Oil Spill in Pulau Rambut and its possible long-term impact on mangrove as waterbirds habitat

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Abstract. In July 2019, an oil spill incident in the northern West Java has reached Pulau Rambut, a Wildlife Sanctuary dedicated for waterbird in Jakarta Bay, Indonesia. The objective of this paper was to record the number of mangrove trees exposed to the oil spill, and provide desk-study analysis of the possible long-term impact of the mangrove. Field visit were conducted on 19 and 22 August. Trees along waterways were examined, plots were stablished in the exposed and non-exposed area. The rhizophores of all trees (n=26) along waterways were covered by the sticky-melted crude-oil, while some leaves were also covered. In the exposed areas, 47 trees (63.51%) were covered by oil, either heavily or partially. For the younger trees, 43.08% poles, 78.74% saplings and 67.35% seedlings were oiled. Desk-study suggested that death of mangrove was not instant, up to one year after the incident for seedlings/sapling. Structural damage of mature trees happened in year-3. Trees and their ecosystem will stabilize in year-5, and recovery can be expected in year-9. As the trees are extremely important for waterbirds, a continuous monitoring of mangrove health need to be conducted to ensure that the waterbirds will not lose their nesting habitat in the future.

1. Introduction
During the extraction for oil in offshore sites, accidents sometimes happened. Crude oil might unintentionally spread out to the surrounding areas and created ecological problems for the marine and seashore environment, including mangroves. On 12 July 2019, there was a sign of crude oil leaking in the off-shore oil mining managed by Pertamina (state owned oil and gas company), near Karawang, West Java Province, Indonesia. Within a few days, the crude oil contamination has been spreading out, mainly to the west. The oil contamination eventually reached Pulau Rambut, a wildlife sanctuary small island dedicated for waterbirds in the Jakarta Bay area, Indonesia, approximately 105 km from the source of oil leaking in Karawang.

Some areas of Pulau Rambut are covered by mangroves and these mangroves have been playing extremely important roles as roosting and nesting areas for 15 species of waterbirds (i.e. egrets, herons, cormorants, ibises, storks, darters). Without the mangroves, Pulau Rambut will lose its function as an important breeding site for the waterbirds in the Jakarta Bay area.
Crude oil that contaminated the mangroves of Pulau Rambut certainly poses a big threat to the survival of the waterbirds, as this island has been known to be the only breeding areas for waterbirds in Jakarta Bay area. World-wide studies has suggested that mangroves are very sensitive toward oil spills [1]. Information on the seriousness of the oil spills is needed to decide further necessary actions. The objective of this paper was to reveal the severity of the oil spill in the mangroves of Pulau Rambut, and to provide analysis on the effect of the oil spill to the long-term survival of the mangroves as waterbirds breeding sites.

2. Method

2.1. Study Area
The research was conducted in Pulau Rambut Wildlife Sanctuary (106.5°41'30"E, 5.5°58'30"S), a small island (45 Ha) located in Jakarta Bay area, Indonesia, approximately 105 Km to west of the source of oil spill (Figure 1). This island plays an important role because it has been used by 15 species of waterbirds as roosting and nesting sites. During breeding season (usually in November to April), more than ten thousand waterbirds of various species have been breed on this island. One of them, Milky stork (*Mycteria cinerea*), has been known to breed only on this island in Java.

The waterbirds have been using mangroves for their roosting and breeding trees. Therefore, it is very important to ensure that the mangroves are in good and healthy condition to support the waterbird population. Mangroves in Pulau Rambut basically consisted of two types, namely primary mangrove (i.e. always inundated by seawater) and secondary mangroves (i.e. inundated by seawater only during high tide). Primary mangroves were located in the north and eastern side of the island mostly consisted of members of Rhizophora genus (*R. mucronata, R. stylosa, R. apiculata*). Secondary mangrove were located approximately in the center of the island, consisted of various species, including *Ceriops tagal, Ceriops decandra, Scyphiphora hydrophyllacea, Pemphis acidula, Xylocarpus mollucensis*, and *Excoecaria agallocha*.

Although the distance between Karawang and Jakarta Bay are quire far; the oil spill has reached Pulau Rambut. Crude oil spills were found landed along the east, north, and south coast mostly as sandy beach or rocky beach. These crude oil has been collected and cleaned everyday by the authorities and local people. Unfortunately, some of the crude oil has been entering the mangroves through high tide. The mangrove that has been exposed to the crude oil was the subject of this study.

2.2. Field Method
Field visit was conducted on 19 and 22 August 2019, totaling 96 person-hour. During the field visit, the tide was low. Most of *Rhizophora* and *Ceriops* tree - both are important nesting/roosting trees - were fruiting. As for the waterbirds, the field visit was coincided with a non-breeding season.

The entire area was visited to observe the existence of crude oil. Areas contaminated by crude oil were grouped into three contaminated level: heavy contamination (pieces of the crude oil were found on more than 70% of the area), moderate (30-70% contamination), and low (less than 30%). Areas where no crude oil was found was categorized as no contamination. The level of contaminations was mapped and analyzed.

Plots were purposively selected to sample the oil exposed trees both in primary and secondary mangroves; plot sizes were 1x1m for seedling (n= 64), 2x2m for saplings (n= 70), 4x4m for poles (n= 255) and 10x10m for tree (n= 106). In addition, all trees along major waterways were also censused. Data recorded were level of contamination within plots, on roots, and on seedlings. The level of contamination was categorized into heavy (3, affecting 70-100% area), medium (2, affecting 30-70% area), low (1, affecting up to 30% area) or none (0, no sign of oil contamination). Tree characteristics also were measured: tree height and tree diameter (measured 20cm above rhizophores, for Rhizophora tree species). Heavily exposed tree along the coast were also marked and mapped.
3. Results and Discussion

3.1. Areas affected by the crude oil

Crude oil entered the mangrove forest through four waterways (2 major and 2 minor waterways), located at the north and northeast of the island. As a result, many pieces of crude oil could be easily found in the northern part of the island in the primary mangrove, on the mud substrates, and thus this area was categorized as the heavy contaminated areas (Figure 2). The moderately contaminated area was located on the southern part of the heavy contaminated area, also on the primary mangrove.

The temporary inundated secondary mangrove was, unfortunately, also contaminated. Although in a lower degree. Apparently, the pieces of crude oil had reached the secondary forest during high tide. In some parts of the island (i.e. southeast and northwest) there was no crude oil found, and categorized as uncontaminated areas.

Mapping patterns of the contaminated area clearly showed that the beach elevation and the position of waterways and play crucial roles. The west, south, and eastern sides of the island were sandy beach. Crude oil landed on these beaches, but not entered the island. On the northern side, however, elevation was low and sea water can easily enter the island through the extant waterways. All four waterways created entrances of the crude oil to the mangroves, together with high tides.

Figure 1 Map of Pulau Rambut Wildlife Reserve in Jakarta Bay area (Indonesia) and its location to the oil spill in Karawang off-shore; arrows are existing waterways where seawater entered the island.
3.2. Crude oil found in mangrove forest

The crude oil that had entered the mangrove forests eventually melted when exposed to the sun, and stick to roots (rhizophores, pneumatophores/prop root), tree trunk, seedlings, and in some area also covered leaves that located close to the high sea tide level (Figure 3). When the melted crude oil already attached to parts of the mangrove trees, naturally it will be difficult to be removed.

All mature trees along the major waterways (n=26) were contaminated by crude oil, so did trees on the selected plots in the primary mangroves. In the secondary mangroves, about half of the trees within selected plots were also contaminated as well (Table 1). Tree species that can be found in the primary mangroves were mostly *R. mucronata*, *R. stylosa*, some *R. apiculata* and *Sonneratia alba*. All roots of these species were contaminated by oil, mostly heavy to moderate level (Table 2). In the secondary mangroves, *Ceriops tagal* and *Excoecaria agallocha* were lightly contaminated. Based on tree stages, clearly mature trees suffered the most from the oil spill. Natural regeneration of the mangroves in the study area was poor, and thus not many seedlings or saplings can be found in the sampled area.
3.3. Impact of the crude oil to the mangroves

During the field visit, there were no sign of death, dying, fallen leaves, or lead deformities of mature trees. Seedlings and saplings also still look healthy. Literatures related to impact of crude oil spill on mangrove forests [2, 3, 4] suggested that the impact was not instant. The acute symptoms – seedling mortality and defoliation of mature trees - may last up to one month, followed by chronic symptoms – mortality of mature trees and other connected ecological damages – which may last up to ten years. Depending on the oil spill intensity, the mangrove ecosystem may show a sign of stabilization in year 4, and continue to recover in year 10 up to year 50 (Table 3). Processes which happened within the mangrove ecosystem and its effect – both short/initial and long-term effect - is explained in Figure 4. Response of the mangrove and its ecological process of recovery is presented in Figure 5.

Susceptibility, persistence, and sensitivity have been known to be important factors that affecting the impact and recovery of the oil spill on mangroves [3]. Unfortunately, long term research on how Indonesian mangrove species responded to oil spill was still lacking. Studies on sensitivity of various mangrove trees toward oil spill in Indonesia [5] showed that Sonneratia has been known to be very sensitive to oil spill, whereas Rhizophora are categorized as sensitive, and Ceriops trees are intermediate.

Considering the long-term sub-lethal impact of the oil spill to the mangrove as waterbird habitat in Pulau Rambut Wildlife Sanctuary, long-term monitoring should be carried out, as also suggested by [6]. Permanent plots have been established in the contaminated and uncontaminated areas in the primary and secondary mangroves. In addition, necessary actions to ensure the availability of the nesting sites need to be taken immediately, including intensive plantation, habitat remediation, and provision of artificial trees, if needed.
### Table 1  Contaminated trees along waterways, in primary mangroves, and in secondary mangroves

| Position               | Contaminated tree Number (Percent) | Average level of contamination* |
|------------------------|-----------------------------------|---------------------------------|
|                        |                                   | Root  | Trunk | Leaves |
| Waterway 1             | 6 (100.0)                         | 3.00  | 1.50  | 1.33   |
| Waterway 2             | 20 (100.0)                        | 3.00  | 1.30  | 0.00   |
| Primary mangrove       | 25 (100.0)                        | 2.80  | 1.20  | 0.40   |
| Secondary mangrove     | 22 (44.9)                         | 0.47  | 0.12  | 0.03   |

*3-heavy (affecting 70-100% area); 2-moderate (30-70% area), 1-low (up to 30% area); 0—no contamination

### Table 2  Level of contamination on parts of trees, listed based on tree species

| Species                     | Stage       | Contaminated tree Number (Percent) | Level of contamination** |
|-----------------------------|-------------|-----------------------------------|----------------------------|
| *Rhizophora mucronata* (primary mangrove) | Tree       | 48 (84.21)                       | Root  | Trunk | Leaves |
|                             | Seedling    | 29 (78.38)                       | 2.14  | 1.07  | 0.32   |
|                             | Sapling     | 19 (55.88)                       | 1.16  |       |        |
|                             | Pole        | 198 (95.65)                      | 0.79  |       |        |
| *Rhizophora apiculata* (primary mangrove) | Tree       | 5 (71.43)                        | 2.35  | 1.07  | 0.35   |
|                             | Seedling    | 1 (100.00)                       | 1.00  |       |        |
|                             | Sapling     | 9 (100.00)                       | 1.00  |       |        |
|                             | Pole        | 0 (0.00)                         | 0.00  |       |        |
| *Rhizophora stylosa* (primary mangrove) | Tree       | 3 (50.00)                        | 1.00  | 0.00  | 0.00   |
|                             | Pole        | 0 (0.00)                         | 0.00  |       |        |
| *Sonneratia alba* (primary mangrove) | Tree       | 1 (100.00)                       | 3.00  | 1.00  | 0.00   |
|                             | Pole        | 0 (0.00)                         | 0.00  |       |        |
| *Ceriops tagal* (secondary mangrove) | Tree       | 11 (40.71)                       | 0.48  | 0.04  | 0.00   |
|                             | Seedling    | 3 (27.27)                        | 0.55  |       |        |
|                             | Sapling     | 0 (0.00)                         | 0.00  |       |        |
|                             | Pole        | 0 (0.00)                         | 0.00  |       |        |
| *Excoecaria agallocha* (secondary mangrove) | Tree       | 5 (41.67)                        | 0.42  | 0.17  | 0.00   |
|                             | Pole        | 2 (8.00)                         | 0.24  |       |        |

**3-heavy (affecting 70-100% of the root/trunk/leaves); 2-medium (30-70%), 1-low (up to 30%); 0—no contamination
Table 3  Effect, symptoms, and response of mangrove on crude oil spills, based on studies in other countries (modified from 7, 8, 9)

| Effect and Symptom | Time         | Mangrove Response                                                                 |
|--------------------|--------------|-----------------------------------------------------------------------------------|
| Initial Effect     | Year 1       | - Defoliation of mature trees and mortality of small (<1m) mangroves (mainly seedlings)  |
|                    | Acute symptom| - Loss of aerial root community                                                    |
|                    | Day 15-30    | - Seedlings and saplings die                                                       |
|                    | Chronic symptom| - Tissues damage to aerial roots                                                   |
|                    | Day 30-year 1| - Defoliation and death of medium (<3m) mangroves                                  |
| Structural Damage  | Year 1-10    | - High mortality of larger (>3m) mangroves                                         |
|                    | Chronic symptom| - Loss of oiled aerial roots                                                       |
|                    | Year 1-5     | - Reduction in litter fall                                                         |
|                    | Chronic symptom| - Reduced survival of seedlings                                                    |
|                    | Year 1-10    | - Death or reduced growth of young                                                 |
|                    |               | - Reduced reproduction                                                             |
|                    |               | - Increased insect damage                                                          |
| Sign of stabilization | Year 4-10   | - Regrowth of new mangroves (sometime deformed)                                    |
| Stabilization      | Year 4-9     | - Recolonization of oil-damaged areas by new seedlings                            |
|                    |               | - Sapling growth is observed                                                       |
|                    |               | - Trees start to colonize oiled site                                               |
|                    |               | - Ecosystem starts to recover, but may not recover fully to its original state     |
| Recovery           | Year 10-50?  | - Complete recovery                                                                |

Figure 4  Summary of the short-term (initial) and long-term response of an oil spill on mangroves [2]
Figure 5  Response of the mangrove on crude oil spills and its ecological process of recovery [9, 10]

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