dominant species in each sampling site.

3. Results and discussions

3.1. Distribution of mangrove tree species

A total of 14 species of mangrove trees were found in all sample plots, which at the tree and sapling stages consisted of 11 species and 13 species, respectively. All mangrove plant species found are classified as true mangrove species. Thus, with a total sample plot of 1.8 ha, there are approximately 42.42% of all species of true mangrove plants found in Indonesia [23]. At each age of the restoration forest, the number of species ranges from 4-6 species, while in the secondary forest there were 9 species (Figure 2). The distribution of mangrove plant species was shown in Table 1.

Based on Table 1, the widest distribution of mangrove species in restoration mangrove forest at the saplings stage was *Rhizophora apiculata*, *R. stylosa* and *Avicennia marina* (100%). The widest distribution at the tree stages was *R. apiculata* with a distribution of 100% and followed by *R. mucronata* (83.33%) and *A. marina* (66.67%). The high distribution of *Rhizophora* spp. in restoration forests because these species were planted species, while the high spread of *A. marina* is due to small seeds that are easily spread as well as *A. marina* is classified as pioneers that are able to grow in open areas [24]. Therefore, there were new mangrove species ranges from 1-3 species that grow in mangrove restoration forests in addition to the species planted. It means mangrove restoration has an important role in conserving mangrove plant diversity.

Besides the planted mangrove species (*Rhizophora* spp.), there were other species growing the restored mangrove forests, such as *Avicennia* spp., *Bruguiera* spp., *Excoecaria agallocha*, *Heritiera littoralis*, and *Lumnitzera racemosa*. Some species were found in restoration forests, but not found in secondary forests, namely *B. cylindrica*, *E. agallocha*, *H. littoralis*, and *L. racemosa*. This result shows that mangrove restoration was successful in conserving mangrove species diversity.
Table 1. Distribution of mangrove plant species in each research site both restored mangroves and secondary mangroves at the eastern coast of North Sumatra

| No | Species                        | Stand age of restored mangroves (year-old) | Secondary mangroves | F (%) |
|----|--------------------------------|------------------------------------------|---------------------|-------|
|    |                                | 5 | 6 | 7 | 8 | 9 |    | S | T | S | T | S | T | S | T | S | T |
| 1  | Avicennia marina               | √ | - | √ | - | √ | √ | √ | √ | √ | 100.0 | 66.7 |
| 2  | Avicennia officinalis          | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3  | Bruguiera cylindrica          | √ | - | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4  | Bruguiera gymnorrhiza         | - | - | - | - | - | - | - | - | - | 16.7 | 16.7 |
| 5  | Bruguiera sexangula           | - | - | - | - | - | - | - | - | - | 16.7 | 16.7 |
| 6  | Ceriops tagal                 | - | - | - | - | - | - | - | - | - | 16.7 | 16.7 |
| 7  | Excoecaria agallocha          | - | - | - | - | - | - | - | - | 16.7 | 16.7 |
| 8  | Heritiera littoralis          | - | - | √ | - | - | - | - | - | - | 16.6 | - |
| 9  | Lumnitzeria racemosa          | - | - | - | - | - | - | - | - | - | 16.7 | - |
| 10 | Rhizophora apiculata          | √ | √ | √ | √ | √ | √ | √ | √ | 100.0 | 100.0 |
| 11 | Rhizophora mucronata          | √ | - | √ | - | √ | √ | √ | √ | - | 33.3 | 83.3 |
| 12 | Rhizophora stylosa            | √ | - | √ | - | √ | √ | √ | √ | √ | 100.0 | 50.0 |
| 13 | Scyphiphora                   | - | - | - | - | - | - | - | - | - | 16.7 | 16.7 |
|    | hydrophyllacea                | - | - | - | - | - | - | - | - | - | 16.7 | 16.7 |
| 14 | Xylocarpus granatum           | - | - | - | - | - | - | - | - | - | 16.7 | - |

Total of Species | 5 | 1 | 6 | 1 | 5 | 3 | 5 | 5 | 4 | 8 | 8 | - | 16.7 |

Remark: S = Sapling stage, T = Tree stage, F = Frequency, √ = occurred, - = Not occurred

3.2. Species composition
R. apiculata was recorded as dominant species in restoration mangrove forests, while A. marina was dominant in secondary forests (Table 2). Based on Table 2, at each stand age of the restoration forest, the highest important value index (IVi) was R. apiculata both for saplings and tree stages. At the age of 6 years, the IVi for saplings and tree stages was 116.04% and 191.34%, respectively. At the age of 7 years, the IVi for saplings and tree stages was 125.40% and 132.22%. At the age of 8 years, the IVi for saplings and tree stages was 103.03 and 191.34%, respectively. At the age of 9 years, the IVi for saplings and tree stages was 116.04% and 132.22%. Furthermore, at the age of 9 years, the IVi for saplings and tree stages was 116.04% and 191.34%, respectively. However, at the age of 5 years stands, the highest IVi was R. apiculata for the saplings stages of 111.52%, while for the highest IVi tree stage was A. marina (300%).

Table 2. Important value index (IVi) in each sampling plot both restored and secondary mangrove forest at the eastern coast of North Sumatra

| No | Stand Characteristic (stand old) | Species                      | RD (%) | RF (%) | RD (%) | IVi (%) |
|----|---------------------------------|------------------------------|--------|--------|--------|---------|
|    |                                 |                              | S | T | S | T | S | T | S | T |
| A. | Restored mangroves (stand old)  | Avicennia marina             | 25.34 | 100.00 | 13.73 | 100.00 | 100.00 | 39.07 | 300.00 |
|    |                                 | Bruguiera sexangula          | 3.31 | - | 3.91 | - | - | - | 7.22 | - |
|    |                                 | Rhizophora apiculata         | 64.46 | - | 47.06 | - | - | - | 111.52 | - |
|    |                                 | Rhizophora mucronata         | 3.24 | - | 15.69 | - | - | - | 18.93 | - |
|    |                                 | Rhizophora stylosa           | 3.65 | - | 19.61 | - | - | - | 23.26 | - |
|    |                                 | Total                        | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 200.00 | 300.00 |
Based on Table 3, the restoration forests from ex-ponds in the study sites have a higher species than R. apiculata potential to conserve mangrove species. Restored mangrove forests at ex-pond areas also have high around the location of the restoration forest. Therefore, mangrove restoration on ex-pond land has the richness of restored mangroves has reached 77.8% of the secondary mangrove forest that is located.

Table 2. Continued

| No | Stand Characteristic | Species                  | S  | T  | S  | T  | S  | T  |
|----|----------------------|--------------------------|----|----|----|----|----|----|
| 2. | 6 years              | *Avicennia marina*       | 2.72 | 5.54 | 10.77 | 14.29 | 36.10 | 13.49 | 58.84 |
|    |                      | *Bruguiera cylindrica*   | 0.48 | -   | 1.53 | -   | -   | 2.01 | -   |
|    |                      | *Heritiera littoralis*   | 0.62 | -   | 1.53 | -   | -   | 2.15 | -   |
|    |                      | *Rhizophora apiculata*   | 74.50 | 88.59 | 41.54 | 71.43 | 32.35 | 116.04 | 191.34 |
|    |                      | *Rhizophora mucronata*   | 1.48 | -   | 10.77 | -   | -   | 12.25 | -   |
|    |                      | *Rhizophora stylosa*     | 20.20 | 5.54 | 33.84 | 14.29 | 31.55 | 54.04 | 49.62 |
|    |                      | **Total**                | **100.00** | **100.00** | **100.00** | **100.00** | **200.00** | **300.00** |
| 3. | 7 years              | *Avicennia marina*       | 12.48 | 41.60 | 25.39 | 40.90 | 40.57 | 37.87 | 123.07 |
|    |                      | *Lumnitzera racemosa*    | 1.06 | -   | 1.59 | -   | -   | 2.65 | -   |
|    |                      | *Rhizophora apiculata*   | 77.78 | 52.94 | 47.62 | 50 | 29.28 | 125.40 | 132.22 |
|    |                      | *Rhizophora mucronata*   | 3.57 | -   | 7.94 | -   | -   | 11.51 | -   |
|    |                      | *Rhizophora stylosa*     | 5.11 | 5.67 | 17.46 | 9.09 | 30.29 | 22.57 | 45.05 |
|    |                      | **Total**                | **100.00** | **100.00** | **100.00** | **100.00** | **200.00** | **300.00** |
| 4. | 8 years              | *Avicennia marina*       | 11.80 | 33.38 | 26.83 | 31.81 | 20.63 | 38.63 | 85.82 |
|    |                      | *Excoecaria agallocha*   | 1.15 | 1.08 | 1.21 | 2.27 | 16.19 | 2.36 | 19.54 |
|    |                      | *Rhizophora apiculata*   | 67.66 | 46.30 | 35.37 | 43.18 | 18.05 | 103.03 | 107.53 |
|    |                      | *Rhizophora mucronata*   | 10.24 | 6.46 | 13.41 | 9.09 | 19.68 | 23.65 | 35.23 |
|    |                      | *Rhizophora stylosa*     | 9.15 | 12.92 | 23.17 | 13.64 | 25.45 | 32.32 | 52.01 |
|    |                      | **Total**                | **100.00** | **100.00** | **100.00** | **100.00** | **200.00** | **300.00** |
| 5. | 9 years              | *Avicennia marina*       | 3.66 | 2.42 | 4.35 | 5.26 | 17.37 | 8.01 | 25.05 |
|    |                      | *Rhizophora apiculata*   | 70.37 | 67.83 | 43.48 | 50 | 21.87 | 113.85 | 139.7 |
|    |                      | *Rhizophora mucronata*   | 9.14 | 14.53 | 26.08 | 13.16 | 39.09 | 35.22 | 66.78 |
|    |                      | *Rhizophora stylosa*     | 16.83 | 15.34 | 26.08 | 31.57 | 21.73 | 42.91 | 68.64 |
|    |                      | **Total**                | **100.00** | **100.00** | **100.00** | **100.00** | **200.00** | **300.00** |

B. Secondary mangroves

|                | *Avicennia marina*       | 21.93 | 62.61 | 25.89 | 42.42 | 13.83 | 47.82 | 118.86 |
|                | *Avicennia officinalis*  | 1.78 | 2.80 | 10.71 | 6.06 | 21.13 | 12.49 | 29.99 |
|                | *Bruguiera gymnorhiza*   | 18.49 | 10.06 | 15.18 | 15.15 | 12.86 | 33.67 | 38.07 |
|                | *Bruguiera sexangula*    | 19.66 | 11.74 | 16.96 | 10.61 | 11.39 | 36.62 | 33.74 |
|                | *Ceriops tagal*          | 15.66 | 3.35 | 9.82 | 9.09 | 10.89 | 25.48 | 23.33 |
|                | *Rhizophora apiculata*   | 1.38 | -     | 0.89 | -   | 2.27 | -   | -   |
|                | *Rhizophora stylosa*     | 3.80 | -     | 0.89 | -   | 4.69 | -   | -   |
|                | *Scyphiphora hydropylacea* | 13.83 | 7.83 | 13.39 | 13.64 | 12.90 | 27.22 | 34.37 |
|                | *Xylocarpus granatum*    | 3.48 | 1.68 | 6.25 | 3.03 | 17.01 | 9.73 | 21.72 |
|                | **Total**                | **100.00** | **100.00** | **100.00** | **100.00** | **200.00** | **300.00** |

Remark: RD = relative density, RF = relative frequency, RB = relative basal area

In secondary forests, *A. marina* has the highest IVi for both saplings and tree stages. The high IVi of *R. apiculata* in restoration forests was caused by the characteristics of the species, such as *R. apiculata* can grow well muddy areas with high levels of salinity as well as the ability to withstand submersion by tides and have hanging roots to breathe [14].

Species richness and density of trees in several types of mangrove forests are presented in Table 3. Based on Table 3, the restoration forests from ex-ponds in the study sites have a higher species than coastal areas of Banda Aceh, but lower than other mangrove forests in North Sumatra. The species richness of restored mangroves has reached 77.8% of the secondary mangrove forest that is located around the location of the restoration forest. Therefore, mangrove restoration on ex-pond land has the potential to conserve mangrove species. Restored mangrove forests at ex-pond areas also have high...
density both regeneration ($\Theta 2.0 – 9.9 \text{ cm}$) and tree stage ($\Theta \geq 10 \text{ cm}$) (Table 3). The restored mangroves also have been evidenced to play an important role in restoring macrozoobenthos diversity [25-26].

**Table 3.** Species richness of mangrove forests in northern Sumatra

| No  | Forest type and location                      | Species Richness | Density (ind/ha) | Reference |
|-----|-----------------------------------------------|------------------|------------------|-----------|
| 1.  | Restored mangroves at Percut Sei Tuan         | 7                | 10,729           | 715       | This study |
| 2.  | Secondary mangroves at Percut Sei Tuan        | 9                | 2,472            | 416       | This study |
|     | Ecotourism mangroves at Kampoeng Nipah, North Sumatra | 32 | 13,112 | 206 | [10] |
| 3.  | Mangrove after tsunami at Nias              | 17               | 44,732           | 47        | [14] |
| 4.  | Mangroves at pond areas at Banda Aceh       | 6                | 723              | 224       | [14] |

4. Conclusions and recommendations
Restoration mangrove forests have good ability in conserving plant diversity that has reached 77.8% of the secondary mangrove forest and around half of all species of true mangrove plants of Indonesia. This study suggested the mangrove restoration activities be continued on degraded mangrove areas in Indonesia, including at ex-pond areas as part of coastal ecosystem restoration and community resiliency.

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