Flora of Danau Dusun Besar conservation forest in Bengkulu Province, Indonesia

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Abstract. Wiryono Mersyah R. Tariana M. 2020. Flora of Danau Dusun Besar conservation forest in Bengkulu Province, Indonesia. Biodiversitas 21: 5640-5649. Few studies on flora of freshwater swamp forest in Sumatra have been published and accessible online. This study aimed to assess the composition and diversity of plant species and to describe the dominant species in conservation forest of Danau Dusun Besar Nature Reserve and Nature Tourism Park in Bengkulu which consists mostly of freshwater swamp forests and a lake. Data collection was done using a combination of quantitative methods with systematic plots and qualitative methods through observation. The quantitative data were analyzed to determine indexes of diversity, evenness and importance value. This study recorded 23 species of trees with diversity index (H') and evenness index (E) of 0.29 and 0.09, respectively, and recorded 136 species of shrubs and herbs with H' and E values of 3.68 and 0.75, respectively. The most dominant species of trees was Alstonia spatulata, of shrubs and herbs Stenochlaena palastris. The small diameter class of trees and the covering of trees with climbers indicated that the large trees had been cut. We recommend further studies with more and better-located plots to get better data on the vegetation composition and structure, including the invasion of alien species Ludwigia peruviana and the effect of climbers on trees.

Keywords: Alstonia spatulata, Cannosperma coriaceum, freshwater swamp, Ludwigia peruviana

Abbreviations: CADDB: Cagar Alam Danau Dusun Besar; TWADTS: Taman Wisata Alam Danau Dendam Tak Sudah

INTRODUCTION

In Sumatra Island, there are three types of forested wetlands: mangrove, peat swamp forest, and freshwater swamp forest. Mangrove grows in saline substrate and is usually located in estuaries and protected shores. Peat swamp forest grows in peat, defined as a soil at least 50 cm deep, which contains 65% of organic matter, while freshwater swamp forest grows on soil periodically inundated with mineral-rich freshwater with pH of 6 or more (Whitten et al. 1984). In practice, however, the distinction between freshwater swamp forest and peat swamp forest is not always clear because the organic matter content of soil in freshwater swamp varies (Davison et al. 2018), and a few centimeters of peat may occur in freshwater swamp forest (Whitmore 1984).

In its pristine condition, freshwater swamp forest in Southeast Asia harbors a great number of plant species. In general, the flora of freshwater swamp forests does not differ at family and genus levels from that of dry land in the same region (Whitmore 1984). Even peat swamp forest which grows in nutrient-poor soil share 80% of its flora to other habitats (Giesen et al. 2018). The current literature on the freshwater swamp forest in Southeast Asia accessible online are few (Chong et al. 2018; Davison et al. 2018; Theilade et al. 2011) because it is understudied (Ho et al 2019), getting less attention than the peat swamp forests and mangrove (Clews et al. 2018). Studies on this habitat are, therefore, necessary. Another reason for this need is the fact that the Southeast Asian freshwater swamp forest is a highly threatened habitat (Ho et al 2019).

Threats to freshwater swamp forest and its surrounding dry forest in Bengkulu City have occurred extensively (Tasori et al. 2014; Eviona 2016). This freshwater swamp forest grows along the edge of a lake, named Danau Dendam Tak Sudah (meaning Unfinished Revenge Lake). The soil in the swamp is categorized as mineral soil, but it is very acidic, with pH of 4-5 (Sudirja and Hindersah 2009). The lake and its surrounding vegetation were designated as a strict nature reserve, called Cagar Alam Danau Dusun Besar (hereafter referred to as CADDB) with an area of 577 ha. The reason for its establishment was the presence of Papilionanthe hookeriana (Rchb.f.) Schltr (previously named Vanda hookeriana), an orchid species protected by Indonesian law (Government regulation no 7, 1999) until 2018 when the Minister of Environment and Forestry issued a new regulation which no longer listed V. hookeriana as a protected species (Minister of Environment and Forestry Regulation no 106, 2018). In 2019, due to the request from the local government, part of the nature reserve area (88.82 ha) was designated as Nature Tourism Park, called Taman Wisata Alam Danau Dendam Tak Sudah (hereafter referred to as TWADTS), so the remaining area of nature reserve is 488.18 ha. Both strict
nature reserve and nature tourism park, according to Indonesian laws, belong to the category of conservation forest, but more activities are allowed in the nature park than in the nature reserve (Act no 5, 1990).

This conservation forest is surrounded by settlements, so it has suffered from encroachment. Much of the forest in the swamp has been cut and the surrounding dry land has been converted into agricultural cultivation, mostly oil palm plantation (Tasori et al. 2014). A study on tree composition of the swamp forest conducted in 2007 found only small-size trees because the large ones had been cut (Permono 2007). Until this study was done, no published data on the flora of this conservation forest area were available. Therefore, this study was conducted to assess the plant species composition and diversity of conservation forest area of CADDB and TWADDTS, and to discuss the dominant species in the swamp forest.

MATERIALS AND METHODS

Study area

This study was conducted in Cagar Alam Danau Dusun Besar (CADDB) and Taman Wisata Alam Danau Dendam Tak Sudah (TWADDTS), Bengkulu, Indonesia; located at 03°47′45″-03°49′01″ N and 102°18′07″-102°20′11″ E (Figure 1). This conservation area has a wet climate with an average temperature of 29-32°C and relative humidity 82-87%. The study site has a flat topography with slopes of 0-8%, and an altitude of 15 m. According to USDA Soil Taxonomy classification, the soil in the swamp forest is categorized as Histosol and Inceptisols, having very low fertility (Sudirja and Hindersah 2009).

Data collection

Trees with diameter at breast height (dbh) of > 10 cm were sampled using 10 m x 10 m plots. A total of 120 plots were located in three zones, i.e., CADDB (80 plots), rehabilitation area within CADDB (20 plots), and TWADDTS (20 plots). The plots were placed systematically along the line located in the swamp which had many trees. The diameter and species of each tree were recorded. Because the swamp forest consisted almost exclusively of two tree species, i.e., Campnosperma coriaceum and Alstonia spatulata, we also recorded other trees that occurred only occasionally in the swamp and its edge, outside the plots, but their dbh was not measured. The outside-plot trees were assumed to have 2 individuals. Some areas of the swamp too deep to walk on were not sampled, so, there might be some species in those areas which had not been recorded.

Figure 1. Location of study in Cagar Alam Danau Dusun Besar (CADDB) and Taman Wisata Alam Danau Dendam Tak Sudah (TWADDTS), Bengkulu, Indonesia
Species of shrubs and herbs were sampled in 120 plots, each measuring 1 x 1 m, located in areas with few trees because they were found most abundant in the open areas. The cover of each species was estimated visually as a percentage. Species accumulating curve shows that the curve has flattened (Figure 2), indicating the sufficiency of the plot number. However, we also found species that occurred only occasionally outside the plots. Mueller-Dombois and Ellenberg (1974) say that rare species are usually not included in the plots. The outside-plot plants were recorded and the cover estimate were assumed to be same as the minimum cover estimate of the inside-plot species, i.e., 5%.

Plant identification was done using identification books of Backer and van der Brink (1963), Backer and van der Brink (1965), Backer and van der Brink (1968), Soerjani et al. (1987), Noda et al. (1994), Moody et al. (1984), and Sukarya (2013), and websites on the internet, i.e., Flora Malesiana (http://portal.cybertaxononomy.org/flora-malesiana), Invasive species compendium (https://www.cabi.org/isc), Australian tropical rain forest plants (http://www.anbg.gov.au/cpbr/cd-keys/RFK7/key/RFK7/Media/Html/index_rfk.htm), Plants of the World online (http://plantsoftheworldonline.org/?). Plant names followed the accepted names in the Plant List (http://www.theplantlist.org/), except for species whose name have not been resolved, i.e., Mangifera foetida, which was taken from invasive species compendium (https://www.cabi.org/isc/datasheet/31668), and Asplenium longissimum Johow from International Plant Names Index (https://www.ipni.org/n/22504-2).

Data analysis

Tree data

The tree data were analyzed descriptively to show the diameter class distribution, and quantitatively to determine the Shannon-Wiener diversity index and evenness index (Mueller-Dombois and Ellenberg 1974), calculated with the following formulas:

**Diversity index:**

$$ H' = - \sum_{i=1}^{s} (pi)(\ln pi) $$

Where:

- $H'$ = species diversity index;
- $s$ = number of species of trees;
- $pi$ = proportion of the $i^{th}$ species = $ni/N$ = (individual number of the $i^{th}$ species / individual number of all species).

**Evenness index:**

$$ E = \frac{H'}{\ln S} $$

Where:

- $E$ = evenness index;
- $S$ = the number of species.

**Shrub and herb data**

The shrub and herb data were analyzed to determine the diversity index of Shannon-Wiener, the evenness index, and importance value (Mueller-Dombois and Ellenberg 1974). The number of individuals for the diversity index was replaced by estimate of cover. The importance value was calculated as follows:

Importance value of the $i^{th}$ Species = Relative cover of the $i^{th}$ species + relative frequency of the $i^{th}$ species.

Where:

- Relative cover of the $i^{th}$ species = $\frac{Total cover of the-i-th Species}{Total cover of all species} \times 100$,
- Frequency of the $i^{th}$ species = $\frac{Number of plots containing the-i-th Species}{Total plots} \times 100$,
- Relative frequency of the $i^{th}$ species = $\frac{Frequency of the-i-th Species}{Total frequency of all species} \times 100$.

Note: The cover and frequency of each of the outside-plot plants were assumed to be the same as the minimum cover (5%) and frequency (0.83%) of the inside-plot species.

**RESULTS AND DISCUSSION**

**Species diversity and composition of trees**

The number of tree species in the study site was 23 (Table 1), belonging to 10 families, with Shannon-Wiener diversity index of 0.29, and evenness index of 0.09. Only two species of trees were found within the plots, namely Alstonia spatulata Blume and Campnosperma coriaceum (Jack) Hallier f. Other species of trees were found occasionally outside the plots, mostly at the edge of the swamp. Both Alstonia and Campnosperma had the highest number of individuals in 15.0-19.9 cm diameter class (Figure 3). The biggest diameter of Alstonia tree was in the
Species diversity and composition of shrubs and herbs

The number of identified shrub and herb species was 136, belonging to 51 families (Table 2), with the Shannon-Wiener diversity index of 3.58 and the evenness index 0.75. The top four families with the highest number of species were Fabaceae (17), Asteraceae (14), Poaceae (13), and Cyperaceae (12). Each of other families had less than 10 species. In addition, 7 unidentified species were also found.

Five species that had importance value higher than 10 were Stenochlaena patula (Burm. f.) Bedd., Scleria ciliaris Nees, Ludwigia peruviana (L.) H. Harra, Persicaria attenuata (R. Br.) Sojak, and Actinoscirpus grossus (L.f.) Goetgh. & D.A. Simpson. Based on the life forms, the shrubs and herbs could arbitrarily be divided into forb which was 58 species, shrub 34, fern 18, grass 13, sedge 9, and liana 4 (Table 2).

Palm

In addition to tree and ground cover species, two species of palm were found in the swamp and adjacent dry land within the conservation forest, namely Nypa fruticans Wurmb and Elaeis guineensis Jacq.

Discussion

Trees

The diversity index (H') of tree species in the study site was only 0.29, considered very low, presumably due to the low species evenness (0.09) and low species richness (only 23). In comparison, in a fresh swamp forest of Cagar Alam Rimbo Panti West Sumatra, Yusuf and Purwaningsih (2009) found 136 species of trees with dbh > 10 cm from 40 families. Meanwhile, Chong et al. (2018) found 288 species of trees with dbh ≥ 5 cm from 60 families in a freshwater swamp forest of Singapore. The low tree diversity in the study site was presumably caused by illegal cutting and forest encroachment (Tasori et al. 2014; Eviona 2016).

The majority of tree species recorded in this study were found in the edge of the swamp where the soil is not permanently inundated. The inundated area was dominated by Alstonia spatulata and Campnosperma coriaceum. Alstonia spatulata, is locally called pulai gabus, the Indonesian word for cork, referring to its ultralight root wood and basalmost stemwood which has been traditionally used as replacement of cork (Baas and Fujii 2020). It is a native species that naturally grows in Burma (Myanmar), Thailand, Cambodia, Vietnam, Peninsular Malaysia, Singapore, Sumatra, Bangkok, Java, Borneo, and New Guinea (Slik 2009 onwards). This species was dominant in the study site because it can grow in poorly drained and frequently flooded soil (Teo 2001). In ancient swamp forest bordering a lake in Bantam (Banten), Endert in 1932 found A. spatulata one of the dominant species (cited in Backer and Van der Brink 1965). The genus Alstonia in general is commonly found in swamp forests in Southeast Asia and New Guinea (Whitmore 1984).

Table 1. List of tree species in the study site, Danau Dusun Besar conservation forest, Bengkulu Province, Indonesia

| Species                  | Family           | No. of individuals |
|--------------------------|------------------|--------------------|
| Alstonia spatulata Blume  | Apocynaceae      | 452                |
| Campnosperma coriaceum   | Anacardiaceae    | 340                |
| Hallier f                 |                  |                    |
| Lannea coromandelica (Hout.) Merr. | Anacardiaceae | 2                |
| Mangifera foetida Lour.   | Anacardiaceae    | 2                  |
| Cerbera manghas L.        | Apocynaceae      | 2                  |
| Trema orientalis (L.) Blume | Cannabaceae   | 2                  |
| Terminalia catappa L.     | Combretaceae     | 2                  |
| Hevea brasiliensis (Wild. ex A.Juss.) Mull.Arg. | Euphorbiaceae | 2 |
| Macaranga sp.             | Euphorbiaceae    | 2                  |
| Mallotus paniculatus (Lam.) Mull.Arg. | Euphorbiaceae | 2 |
| Acacia mangium Willd.     | Fabaceae         | 2                  |
| Archidendron pauciflorum (Benth.) LC.Nielsen | Fabaceae | 2 |
| Gliricidia sepium (Jacq.) Walp. | Fabaceae | 2 |
| Pericarpus indicus Willd. | Fabaceae         | 2                  |
| Peronema canescens Jack   | Lauraceae        | 2                  |
| Tectona grandis L.f.      | Lauraceae        | 2                  |
| Vitex pinnata L.          | Lauraceae        | 2                  |
| Cinnamomum porrectum (Roxb.) Kosterm. | Lauraceae | 2 |
| Ficus benjamina L.        | Moraceae         | 2                  |
| Ficus fistulosus Reinw. ex Blume Ficus septica Burm.f. | Moraceae | 2 |
| Psidium guajava L         | Myrtaceae        | 2                  |
| Syzygium sp.              | Myrtaceae        | 2                  |

Note: The number of individuals of species other than Alstonia and Campnosperma was assumed to be 2.
Table 2. The list of species shrubs and herbs with their importance values, families and life forms in the study site

| Species                              | Family              | Life form       | Rel. cover | Rel. freq. | IV  |
|--------------------------------------|---------------------|-----------------|------------|------------|-----|
| Stenochlaena palustris (Burm. f.) Bedd. | Blechnaceae         | Climbing fern   | 10.51      | 7.74       | 18.25 |
| Scleria ciliaris Nees                | Cyperaceae          | Sedge           | 7.04       | 7.74       | 14.78 |
| Ludwigia peruviana (L.) H.Hara       | Onagraceae          | Shrub           | 8.49       | 5.23       | 13.72 |
| Persicaria attenuata (R. Br.) Sojak  | Polygalaceae        | Erect forb      | 5.66       | 5.65       | 11.31 |
| Actinocirsus grossus (L.f.) Goeth. & D.A.Simpson. | Cyperaceae        | Sedge           | 6.61       | 3.97       | 10.58 |
| Crinum asiaticum L.                  | Amaryllidaceae      | Erect forb      | 7.29       | 2.93       | 10.22 |
| Nepenthes mirabilis (Lour.) Druce    | Nepenthaceae        | Climbing forb   | 3.60       | 3.14       | 6.74  |
| Uncaria acida (Hunter) Roxb          | Rubiaceae           | Liana           | 3.09       | 3.56       | 6.65  |
| Mimosa pigra L.                      | Fabaceae            | Shrub           | 3.00       | 3.56       | 6.56  |
| Mikania micrantha Kunth              | Asteraceae          | Climbing forb   | 1.97       | 3.14       | 5.11  |
| Colocasia esculenta (L.) Schott      | Araceae             | Erect forb      | 2.57       | 2.51       | 5.08  |
| Cyclodus interruptus (Willd.) H. Itô | Thelyperidaceae     | Terrestrial fern| 2.10       | 2.72       | 4.82  |
| Imperata cylindrica (L.) Raeusch.    | Poaceae             | Grass           | 1.97       | 2.09       | 4.07  |
| Panicum maximum Jacq.                | Poaceae             | Creeping forb   | 2.02       | 1.67       | 3.69  |
| Merremia umbellata (L.) Hallier f    | Convulvulaceae      | Climbing forb   | 1.63       | 1.67       | 3.30  |
| Paspalum distichum L.                | Poaceae             | Spreading shrub | 1.54       | 1.26       | 2.80  |
| Fimbriatula littoralis Gaudich.      | Cyperaceae          | Sedge           | 1.72       | 1.05       | 2.76  |
| Ludwigia octovalvis (Jacq.) P.H.Raven | Onagraceae          | Shrub           | 1.72       | 1.05       | 2.76  |
| Asystasia gangetica (L.) T. Anderson | Acanthaceae         | Creeping forb   | 0.94       | 1.46       | 2.41  |
| Ludwigia hislopii (G.Don) Estell     | Onagraceae          | Shrub           | 1.50       | 0.84       | 2.34  |
| Senna afata (L.) Roxb                | Fabaceae            | Shrub           | 1.20       | 1.05       | 2.25  |
| Dicranopteris linearis (Burm. f.) Underw. | Convulvulaceae     | Climbing forb   | 0.94       | 1.26       | 2.20  |
| Ipomoea aquatica Forssk.             | Convulvulaceae      | Creeping forb   | 1.54       | 0.63       | 2.17  |
| Nepheirops biserata (Sw.) Schott     | Nephelepdaceae      | Terrestrial fern| 0.69       | 1.26       | 1.94  |
| Davallia denticulata (Burm. f.) Mett. ex Kuhn | Davalliaiceae     | Epiphytic or terrestrial fern | 0.86 | 1.05 | 1.90 |
| Melastoma malabathricum L.           | Rubiaceae           | Shrub           | 0.86       | 0.84       | 1.69  |
| Chamaecrista minimosoides (L.) Greene. | Fabaceae           | Shrub           | 1.03       | 0.42       | 1.45  |
| Psychotria sarmentosa Blume          | Rubiaceae           | Liana           | 0.60       | 0.84       | 1.44  |
| Sphenocotyla triolobata (L.) Pruski  | Asteraceae          | Creeping forb   | 0.94       | 0.42       | 1.36  |
| Asplenium longissimum J ohow          | Aspleniaceae        | Terrestrial fern| 0.47       | 0.84       | 1.31  |
| Thunbergia alata Bojer ex Sims       | Acanthaceae         | Climbing forb   | 0.47       | 0.84       | 1.31  |
| Pteris vittata L.                    | Pteridaceae         | Terrestrial fern| 0.51       | 0.63       | 1.14  |
| Centrosema molle Benth.              | Fabaceae            | Climbing forb   | 0.43       | 0.63       | 1.06  |
| Mimosa invisa Colla                  | Fabaceae            | Climbing herb   | 0.51       | 0.42       | 0.93  |
| Salvinia adnata Desv.                | Salviniaeae         | Aquatic fern    | 0.51       | 0.42       | 0.93  |
| Schoenoplectiella mucronata (L.) Jung & H.K.Choi | Cyperaceae        | Sedge           | 0.30       | 0.63       | 0.93  |
| Blumea balsamifera (L.) DC.           | Asteraceae          | Shrub           | 0.43       | 0.42       | 0.85  |
| Ludwigia ascendens (L.) H.Hara       | Onagraceae          | Creeping forb   | 0.43       | 0.42       | 0.85  |
| Lycopodiella cernua (L.) Pic. Serm.  | Lycopodiaceae       | Creeping fern   | 0.43       | 0.42       | 0.85  |
| Waltheria indica L.                  | Malvaceae           | Shrub           | 0.60       | 0.21       | 0.81  |
| Ardisia humilis Vahl                 | Rubiaceae           | Shrub           | 0.34       | 0.42       | 0.76  |
| Manihot esculenta Crantz             | Euphorbiaceae       | Shrub           | 0.34       | 0.42       | 0.76  |
| Mimosa pudica L.                     | Fabaceae            | Creeping forb   | 0.34       | 0.42       | 0.76  |
| Polygala paniculata L.               | Polygalaceae        | Erect forb      | 0.34       | 0.42       | 0.76  |
| Echinocloa colona (L.) Link          | Poaceae             | Grass           | 0.26       | 0.42       | 0.68  |
| Flagellaria indica L.                | Flagellariaceae     | Semi woody climber| 0.26     | 0.42       | 0.68  |
| Nepenthes ampularia Jack             | Nepenthaceae        | Climbing forb   | 0.26       | 0.42       | 0.68  |
| Nepheirops cordifolia (L.) C. Presl  | Nephelepdaceae      | Terrestrial fern| 0.26       | 0.42       | 0.68  |
| Phymatosoros pusillus (G. Forst.) Large, Braggins & P.S. Green | Polypodiaceae  | Terrestrial or epiphytic fern | 0.26 | 0.42 | 0.68 |
| Chromolaena odorata (L.) R.M.King & H.Rob. | Asteraceae | Climbing forb, woody at old age | 0.17 | 0.42 | 0.59 |
| Chrysopogon acicularus (Retz.) Trin. | Poaceae             | Grass           | 0.17       | 0.42       | 0.59  |
| Elephantopus tomentosus L.           | Asteraceae          | Grass           | 0.17       | 0.42       | 0.59  |
| Fimbriatula aestivalis Vahl          | Cyperaceae          | Sedge           | 0.17       | 0.42       | 0.59  |
| Ipomoea triloba L.                   | Convulvulaceae      | Creeping forb   | 0.17       | 0.42       | 0.59  |
| Lygodium longifolium (Wild.) Sw      | Lygodiaceae         | Climbing fern   | 0.17       | 0.42       | 0.59  |
| Rhynchospora corymbosa (L.) Britton  | Cyperaceae          | Sedge           | 0.17       | 0.42       | 0.59  |
| Alpinia zerumbet (Pers.) B.L.Burt & R.M.Sm | Cyperaceae       | Erect forb      | 0.34       | 0.21       | 0.55  |
| Cleome rutidosperma DC.               | Cleomeaceae         | Spreading to erect forb | 0.34 | 0.21 | 0.55 |
| Axonopus compressus (Sw.) P.Beauv.    | Poaceae             | Grass           | 0.26       | 0.21       | 0.47  |
| Breynia vitt-ideae (Burm.f.) C.E.C.Fisch. | Phyllantaceae     | Shrub           | 0.26       | 0.21       | 0.47  |
| Celosia argentea L.                  | Amaranthaceae       | Forb            | 0.26       | 0.21       | 0.47  |
| Scientific Name                  | Family           | Life Form          | Frequency |
|---------------------------------|------------------|--------------------|-----------|
| Plectranthus amboinicus         | Lamiaceae        | Shrub              | 0.26      |
| Hyptis capitata Jacq.           | Lamiaceae        | Shrub              | 0.26      |
| Hyptis suaveolens (L.) Poit.    | Lamiaceae        | Shrub              | 0.26      |
| Ipomoea fistulosa Mart. ex Choisy | Convolvulaceae   | Creeping shrub     | 0.26      |
| Kyllinga polyphylla Willd. ex Kunth | Cyperaceae     | Sedge              | 0.26      |
| Oxalis corniculata L.           | Oxalidaceae      | Erect forb         | 0.26      |
| Aescythus radicans Jack         | Gesneriaceae     | Climbing forb      | 0.17      |
| Alysicarpus vulgaris (L.) DC.    | Fabaceae         | Creeping forb      | 0.17      |
| Calopogonium mucunaoides Desv.  | Fabaceae         | Shrub              | 0.17      |
| Crotalaria pallida Aiton        | Fabaceae         | Erect forb         | 0.17      |
| Dactylotum eygptium (L.) Willd. | Poaceae          | Grass              | 0.17      |
| Sida acuta Burn.f               | Malvaceae        | Shrub              | 0.17      |
| Sida rhombifolia L.             | Malvaceae        | Shrub              | 0.17      |
| Stachytopheta jamaicensis (L.) Vahl | Verbenaceae     | Shrub              | 0.17      |
| Artenema longifolium (L.) Vaite | Linderniaceae    | Erect forb         | 0.09      |
| Ceratopters thalictroides (L.) Brongn. | Pteridaceae | Aquatic fern       | 0.09      |
| Eclipta prostrata (L.) L.       | Asteraceae       | Prostrate forb     | 0.09      |
| Fairena umbellata Rotb.         | Cyperaceae       | Sedge              | 0.09      |
| Hedodis corymbosa (L.) Lam.     | Rubiaceae        | Erect for          | 0.09      |
| Linnocharis flavata (L.) Buchenau | Alismataceae    | Floating for       | 0.09      |
| Lygodium microphyllum (Cav.) R. Br. | Lygodiaceae   | Climbing fern      | 0.09      |
| Melochia corchorifolia L.       | Malvaceae        | Shrub              | 0.09      |
| Oxalis barrieri L.              | Oxalidaceae      | Erect for          | 0.09      |
| Paritaria judaica L.            | Urticaceae       | Erect or prostrate forb | 0.09 |
| Poenetus purpureum Schumach     | Poaceae          | Grass              | 0.09      |
| Peperomia pellucida (L.) Kunth   | Piperaceae       | Grass              | 0.09      |
| Phyllanthus niruri L.           | Phyllanthaceae   | Erect for          | 0.09      |
| Stylosanthes humilis Kunth      | Fabaceae         | Creeping for       | 0.09      |
| Croton hirtus L'Hér.             | Euphorbiaceae    | Erect for          | 0.04      |
| Acalypa indica L.*              | Euphorbiaceae    | Erect for          | 0.04      |
| Ageratum conyoides (L.) L.      | Asteraceae       | Erect for          | 0.04      |
| Asplenium nidus L.              | Aspleniaceae     | Epiphytic and terrestrial fern | 0.04 |
| Brucea javanica (L.) Merr.      | Simaroubaceae    | Shrub              | 0.04      |
| Calotropis gigantea (L.) Dryand. | Apocynaceae     | Shrub              | 0.04      |
| Cenchrus echinatus L.           | Poaceae          | Grass              | 0.04      |
| Cleistanthus monoicus (Lour.) Müll.Arg. | Phyllanthaceae | Shrub              | 0.04      |
| Chloridium surinamense L.       | Asteraceae       | Shrub              | 0.04      |
| Clidemia hirta (L.) D. Don      | Melastomaceae    | Shrub              | 0.04      |
| Clitoria laurifolia Poir.       | Fabaceae         | Shrub              | 0.04      |
| Crosocephalum crepidioides (Benth.) S.Moore | Asteraceae | Erect for          | 0.04      |
| Cyathiumum cinereum (L.) H. Rob. | Asteraceae       | Erect for          | 0.04      |
| Cymbopogon calcicola C.E.Hubb.  | Poaceae          | Grass              | 0.04      |
| Cynodon dactylon (L.) Pers.     | Poaceae          | Grass              | 0.04      |
| Cyperus procerus Rotb.          | Cyperaceae       | Sedge              | 0.04      |
| Cyperus rotundus L.             | Cyperaceae       | Sedge              | 0.04      |
| Desmodium heterophyllum (Wild.) DC. | Fabaceae     | Creeping for       | 0.04      |
| Dioscorea hispida Dennst.       | Dipsaciaceae     | Climbing for       | 0.04      |
| Diplazium esculentum (Retz.) Sw | Athyriaceae      | Terrestrial fern   | 0.04      |
| Eleusine indica (L.) Gaertn.    | Poaceae          | Grass              | 0.04      |
| Ergrostis amabilis (L.) Wight & Arn. | Poaceae     | Grass              | 0.04      |
| Euphorbia heterophylla L.       | Euphorbiaceae    | Erect for          | 0.04      |
| Euphorbia hirta L.              | Euphorbiaceae    | Erect for          | 0.04      |
| Lantana camara L.               | Verbenaceae      | Shrub              | 0.04      |
| Leucas zeylanica (L.) W.T.Aiton | Lamiaceae        | Erect for          | 0.04      |
| Linderaea enstifolia Sw.        | Linderaeae       | Epiphytic or terrestrial fern | 0.04 |
| Ludwigia perennis L.            | Onagraceae       | Shrub              | 0.04      |
| Musa paradisiaca L.             | Musaceae         | Large for          | 0.04      |
| Musaenda frondosa L.            | Rubiaceae        | Shrub              | 0.04      |
| Nymphaea lotus L.               | Nymphaeaceae     | Aquatic for        | 0.04      |
| Oldenlandia auricularia (L.) K.Schum | Rubiaceae     | Erect for          | 0.04      |
| Papilioniante hookeriana (Rchb.f.) Schltr. | Orchidaceae | Climbing for       | 0.04      |
| Passiflora foetida L.           | Passifloraceae   | Climbing-creeping for | 0.04 |
| Pericampylus glaucus (Lam.) Merr. | Menispermaceae   | Liana              | 0.04      |
| Phyllanthus amarus Schumach. & Thonn. | Phyllanthaceae | Shrub              | 0.04      |
| Phyllanthus urinaria L.         | Phyllanthaceae   | Erect for          | 0.04      |
| Phyllanthus virgatus G.Forst.   | Phyllanthaceae   | Erect for          | 0.04      |
| Phymatosorus scolopendria (Burn. f.) Pic. Serm | Polypodiaceae | Terrestrial fern | 0.04      |
| Plectranthus amboinicus (Lour.) Spreng. | Lamiaceae | Erect for          | 0.04      |
Another frequently found tree species in the swamp was *Campnosperma coriaceum*, also called *terentang paya*. This species is naturally found in Peninsular Thailand, Peninsular Malaysia, Sumatra, Borneo and New Guinea (Slik 2009 onward). It usually grows in swamp forests in Southeast Asia and New Guinea (Whitmore 1984), but its distribution is not limited to swamp, because it is also found in other types of ecosystems (Giesen et al. 2018).

Both *Alstonia* and *Campnosperma* had small diameter. The biggest proportion of trees had a diameter class of 15.0-19.9 cm. *Campnosperma* even had the biggest diameter smaller than 30 cm, while *Alstonia* had only two individuals with a diameter class of 30.0-34.9 cm. In undisturbed forest, *Campnosperma coriaceum* may have a diameter of 90 cm, while *Alstonia spatulata* 40 cm (Flora Malesiana 2020). The small size of trees, in addition to the low diversity, indicates that the swamp forest has been cleared. Another indication of forest clearing was the abundance of climbers, which usually thrive in young secondary forests (Paul and Yavitt 2011). The crowns of *Alstonia* and *Campnosperma* were almost invisible because they were covered by climbers (Figure 4).

**Shrubs and herbs**

The species richness of shrubs and herbs was 136, with the Shannon-Wiener diversity index of 3.68, considered high because the value of $H'$ in most studies falls between 1.5 and 3.5 (Margurran 2004). In addition, 7 unidentified was also found. Considering that many species were found outside the plots, there might be many other species that were not recorded in this study. Mueller-Dombois and Ellenberg (1974) state that species that occur only occasionally may not be included in the plots.

Among the shrubs and herbs, *Stenochlaena palustris* had the highest importance value, i.e., 18.75 (Table 2). This species is a long scrambling fern commonly found in swampy places, but it also grows in dry lands, such as open places, secondary forests, rubber gardens, oil palm plantations, river banks, and roadsides (Chai 2016). In 1938, Van Steenis reported that plenty of *S.palustris* was found in swamp forests in Tanjung Priuk, Jakarta (cited in Backer and Van der Brink 1965). This species is widely distributed, including tropical Asia, northeast Australia, and eastwards to Tonga and Samoa (Flora Malesiana 2020). In Sarawak, Malaysia, this edible fern is sold in restaurants (Chai 2016). In the study site, *S.palustris* was not only very abundant on the ground but also in the forest canopy, because this species climbed up the tree and covered the tree crowns of *Alstonia* and *Campnosperma* almost completely.

The next abundant climber in the swamp was *Nepenthes mirabilis* with an importance value of 6.74, the 7th highest among the ground cover in this study site (Table 2). It is not surprising that *N. mirabilis* was abundant in this study site, which has very low soil fertility (Sudirja and Hindersah 2009), because the genus *Nepenthes*, in general, can grow in nutrient-poor soil (Adam et al. 1992). In two study sites in South Sumatra which had very acidic soil with low nutrient content, *N. mirabilis* was the only species of *Nepenthes* found (Mardhiana et al. 2012). Among the species of *Nepenthes*, this species was the most widely distributed, stretching from Thailand, Indo-China, Peninsular Malaysia, through Indonesia, the Philippines, New Guinea to Australia, and this species usually grows abundantly in swamp (Adam et al. 1992). In Bangka Belitung Province, *N. mirabilis* was also found in swamp forest (Rizqiani et al. 2018), and in peat swamp of Borneo, *N.mirabilis* was also the dominant climber (Hidayat et al. 2018). In Halmahera Island, *N. mirabilis* was found in lowland forest and edge of swamp (Cahyono et al. 2019).

Another abundant climber was *Uncaria acida* with an importance value of 6.65, ranked 7th among ground cover species (Table 2). Like other species in the genus *Uncaria*, this liana has hooks on its stem, enabling it to climb trees. This species can be locally abundant in humid primary and secondary forest, also along rivers, and swampy areas, at low altitudes (Backer and Van der Brink 1965; Subarnas 2001). This species was previously considered extinct in Singapore, but it has been found twice recently (Turner 2018). In peat swamp forest in Berbak National Park in Jambi Province, Sumatra *U. acida* survived forest fire occurring in the peat swamp (Eik et al. 2009). Another *Uncaria*, i.e., *U. longifolia* was found in freshwater swamp in Singapore (Tan et al. 2013).

### Table 2. The list of the most abundant species in swamp forest of Berau, East Kalimantan Province

| Species Name | Family | Life Form | Importance Value |
|--------------|--------|-----------|------------------|
| Premna serratifolia L. | Lamiaceae | Shrub | 100.00 |
| Richardia brasiliensis Gomes | Rubiaceae | Creeping forb | 100.00 |
| Senna tora (L.) Roxb. | Fabaceae | Shrub | 100.00 |
| Sesbania sesban (L.) Merr. | Fabaceae | Shrub | 100.00 |
| Spermacoce laevis Lam. | Rubiaceae | Erect forb | 100.00 |
| Synekdorea nodiflora (L.) Gaertn. | Asteraceae | Erect forb | 100.00 |
| Tetracera sarmentosa (L.) Vahl | Dilleniaceae | Liana | 100.00 |
| Tridax procumbens (L.) L. | Asteraceae | Creeping forb | 100.00 |

*Note: IV = importance value. The species from Acalypha downward were found outside the plots.*
Among the shrubs, *Ludwigia peruviana* was the most abundant in the study site, with an importance value of 13.72, ranked 3rd among the ground cover (Table 2; Figure 4). This species, also known as Peruvian primrose, Peruvian water primrose, ludwigia, Peruvian primrose bush, water primrose, is native to Mexico, Central America, the Caribbean, and South America, but has been naturalized in tropical and sub-tropical areas in the world and regarded as an environmental weed in Australia since 1971. Within 25 years, it occupied 40% of wetlands in Australia (Chandrasena et al. 2002). This species which usually grows in wetland has become a serious threat to biodiversity in Dhansiri and Kopili catchment areas of Assam, North East India because it has replaced the native species, even forming pure stand (Barua et al. 2017). This species was also a threat to restoration of broadleaf marshes on the Kissimmee floodplain, in Central Florida, USA (Toth 2010). In Sri Lanka, infestations of *Ludwigia peruviana* and *L. octovalvis* have increased in reclaimed marshlands and drainage canals, while several other species of *Ludwigia* continue to be major weed problems in rice agriculture (Rajapakse et al. 2011). In Indonesia, *L. peruviana* is considered weed of minor importance to rice (Soerjani et al. 1987). In Pantnagar, India, another species from the same genus, i.e., *L. perennis* is an invasive alien species threatening the native species. Due to similarity in climate, exotic plants from tropical American rank the most dominant invasive alien species in Pantnagar (Rastogi et al. 2015).

Growing in mixed stands with *S. palustris* and *L. peruviana* was *Scleria ciliaris*, a species of Cyperaceae. It had an importance value of 14.78, ranked 2nd among the ground cover species (Table 2; Figure 5). This species is native to tropical Asia, tropical Australia, the Solomons, and Carolines (Flora Malesiana 2020). In a rubber plantation near Bukit Dua Belas National Park in Jambi, it became the second most dominant invasive species (Wahyuni et al. 2015). Meanwhile, in grassland dominated by *Imperata cylindrica* in Katingan District, Central Kalimantan Province, *S. ciliaris* was also the second dominant species (Usmadi et al. 2020). *S. bancana* (synonym of *S. ciliaris*) was also found in coalmine overburden dumping site in Satui, South Kalimantan Province (Novianti et al. 2017).

**Figure 4.** From left to right: *Uncaria acida* covering *Alstonia spatulata*; *Stenochlaena palustris* covering *Campnosperma coriaceum*; *Persicaria attenuata* dominating an open area; *Ludwigia peruviana* dominating an open area.

**Figure 5.** From left to right. *Crinum asiaticum* abundant in some locations; *Actinoscirpus grossus* dominating an open area; *Scleria ciliaris*, in the middle of the picture in the right, and *Persicaria attenuata*, in the front, dominating an open area.
Another sedge, *Actinoscirpus grossus* or *Scirpus grossus*, was also found abundant in some open space in the swamp with an importance value of 10.58, ranked 5th among the ground cover species (Table 2; Figure 5). This perennial sedge is native to tropical Asia, tropical Australia (Flora Malesiana 2020), and usually grows in swampy areas, marshes, ditches, and it may be dominant locally (Soerjani et al. 1987). It is considered a pan-tropical weed in the rice fields, drainage and irrigation canals, riverbanks (Majrashi et al. 2013). Beside having negative impacts, this species also has positive impacts for the environment because of its ability to absorb Al and Fe from the water, so it has been used for phytoremediation of contaminated water (Al-Badawi et al. 2015; Ismail et al 2019).

In some open wet places in this study site, *Persicaria attenuata* was found abundant, forming almost a pure stand (Figure 4). It had an importance value of 11.31, ranked 4th among the ground cover species (Table 2). This species with common English names of smartweed, watersmartweed, hairy knotweed is widespread in the tropics and subtropics of Africa, Asia and Australia, growing along the edge of swamp, dams, lagoons, bilabong and rivers, which may form thick, pure stand (Calvert and Liessmann 2014). Although this species was dominant in some open spaces in the swamp, this species was not listed as weeds of rice, while another species of the same genus, *Polygonum barbatum* (a synonym of *Persicaria barbata*) was listed, but this was of minor concern (Soerjani et al. 1987). With its ability to form thick pure stand, *Persicaria attenuata* can withstand the invasion of alien species (Calvert and Liessmann 2014).

Another forb found abundant in the study site was *Crinum asiaticum* (Figure 5), ranked 6th among the ground cover species (Table 2). It is native to Indian Ocean, tropical and subtropical Asia to Southwest Pacific and can grow in many types of habitat, i.e., sandy shores, freshwater swamps, mangroves, savannah to desert areas, up to 700 m above sea level (Sukaryta 2013). This species was also found in lowland wetland in Morang District of Nepal (Koirala and Jha 2011). Like *A. grossus*, *C. asiaticum* can accumulate metals as reported by Amin et al. (2015) that in Kawai wetland on Obi Island, North Maluku Province, *C. asiaticum* was the most dominant species and accumulated the highest concentration of metals both in roots and shoots.

**Palm**

A species of palm found abundant in some places in the swamp was *Nypa fruticans*. The genus *Nypa* was one of the oldest palms whose fossil records show that this genus was found in many parts of the world, but its current distribution is limited to tropical areas (Gomez-Navarro 2009). *Nypa fruticans* is naturally distributed from Asia extending to Europe, Africa, and America, but it is now found only in the tropical Indo-West Pacific region, from Sri Lanka through Asia to Northern Australia and the Western Pacific islands (Hossain and Islam 2015). Although this species has many benefits for society (Hossain and Islam 2015), it has become an invasive weed species in West Africa since its introduction in the early twentieth century (Noblik et al. 2018). Its superior root system enables this species to exploit nutrient in the environment and its buoyant seeds lead to its widespread distribution in Nigeria, threatening mangrove ecosystem (Numbere 2019).

**Conclusion and recommendation for future studies**

This study has shown the dominant plant species in the swamp forest, consisting of trees, shrubs and herbs. However, due to its small number of plots, this study has not completely described the flora of the swamp forest. Further studies with more sample plots located properly by considering the spatial heterogeneity of habitat will give more comprehensive description of the structure and composition of the swamp forest.

Studies on specific topic can be conducted to add the ecological understandings and help biodiversity conservation. For example, the abundance of climbers which cover the tree crowns should be studied to give us better understanding on the effects of climbers on trees. Climbers are competitors of trees in getting sunlight from above the crowns and in getting nutrients from the soil, and therefore, they may slow the succession rate of the secondry forest (Paul and Yavitt 2011). Another topic is the invasisvion of alien species, *Ludwigia peruviana*. According to the Indonesian law, the objective of strict nature reserve (cagar alam) is to preserve the specific natural ecosystem. Currently the ecosystem in the study site as a strict nature reserve has been drastically changed by illegal cutting and alien species invasion, and therefore should be restored.

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