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# Empowerment of Abandoned Ponds for Sustainable Mangrove Rehabilitation Activities in Percut Sei Tuan, Deli Serdang, Indonesia

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**Abstract.** Mangrove ecosystems provide important functions for ecosystem service. However, the degradation of mangrove forests, especially conversion to aquaculture ponds is a driver for deforestation. Therefore, this study aimed to analyze the mangrove vegetation and duration of inundation in ponds before and after rehabilitation activities were conducted on abandoned ponds. In this analysis, we used the census method to collect structural data, the Important Value Index (IVI), composition and structure, and the diversity index. To determine the duration of inundation at the observation sites in a pond in Tanjung Rejo, Percut Sei Tuan village, we deployed one water logger and two Mini Buoys at ponds. At the observation site, eight pure mangrove species have been founded, namely *Avicennia alba*, A. *marina*, *Bruguiera gymnorrhiza*, *Excoecaria agallocha*, *Rhizophora apiculata*, R. *mucronata*, R. *stylosa*, and *Nypa fruticans*. The main species was A. *marina* which is a total of 756 idv/ha at the seedling stage 52.81 idv/ha at the sapling stage, and 268.09 idv/ha at the tree level. The highest IVI has founded in seedlings, saplings, and trees at A. *marina*, which was 99.30%. 80.41% and 94.49%, respectively. Rehabilitated *Avicennia* spp that grew only 2.4% from 2000 seedlings. The low growth of seedlings was influenced by the pond condition which was always in a state of flooding. The current study provides important information that in carrying out planting or rehabilitation activities it is necessary to determine which inundation rotation should be a priority considered.

**Keyword:** Diversity Index, Flooding, Mangrove Ecosystems, Ponds, Rehabilitation

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# 1 Introduction

Mangrove ecosystems are habitats for various marine flora and fauna species to interact. They are tolerant of high salinity and are affected by ocean waves. The mangrove ecosystem is a very productive ecosystem consisting of woody trees and shrubs, capable of absorbing and storing large amounts of blue carbon [1]. The intertidal zone dominates tropical and subtropical coastlines located at the border between land and sea at low latitudes, and can adapt to vital climate changes [1]-[2]. However, every year mangrove forests in the tropics continue to experience a decrease in area. Since 2004, mangrove forests have decreased by 51.9%, and commercial aquaculture contributes to 28% of the total mangrove losses in all countries. It caused around 544,000 ha of mangrove forests are converted into other land allotments [3].

The preservation of the mangrove ecosystem is highly dependent on the existence of biodiversity. However, threats to mangrove biodiversity due to the logging of mangroves for firewood and housing materials, especially conversion to ponds, still occur. Aquaculture development is the main reason for mangrove loss in many Asian countries [4]-[5]. With increasing awareness of the importance of mangroves, rehabilitating cultivated ponds back into mangrove forests has become a popular initiative. Therefore, to reduce losses, rehabilitation becomes the main conservation agenda in mangrove ecosystems [6]-[7].

Conservation and rehabilitation of mangroves need to be considered to maintain and increase biodiversity. A total of 2000 seedlings were planted with the *Avicennia marina* species which is conducted in August 2021 in a community-owned pond in Tanjung Rejo Village, Perut Sei Tuan District, Deli Serdang Regency, North Sumatra. Therefore, this study aims to analyze vegetation before and after rehabilitation through planting seedlings which is three months of planting and to gain important information about inundation rotation for seedling growth.

# 2 Research Method

## 2.1 Research Time and Site

The observations were conducted on community-owned ponds in Tanjung Rejo Village, Percut Sei Tuan District, Deli Serdang Regency, North Sumatra which is located at 3.732 N and 98.773324 E (Figure 1). There are three ponds used for vegetation data collection with an area of 124x37 m (pond I), 175x53.2 m (pond II), and 29x111 m (pond III), respectively. Planting activities were carried out at the ponds in August 2021. A total of 2000 seedlings have been planted in an abandoned pond belonging to the people of Tanjung Rejo Village. The distance 1x1 m was used for *Avicennia marina*. After three months, the number and height of surviving seedlings were measured to determine the percentage of successful planting.

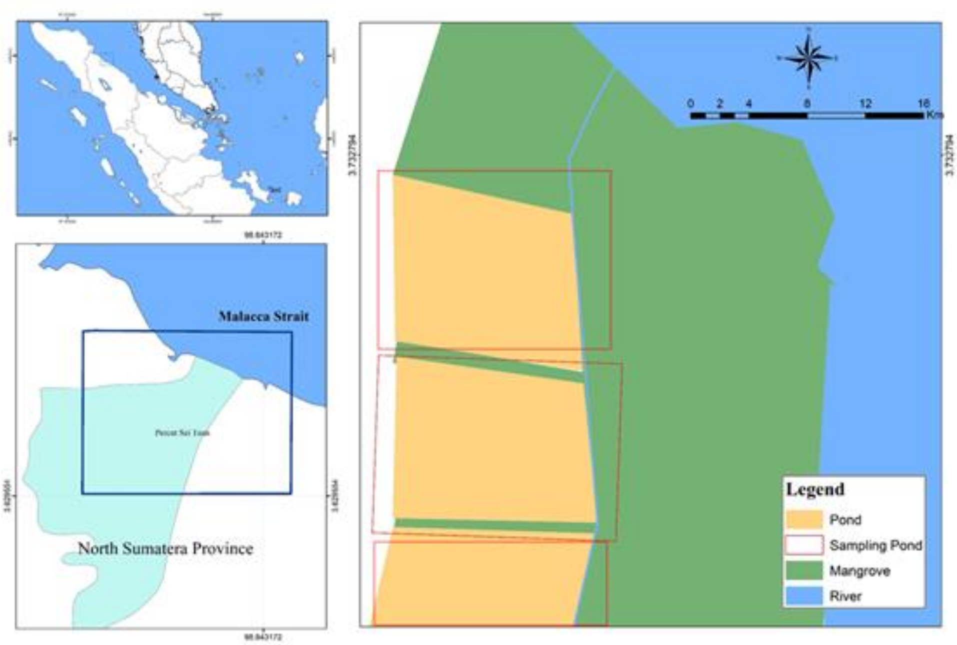


**Figure 1** Sampling sites showing three abandoned ponds in Percut Sei Tuan

## 2.2 Mini Buoy Installation

To observe the success of rehabilitation, a water logger with Minibouy was installed at the same time as planting. Water loggers are used to obtaining results from the hydrological analysis, where the hydrological system in mangrove forests is dominated by the inflow and outflow of seawater periodically following the tidal cycle [8]. The hydrological parameters measured by installing a mini buoy logger planted in the restoration area are inundation per tidal (min), current velocity (m/s), and wave orbital velocity (m/s).

## 2.3 Data collection

Collecting data for vegetation analysis using the census method or measuring all plants in the three ponds starting from seedlings, saplings, and trees. Observed parameters were the name of species, diameter, and height. Individual characteristics include seedling stage (height < 1.5 m), sapling stage (height > 1.5 m, dbh 5.0 cm) and tree stage (dbh > 5.0 cm) [9].

## 2.4 Data analysis

The physical condition of mangrove vegetation can reveal the density of the ecosystem. This condition requires an environmental form that can be identified using various parameter values such as stem diameter, height, dominance, relative dominance, frequency, and relative frequency [10]. Vegetation data were analyzed to measure the relative values of density, frequency, abundance, and species dominance. To express the dominance and biological success of each species with a single value, the concept of Important Value Index (IVI) as a relative better expression of the ecological importance of a species

$$\text{Density} = \frac{\text{Number of individuals of a species)}}{\text{area of sample plot}} \quad (1)$$

$$\text{Relative density (RD)} = \frac{\text{total number of individual of a species}}{\text{total number of all individuals of all species}} \times 100\ \% \quad (2)$$

$$\text{Frequency} = \frac{\text{Number of plots containing type}}{\text{(Number of all plots}} \quad (3)$$

$$\text{Relative frequency (RF)} = \frac{\text{frequency of a species}}{\text{frequency pf all a species}} \times 100\ \% \quad (4)$$

$$\text{Dominansi/ Basal Area} = \tfrac{1}{4} \pi d^2 \quad (5)$$

$$\text{Relative Basal Area (RBA)} = \frac{\text{basal area of a species}}{\text{total basal area of all species}} \times 100\ \% \quad (6)$$

Important Value Index (IVI):

IVI = RD + RF (for seedling stage).

IVI = RD + RF + RBA (for sampling and tree).

Diversity Index (H')

Species diversity was determined using the Shannon-Wiener index

$$H' = -\Sigma pi\ (\ln pi) \quad (7)$$

Where pi is the number of individuals of a species divided by the number of individuals of all species. Evenness or species per cycle index E = S / (log ni log ns). Where S is the number of species in the stand, and ni and ns are the species density values. The diversity classification can be identified based on the value obtained and categorized based on three stages of diversity, namely: if H' (0 < 2) is low, H' (2-3) is categorized as moderate, H' (> 3) or higher [11]. The Diversity Index can also be calculated using the Taxonomy Index.

$$\Delta^{+} = [\sum\sum{}_{i<j}\omega_{ij}] / [\ S(s\text{-}1)/2] \quad (8)$$

Where: Δ+ = Taxonomy Index

S = Number of species present and for double addition

i and j = range of species presence

The Taxonomic Diversity Index is used to see similarities or comparisons with the Shannon Wienner index [12] defined a diversity/difference measure that satisfies the above requirements by combining higher taxon richness and evenness concepts.

## 3 Results and Discussion

### 3.1 Species Composition

The observation found eight pure mangrove species were found at the sapling and tree stage, and six species at the seedling stage (Table 1). It means about 24% of the 33 pure mangrove species in Indonesia [13]-[14]. The major species in the three ponds was A. *marina*. It can be seen that the number of individuals and the highest IVI are found in A. *marina* (Table 1 and Table 5). The same results from the previous study by [15] were in the Percut Sei Tuan mangrove forest with 10 species and the dominant species was A. *marina*.

**Table 1** The density of species found in Ponds at Percut Sei Tuan

| No | Species | Family | Density Indv/ha | | |
|---|---|---|---|---|---|
| | | | Seedling | Sapling | Tree |
| 1 | *Avicennia alba* | Acanthaceae | 91 | 30 | 40 |
| 2 | *Avicennia marina* | Acanthaceae | 439 | 53 | 268 |
| 3 | *Bruguiera gymnorrhiza* | Rhizophoraceae | 2 | 1 | 1 |
| 4 | *Excoecaria agallocha* | Euphorbiaceae | - | 1 | 25 |
| 5 | *Rhizophora apiculata* | Rhizophoraceae | 6 | 1 | 9 |
| 6 | *Rhizophora mukronata* | Rhizophoraceae | - | 1 | 2 |
| 7 | *Rhizophora stylosa* | Rhizophoraceae | 127 | 46 | 168 |
| 8 | *Nypa fruticans* | Arecaeae | 1 | 2 | 8 |
| Total | | | 666 | 132 | 515 |

**Table 2** Calculation of average height and diameter at seedling, sapling, and tree stages

| No | Species | Height | | | Diameter | |
|---|---|---|---|---|---|---|
| | | Seedling (cm) | Sapling (m) | Tree (m) | Sapling (cm) | Tree (cm) |
| 1. | *A. alba* | 38.26±19.21 | 5.63±0.22 | 8.12±0.29 | 4.27±0.24 | 11.16±5.69 |
| 2. | *A. marina* | 47.19±44.05 | 5.36±0.80 | 7.85±0.62 | 3.85±0.47 | 11.53±4.78 |
| 3 | *B. gymnorrhiza* | 98.75±14.05 | 3.00±0.00 | 8.00±0.00 | 3.60±0.00 | 12.55±6.01 |
| 4 | *E. agallocha* | - | 8.00±0.00 | 7.58±0.59 | 4.40±0.00 | 11.24±3.38 |
| 5 | *R. apiculata* | 63.60±11.06 | 5.50±0.71 | 6.20±0.75 | 3.92±0.31 | 7.11±1.43 |
| 6 | *R. mukronata* | - | 4.00±0.00 | 5.50±1.08 | 4.00±0.00 | 6.65±1.07 |
| 7 | *R. stylosa* | 76.28±42.74 | 6.12±0.60 | 7.03±0.62 | 4.260±50 | 7.48±1.37 |

Table 1 shows the highest number of individuals for the seedling was A. *marina* with a total of 756 idv/ha. A. *marina* can grow in extreme environments, where water and soil experience ups and downs carrying various types of minerals ([16]. At the sapling stage, the highest number of individuals was found in A. *marina* with a total of 53 idv/ha, and the lowest was B. *gymnorrhiza*, E. *agallocha*, and R. *mucronata* with each individual one idv/ha. As for the tree level, the highest number of individuals was found to be A. *marina* with a total of 268.09 idv/ha and the lowest was the species B. *gymnorrhiza* with a total of one idv/ha. The growth of mangrove plants is largely determined by environmental conditions such as inundation, soil, and the climate that supports their growth [18]. It is in line with research that has been conducted by [19] in the mangrove forest of Percut Sei Tuan.

**Table 3** Frequency, Dominance at the Seed stage, Saplings, and Trees

| No | Species | Frequency | | | Dominance | |
|---|---|---|---|---|---|---|
| | | Seedling | Sapling | Tree | Sapling | Tree |
| 1. | *A. alba* | 0.33 | 0.33 | 0.33 | 8.32 | 56,68 |
| 2. | *A. marina* | 1.00 | 1.00 | 1.00 | 6.74 | 60,55 |
| 3 | *B. gymnorrhiza* | 0.33 | 0.33 | 0.33 | 5.90 | 71,75 |
| 4 | *E. agallocha* | - | 0.33 | 1.00 | 8.82 | 57,53 |
| 5 | *R. apiculata* | 0.33 | 0.33 | 0.33 | 7.00 | 23,00 |
| 6 | *R. mukronata* | - | 0.33 | 0.33 | 7.29 | 20,14 |
| 7 | *R. stylosa* | 1.00 | 1.00 | 1.00 | 8.28 | 25,49 |

The highest frequency at seedling, sapling, and tree stages was found in A. *marina* species, namely 1, which means that both species were always present in the three ponds observed. The highest dominance of the highest seedling stage was found in the type of E. *agallocha*, and at the tree stage was B. *gymnorrhiza*. The dominance height was closely related to plant diameter (Table 2). It was related to the formula for finding the dominance value.

**Table 4** Relative Density (RD), Relative Frequency (RF), and Relative Dominance (RDOM) at the Seedling, Sapling, and Tree stages

| No | Spesies | RD (%) | | | RF (%) | | | RDOM (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Seed-ling | Sap-ling | Tree | Seed-ling | Sap-ling | Tree | Sapling | Tree |
| 1. | *A. alba* | 13.70 | 22.57 | 7.80 | 11.11 | 9.09 | 7.69 | 15.89 | 17.99 |
| 2. | *A. marina* | 65.97 | 40.27 | 52.20 | 33.33 | 27.27 | 23.08 | 12.87 | 19.21 |
| 3 | *B. gymnorrhiza* | 0.35 | 0.44 | 0.23 | 11.11 | 9.09 | 7.69 | 11.28 | 22.77 |
| 4 | *E. agallocha* | - | 0.44 | 4.86 | - | 9.09 | 23.08 | 16.85 | 18.25 |
| 5 | *R. apiculata* | 0.87 | 0.88 | 1.69 | 11.11 | 9.09 | 7.69 | 13.37 | 7.30 |
| 6 | *R. mukronata* | - | 0.44 | 0.45 | - | 9.09 | 7.69 | 13.92 | 6.39 |
| 7 | *R. stylosa* | 19.11 | 34.96 | 32.77 | 33.33 | 27.27 | 23.08 | 15.82 | 8.09 |

The highest relative densities at the seedling, sapling, and tree stages were *Avicennia marina* species, namely 65.97%, 40.27%, and 52.20%, respectively. Meanwhile, at the seedling stage, E. *agallocha* and R. *mucronata* were not found, sapling stage 0.44% and tree 0.23%. The highest relative frequency at the seedling, sapling, and tree stages was found in A. *marina* species, namely 33.33%, 27.27%, and 23.08%. It means that both types were always founded in the three ponds observed. Meanwhile, the highest relative dominance was found in B. *gymnorrhiza*, followed by A. *marina*, namely 22.77%, and 19.21% (the results can be seen in Table 4). The dominance of mangrove species varies in each area. If the stem size is larger, it will expand its dominance [17].

**Table 5** Important Value Index at the Seedling, Sapling, and Tree stages

| No | Species | Important Value Index | | |
|---|---|---|---|---|
| | | Seedling (%) | Sapling (%) | Tree (%) |
| 1. | *A. alba* | 24.81 | 47.55 | 33.47 |
| 2. | *A. marina* | 99.30 | 80.41 | 94.49 |
| 3 | *B. gymnorrhiza* | 11.46 | 20.81 | 30.68 |
| 4 | *E. agallocha* | - | 26.38 | 46.19 |
| 5 | *R. apiculata* | 11.98 | 23.35 | 16.69 |
| 6 | *R. mukronata* | - | 23.46 | 14.54 |
| 7 | *R. stylosa* | 52.44 | 78.05 | 63.93 |

Based on Table 5, it can be seen that the A. marina has the highest IVI at the seedling, sapling, and tree stages, which is 99.30%, 80.41%, and 94.49%. According to [18], species with an IVI of 10% at the seedling and 15% at the sapling stages can be categorized to be quite influential species in the region. Meanwhile, at the Sapling IVI stage, the lowest was found in B. *gymnorrhiza*, which was 20.81%. at the tree stage is R. *mucronata* which is 14.54%.

**Table 6** Shannon Wiener Diversity Index and Taxonomic Diversity Index at Seedling, Sapling, and Tree Stages

| No | Spesies | Diversity Index (H') | | | Taxonomic Diversity Index | | |
|---|---|---|---|---|---|---|---|
| | | Seed-ling | Sapling | Tree | Seedling | Sapling | Tree |
| 1. | *A. alba* | 0.27 | 0.34 | 0.20 | 0.07 | 0.11 | 0.04 |
| 2. | *A. marina* | 0.27 | 0.37 | 0.34 | 0.33 | 0.20 | 0.26 |
| 3 | *B. gymnorrhiza* | 0.02 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 |
| 4 | *E. agallocha* | - | 0.02 | 0.15 | - | 0.00 | 0.02 |
| 5 | *R. apiculata* | 0.04 | 0.04 | 0.07 | 0.00 | 0.00 | 0.01 |
| 6 | *R. mukronata* | - | 0.02 | 0.02 | - | 0.00 | 0.00 |
| 7 | *R. stylosa* | 0.32 | 0.37 | 0.37 | 0.09 | 0.17 | 0.16 |

Shows that the diversity index value only ranges from 0.02-0.37, and it can be stated that the stage of mangrove diversity in the observation area is included in the criteria classified as low at the seedling stage and moderate at the Sapling and Tree stage. Because according to [11] the Shannon-Wiener index (H′ 0<2 = indicates low species diversity [11]. The low diversity of mangrove species in a research location is caused by several things, namely environmental conditions that are only able to support the growth of certain species [11]. [20] explains that species diversity in a community will be high if the community consists of several species and no species dominates. If a community has a low diversity value, then the community itself will consist of several species and the presence of dominant species.

Table 6 depicts that the A. *marina* has the highest value of the index of taxonomic diversity at the seedling, sapling, and tree stages with values of 0.33, 0.20, and 0.26, respectively. While the lowest stage of seedling, sapling, and tree was found at R. *mucronata* (0.00). The diversity index in a community is highly dependent on the number of individuals and species present in the community.

This result is in accordance with a study [12] which reported that adequate size within a particular taxonomic group should not only be a function of the number of species present and their relative abundance but should also include information about species relatedness. The Taxonomic Diversity Index is carried out when the effort to measure data is not controlled and the data only consists of the presence or absence of species.

### 3.2 Vegetation Structure After Rehabilitation

After three months, only 48 individuals of the 2000 planted A. *marina* survived (equivalent to 2.4%) with a height of 25-75 cm. The low growth of seedlings was influenced by various factors. One is the condition of the pond is always flooding. The always flooding pond condition can be proven by the results obtained by the Mini Bouy, as displayed in Figures 2-3 and Tables 7-8.

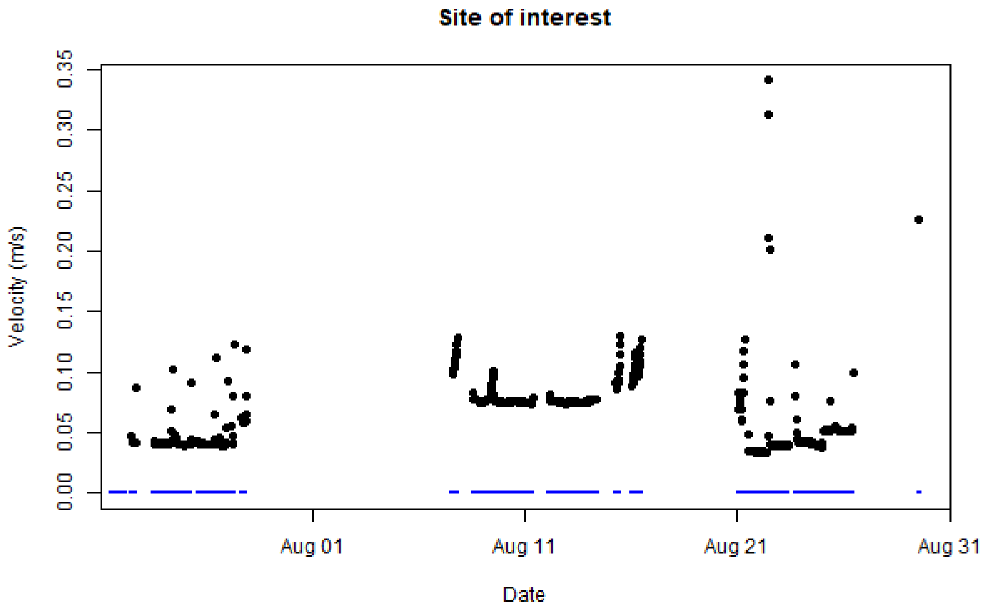


**Figure 2** Mini buoy 1 of planting area

**Table 7** Measurement of Mini buoy 1 logger in planting area

| | min | mean | median | Max |
|---|---|---|---|---|
| *Inundation per tide* (min) | 2.00 | 304.24 | 43.67 | 4203.33 |
| *Current velocity* (m/s) | 0.03 | 0.06 | 0.05 | 0.34 |
| *Wave orbital velocity* (m/s) | 0.00 | 0.00 | 0.00 | 2.04 |
| *Windows of opportunity* (d) | 0.09 | 0.72 | 0.52 | 2.53 |

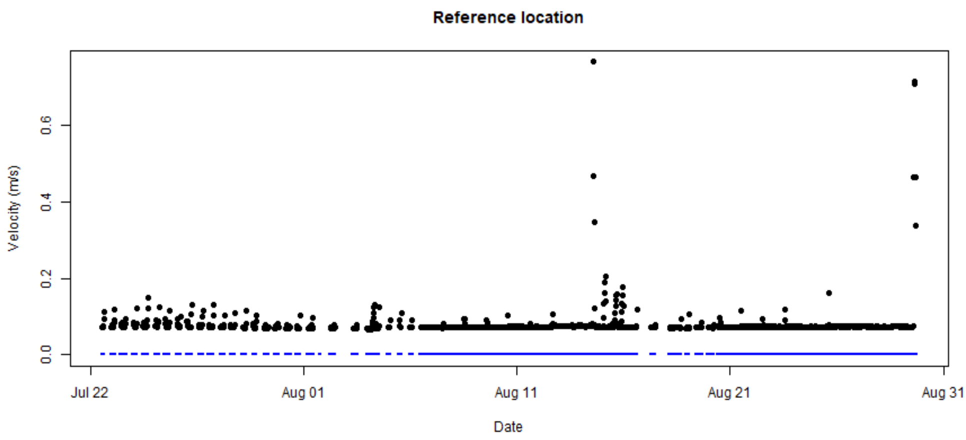


**Figure 3** Mini bouy 2 of planting area

**Table 8** Measurement of Mini bouy logger 2 in planting area

| | min | mean | median | Max |
|---|---|---|---|---|
| *Inundation per tide* (min) | 1.00 | 843.23 | 353.17 | 13845.33 |
| *Current velocity* (m/s) | 0.07 | 0.08 | 0.07 | 0.77 |
| *Wave orbital velocity* (m/s) | 0.00 | 0.01 | 0.00 | 8.60 |
| *Windows of opportunity* (d) | 0.04 | 0.26 | 0.23 | 0.80 |

Table 7 and Table 8 summarize the stage of inundation at the planting site was high. The average inundation on the two loggers was 304.24 and 843.23, while the maximum inundation could reach 4203.33 and 13845.33. According to [21], there will be no mangroves that can survive >400/tidal min. Moreover, the planted seeds are low in survival ability. Meanwhile, Avicennia marina's tolerance for inundation was 400–800 minutes/day and 200–400 minutes/inundation. Inundation always occurs due to the condition of the ponds that do not have adequate sluice gates. Therefore, there is no water entering and leaving which causes the rotting of the seedlings. This die-back *Avicennia marina* occurred in all observed sited. Tides affect seedling growth, while the long-term inundation can cause stem rot of seedlings [22]-[23].

## 4 Conclusion

At the observation site, eight true mangrove species were found, *Avicennia alba*, *Avicennia marina*, *Bruguiera gymnorrhiza*, *Excoecaria agallocha*, *Rhizophora apiculata*, *Rhizophora mukronata*, *Rhizophora stylosa*, and *Nypa fruticans*. The low rate of seedling growth was influenced by the condition of the pond which was always in a state of flooding. This data and the inundation rotation are expected to be a priority considerant in planting or rehabilitation activities.

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