The diversity of \textit{Nepenthes} at the post-mining area in Sintang District, West Kalimantan, Indonesia

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Abstract. Setiawan H, Wardhani HAK, Kamaludin, Hutagaol RR, Afriani R. 2018. The diversity of \textit{Nepenthes} at the post-mining area in Sintang District, West Kalimantan, Indonesia. Biodiversitas 19: 1820-1827. \textit{Nepenthes} is a tropical pitcher plant found in Indonesian archipelago and lives in nutrient leak habitat. One of \textit{Nepenthes} nutrient leak habitat commonly found in Kalimantan Island is the post-mining area. This research aimed to know the habitat condition, species composition, species richness and diversity index of \textit{Nepenthes} in Post-mining area in Sintang District, West Kalimantan Province. Thirty plots, each measuring 5 x 5-meter square, were established to survey the \textit{Nepenthes} diversity in five locations of the post-mining area in Sintang District. There were 910 individuals of \textit{Nepenthes} found spreading in two sub-Districts and five areas. Habitat condition in the post-mining area tended to be high in light intensity and temperature but low in humidity. Five \textit{Nepenthes} species were found, namely \textit{N. ampullaria}, \textit{N. bicalcarata}, \textit{N. gracilis}, \textit{N. mirabilis}, and \textit{N. rafflesiana}. Four natural hybrids were also found including \textit{N. xhookeriana}, \textit{N. xskuhingensis}, \textit{N. xneglecta}, and \textit{N. xtrichocarpa}. The species richness in the post-mining area were 1.25 in Danau BTN (Bank Tabungan Negara/State Savings Bank) 0.95 in Dusun Kerangas, 0.58 in Sungai Ana Village, 0.21 in Jerora 1 and 0.20 in Danau Baning. The diversity index in Danau BTN, Dusun Kerangas, Sungai Ana, Jerora 1 and Danau Banning area were of low levels, respectively, 1.66, 1.3, 1.0, 0.64, and 0.68. Cluster analysis of species richness, diversity index, and abiotic factors showed that Danau Baning-Sungai Ana-Jerora 1 was grouped in the same cluster while Danau BTN and Dusun Kerangas were in a separate cluster.

Keywords: Diversity, \textit{Nepenthes}, post-mining, Sintang District

**INTRODUCTION**

\textit{Nepenthes} (Family of Nepenthaceae) is the largest genus of pitcher plants (Moran and Clarke 2010). The genus contained 114 species over the world (IUCN) and distributed from Eastward of Madagascar to New Caledonia at Pacific Ocean (Jebb and Cheek 1997). Indonesian Archipelago is a central diversity of \textit{Nepenthes} with 32 endemic species in Borneo Island, 24 endemic species in Sumatera Island and some species found in Java, Sulawesi, and Papua Islands (Jebb and Cheek 1997; Clarke 2001; Clarke 2006;).

\textit{Nepenthes} are tropical carnivorous plants that evolved it leaf extensions into jug shaped structures which contain a pool of digestive enzymes to attract, trap and digest animals for its nutritional benefits (Clarke 2006). \textit{Nepenthes} pitchers are passive, gravity-driven traps that show distinct functional zonation on their inner surfaces (Moran and Clarke 2010). Beside prey capturing, an extra nutrition also can be extracted from other scenario such as litterfall with “carpets” of pitchers at ground level and animal faces (\textit{Kerivoula hardwickii}’s faces of \textit{N. hemsl eyana} and \textit{Tupaia Montana}’s faces of \textit{N. lowii}) (Clarke 2006; Moran and Clarke 2010; Gaume et al. 2016). This condition (nutrition sequestering by the pitcher) is vital because \textit{Nepenthes} commonly found in lack nutrient habitat (Latiff et al. 2014).

The post-mining area is one of nutrient-deficient habitat where the \textit{Nepenthes} is easily found. This area was formed by abandoned illegal gold mining or other mining activity in open space, usually in kerangas forest or watershed. This habitat is similar to kerangas forest which generally has siliceous and acidic soil, higher temperature and lower humidity, all of which are preferred by \textit{Nepenthes} (Latiff et al. 2014). In Sintang District, West Kalimantan Province, numbers of post-gold mining areas are increasing every year because of the local government policy to create a better ecosystem and fulfill the vision of ”the Sustainable Sintang District.” This research aimed to determine the species composition, species richness and diversity index of \textit{Nepenthes} in post-mining area in Sintang District.

**MATERIALS AND METHODS**

This research was conducted during February-July 2018 in five locations of post-mining areas in Sintang District, West Kalimantan Province. The post-mining areas are located in two sub-districts, i.e., Sintang Sub-district and Sepauk Sub-district. There were four post-mining areas in Sintang Sub-district namely post-mining Sungai Ana, post-mining Danau BTN (Bank Tabungan Negara/State Savings Bank),...
Bank), post-mining Jerora 1, and post-mining Danau Baning. There were no longer mining activities in these four locations, and the areas are now being used for other activities such as tourism (swimming pool at the ex-mining hole), settlement area, and swallow-nest farm. Another location is in Sepauk Sub-district at Kerangas Village, where mining activity (gold and sand mining) is still ongoing but the sampling plots were placed on around the mining area. In each location, a plot of 5 m x 5 m size was set up to observe the *Nepenthes*. The location was determined by using a purposive sampling technique to ensure the presence of *Nepenthes* (Lestariningsih and Setyaningsih 2017). The research site was surveyed comprehensively in localities with *Nepenthes* presence, but the plots were set up randomly and discontinuously (Latiff et al. 2014; Lestariningsih and Setyaningsih 2017). Well-known *Nepenthes* were identified directly in the fields while unknown species were collected as herbarium specimen for further identification. Data collection in plots included several variables such as habitat description (another biodiversity in the location of *Nepenthes* presence) and microclimate (humidity, light intensity, and air temperature) which were later analyzed by PAST ver. 2.14’s software (Hammer et al. 2001). Morphological data were analyzed descriptively, species richness was analyzed with Margalef’s index (Aslam 2009; Endrawati et al. 2017), and diversity index was calculated using Shannon-Wiener’s diversity index (Aslam 2009; Olopade and Rufai 2014; Komara et al. 2016).

Figure 1. Study area in two sub-districts (Sintang and Sepauk Sub-district) of Sintang District, West Kalimantan Province, Indonesia. Red dots mean study sites.
Margalef’s index of species richness = (S-1)/ ln N

Where:
S : total species number
N : total individual number in the sample
ln : natural logarithm

Shannon-Wiener’s diversity index : H = - ∑ Pi ln Pi

Where:
Pi : S / N
S : total species number
N : total individual number in the sample
ln : natural logarithm

RESULTS AND DISCUSSION

Habitat conditions

All Nepenthes habitat referred to in this research is the post-mining areas in Sintang District. Some of this habitat was active illegal mining areas, and others were shifted to other activities like residential area and tourism. Before the illegal mining activity took place, all of this habitats were Kerangas forest. The soil in Kerangas forest was generally siliceous and acidic, the canopy was much lower than Dipterocarpaceae forest and tended to be more uniform (Clarke 2006).

In this research, habitat condition of the post-mining area was represented by air temperature, humidity, and light intensity (Table 1). All the variation of microclimate is dependent on the canopy and vegetation over the area. In an open area with less vegetation, air temperature and light intensity tended to be higher while the humidity was low (Table 1). This condition affected the presence of Nepenthes. In the area with high air temperature and light intensity like Sungai Ana, Danau Baning and Jerora 1, the number of species found tended to be less than that in closed canopy area with lower air temperature and light intensity like Danau BTN and Dusun Kerangas (Table 1). Clarke (2006) found that the climate of undisturbed Kerangas (the area before mining activity) is superficially similar to that in mixed Dipterocarpaceae forests. This type of climate supports the living of more Nepenthes as compared to the open canopy area.

N. gracilis and N. mirabilis were prone to be on the habitat with open canopy area while N. ampullaria and N. bicalcarata preferred the area with close canopy and high in humidity (Table 1). N. rafflesiana were found in both open and closed canopy areas. Most of Nepenthes hybrid was found in close canopy area while only one other species was found in open canopy area (N. xneglecta). N. xneglecta is a hybrid of N. gracilis and N. mirabilis. Although both Nepenthes commonly live in the same habitat, the hybrid was rarely found. The high abundance of the parents may likely be the reason for the existence of this hybrid (Clarke 2006).

Nepenthes compositions

There were five Nepenthes species and four natural hybrids that were found in five locations within 30 plots. Nepenthes found in the post-mining area included N. ampullaria Jack, N. bicalcarata Hook.f, N. gracilis Korth, N. mirabilis (Lour.) Druce, and N. rafflesiana Jack. var. typical. Moreover, four natural hybrids of Nepenthes were also found, i.e., N. ampullaria x N. rafflesiana (N. xhookeriana), N. ampullaria x N. mirabilis (N. xchuchingensis), N. gracilis x N. mirabilis (N. xneglecta), N. ampullaria x N. gracilis (N. xtrichocarpa). A total of 910 Nepenthes individuals were found in this research; the highest number was N. gracilis (401 ind) followed by N. mirabilis (245 ind) in the second place (Figure 2).

Table 1. Humidity, air temperature, light intensity and number of individuals in each survey location

<table>
<thead>
<tr>
<th>Location</th>
<th>Hm (%)</th>
<th>Temp (°C)</th>
<th>Lig (lux)</th>
<th>N.amp</th>
<th>N.bic</th>
<th>N.gra</th>
<th>N.mir</th>
<th>N.raf</th>
<th>N.xho</th>
<th>N.xkh</th>
<th>N.xne</th>
<th>N.xtr</th>
<th>Total of ind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sungai Ana (open canopy)</td>
<td>52.17</td>
<td>36.43</td>
<td>25970</td>
<td>0</td>
<td>0</td>
<td>58</td>
<td>68</td>
<td>43</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Jerora 1 (open canopy)</td>
<td>52.33</td>
<td>34.07</td>
<td>43915</td>
<td>0</td>
<td>0</td>
<td>82</td>
<td>43</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>125</td>
</tr>
<tr>
<td>Danau Baning (open canopy)</td>
<td>53.00</td>
<td>33.83</td>
<td>31556</td>
<td>0</td>
<td>0</td>
<td>57</td>
<td>75</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>132</td>
</tr>
<tr>
<td>Danau BTN (closed canopy)</td>
<td>65.67</td>
<td>32.68</td>
<td>14823</td>
<td>34</td>
<td>49</td>
<td>126</td>
<td>13</td>
<td>20</td>
<td>17</td>
<td>9</td>
<td>0</td>
<td>12</td>
<td>280</td>
</tr>
<tr>
<td>Dsn Kerangas (closed canopy)</td>
<td>73.83</td>
<td>29.7</td>
<td>8241</td>
<td>62</td>
<td>96</td>
<td>78</td>
<td>46</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>198</td>
</tr>
</tbody>
</table>

Note: Hm: humidity; Temp: air temperature; Lig: light intensity; N.amp: N. ampullaria; N.bic: N. bicalcarata; N.gra: N. gracilis; N.mir: N. mirabilis; N.raf: N. rafflesiana; N.xho: N. xhookeriana; N.xkh: N. xchuchingensis; N.xne: N. xneglecta; N.xtr: N. xtrichocarpa; Total of ind: total of individuals
Description of Nepenthes

Each *Nepenthes* has a specific morphologic character that makes it distinct from one to another. This particular characteristic was used as a simple field identification of *Nepenthes*. The most variations appeared in the pitcher morphology and its colors (Clarke 2006). Some descriptions of *Nepenthes* found in post-mining habitat were different from those of *Nepenthes* in other habitats. The specific characters are presented below.

*Nepenthes ampullaria*

*Nepenthes ampullaria* has a unique lid of the pitchers which are cuneate and reflexed. These *Nepenthes* pitchers vary in colors such as light green, dark green, red, dark brown, bright green with red peristome, red with green peristome, green with red and brown blotches, red with brown blotches and some other combinations. In the post-mining area, *N. ampullaria* tended to be smaller than that in undisturbed habitat. The smaller size of *N. ampullaria* is an adaptive mechanism resulted from the lack of nutrient and to prevent the evaporation in an open area (Clarke 2006; Bauer et al. 2011).

*Nepenthes bicalcarata*

*Nepenthes bicalcarata* has a specific character that is distinct from other *Nepenthes* species, i.e., a pair of large thorns under the pitcher lid. This pair of large thorns is used to attract the nectar preys to enter the pitcher. The pitcher of *N. bicalcarata* is commonly found in two different forms; an upper pitcher and a lower pitcher in one individual to capture different types of preys. *N. bicalcarata* plants are the largest of genus *Nepenthes*, although the pitchers are not the largest one (Clarke 2006). *N. bicalcarata* has the largest stem and leaf in the *Nepenthes* genera. The stem of this plant can reach five m long in the post-mining area in Sintang District while other *Nepenthes* species can only achieve less than one meter in length.

*Nepenthes gracilis*

*Nepenthes gracilis* was commonly found in post-mining areas in Sintang District. Its pitcher is relatively smaller than that of other lowlands *Nepenthes* (less than 15 cm height). Its stem is triangular and climbs other vegetation to get better light. In the post-mining area, *N. gracilis* was found as a pioneer plant after the mining activity was closed. In this research, *N. gracilis* was always seen with *N. mirabilis* (Table 1) because both *Nepenthes* live in the same habitat (Clarke 2006; Setiawan et al. 2015).

*Nepenthes mirabilis*

*Nepenthes mirabilis* was the most adaptive *Nepenthes* in the post-mining area along with *N. gracilis*. It was found in different colors from light green to dark brown. Sometimes, it was found in full red, stem, leaves, and pitcher, especially in the profoundly disturbed habitat like post-mining area (Figure 3). This *Nepenthes* has most familiar flowers and fruits over seasons (Handayani 2017). In the post-mining area, the arthropods and wind factors facilitate the spread of the seed to entire habitat at the post-mining area.

*Nepenthes rafflesiana*

*Nepenthes rafflesiana* is lowland *Nepenthes* species in which lower and upper pitcher has many differences. The lower pitcher was more bulbous and had a pair of wing running from top to bottom. The upper pitcher looked more attractive with horn-shape and had a big lid to cover the peristome. Pitcher mouth of this *Nepenthes* was oblique and elongated into the neck at the back. Pitcher of *N. rafflesiana* was varying in colors from green to brown and blotches cover the pitcher’s body (Listiawati and Siregar 2008). In the post-mining area, the color of *N. rafflesiana* pitcher was generally light green to dark green with red/brown blotches. This color variation is less than that in undisturbed habitat as an adaptation from habitat stress in the heavily disturbed post-mining area (Clarke 2006).

*Nepenthes xhookeriana*

*Nepenthes xhookeriana* is a natural hybrid from *N. ampullaria* and *N. rafflesiana*. The characteristic of *N. xhookeriana* is the combination of both of its parents. The pitcher was round and smaller than that of *N. rafflesiana*. The peristome of the pitcher was extended but less than that of *N. rafflesiana*. The lid of the pitcher was similar to that of *N. ampullaria* but broader and taller than one. The upper pitcher was ovoid and smaller than lower pitcher. The appearance of upper pitcher in *N. xhookeriana* was a contrast of *N. ampullaria* because *N. ampullaria* rarely produced it. The upper pitcher of *N. xhookeriana* was predicted from *N. rafflesiana* parentals (Clarke 2006).

*Nepenthes xkuchingensis*

*Nepenthes xkuchingensis* is a natural hybrid from *N. ampullaria* and *N. mirabilis*. According to Clarke (2006), this hybrid species was commonly found in Borneo but somehow appeared among both parental populations. In the post-mining area at Sintang District, it was only found in one location; in Danau BTN pal IV at Kapuas Kanan Hulu Village. The lower pitcher is more like that of *N. mirabilis* with well-developed wings and expanded peristome. The leaf size ranged between both parents and was smoother than that of *N. ampullaria*.

*Nepenthes xneglecta*

*Nepenthes xneglecta* is known as a natural hybrid from *N. gracilis* and *N. mirabilis*. According to Clarke (2006), even though both plants were commonly found in the same habitat but natural hybrids were rarely found. *N. xneglecta* is more like *N. gracilis* in shape, but in size, it is more like *N. mirabilis*. The leaf of its hybrid has the same characteristic as that of *N. mirabilis*. The stem of *N. xneglecta* is more cylindrical than *N. gracilis*.

*Nepenthes xtrichocarpa*

*Nepenthes xtrichocarpa* is a natural hybrid of *N. ampullaria* and *N. gracilis*. It was found in sandy-siliceous habitat in Danau BTN pal IV at Kapuas Kanan Hulu Village. The pitcher is relatively the same size as *N.
gracilis but slightly wider in all aspects. The peristome is more like that of N. ampullaria. The lower pitcher is usually found in clumps cover the ground layer. The upper pitcher appears as a prove that N. gracilis parental is more dominant in this hybrid species. The upper pitcher is more like a “cup” with the lower part is smaller than the upper part.

Species richness

The post-mining area with the highest species richness (1.25) was Danau BTN in Kapuas Kanan Hulu Village followed by Dusun Kerangas and Sungai Ana Village with species richness of, respectively, 0.95 and 0.58. The lowest species richness was found in Jerora 1 (Jerora 1 Village) and Danau Baning (Banning Kota Village), respectively, 0.21 and 0.20 (Figure 4).

All of this Nepenthes species were found in post-mining areas affected by different community activities. Danau BTN is a post-mining area already covered by secondary vegetation like Resam fern (Gleichenia spp.), Geronggang (Cratoxylum arborescens), and Jonger (Pliariaium alternifolium). The dead root, stem and leaf of Resam fern are good growth media for lowland Nepenthes. Geronggang and Jonger are canopy trees in Kerangas habitat. The vegetation is an essential aspect of Nepenthes growth as it affects microclimate, soil organic matter, and biodiversity in that specific area/habitat (Clarke 2001; Clarke 2006).

The diversity index was used to determine the diversity of Nepenthes in each plot. The Shannon-Wiener Diversity Indices in five locations of the post-mining area showed some differences. The highest diversity index was found in Danau BTN (1.66) followed by Dusun Kerangas (1.30), Sungai Ana (1.00), Danau Baning (0.68), and Jerora 1 (0.64) (Figure 5). All of these diversity indices were categorized as less diverse (Gandhi and Sundarapandian, 2014). The diversity of Nepenthes in the post-mining area was impacted by habitat condition. In the location with high vegetation canopy cover like Danau BTN, the Nepenthes tended to be more diverse than that in open areas like Jerora 1 and Danau Baning since the soil nutrients in vegetated area (Danau BTN) was higher (than the disturbed area), which provided enough nutrient for plants growth (Singh et al. 2015).

Cluster analysis

Cluster analysis was used to identify the similarity between each location based on species richness, Shannon-Wiener index, and abiotic factors. Cluster analysis divided the sites into three clusters, in which, Danau Baning, Sungai Ana and Jerora 1 were in one group, and Dusun Kerangas and Cluster Danau BTN were in a separate group (Figure 6).

Danau Baning, Sungai Ana and Jerora 1 are post-mining areas characterized by open canopy area, high temperature, and light intensity and low humidity. This cluster was also characterized with N. mirabilis as the dominant species. N. mirabilis was known as the most adaptive species in the genus and can live in a harsh habitat with high light intensity and temperature (Clarke 2006).

The cluster containing Danau BTN was characterized by the existence of N. bicalcarata, N. xkuchingensis, N. xhookeriana, N. xtrichocarpa. This area was a vegetated area with specific Kerangas secondary vegetation like Gleichenia spp and Cratoxylum arborescens. This vegetation makes a good condition (microclimate) for the growth of these Nepenthes.

Dusun Kerangas was a post-mining area, some of which were covered by secondary Kerangas vegetation. Different from Danau BTN, there were less Gleichenia spp. in Dusun Kerangas, but the area was covered by Cratoxylum spp. and other three species. The humidity was relatively higher, and the light intensity was the lower than other areas (Clarke 2006).

Based on biplot analysis, the group of Danau Baning-Sungai Ana-Jerora 1 was characterized by very dominant N. mirabilis in this area (Figure 7). Most of N. mirabilis was found in this group area. Dusun Kerangas was placed in a separate group characterized by high humidity and N. ampullaria. N. ampullaria was known as a species which tends to prefer a close canopy where it scrambles among low bushes (Clarke 2006). The group comprising Danau BTN was a group with many characters such as N. bicalcarata, N. xhookeriana, N. xtrichocarpa, and N. kuchingensis. Danau BTN was a vegetated habitat that supports the growth of Nepenthes. The existence of many Nepenthes in the same habitat provided a higher opportunity to find a hybrid species (Clarke 2006).

Figure 4. Species richness of Nepenthes in the post-mining area

Figure 5. Shannon-Wiener diversity index in the post-mining area
In conclusion, *Nepenthes* found in the post-mining area at Sintang Regency consisted of five *Nepenthes* species and four natural hybrids namely *N. ampullaria* Jack., *N. bicalcarata* hook.f., *N. gracilis* Korth., *N. mirabilis* Lour (Druce), *N. rafflesiana* Jack., *N. xhookeriana*, *N. xkuchingensis*, *N. xneglecta*, and *N. xtrichocarpa*. The condition of the post-mining area promoted the *Nepenthes* growth both in open canopy and closed canopy areas. There were 910 individuals of *Nepenthes* found with *N. gracilis* and *N. mirabilis* the top two in individual number (401 and 245 number of individuals, respectively). Species richness showed the number of species found in the
specific location. The highest species richness was found in Danau BTN (1.25), followed by that in Dusun Kerangas (0.95), Sungai Ana Village (0.58), Jerora 1 (0.21) and Danau BTN (0.20). The diversity index in Danau BTN, Dusun Kerangas, Sungai Ana, Jerora 1 and Danau Baning were on a low level, respectively, 1.66, 1.3, 1.0, 0.64, and 0.68. Based on cluster analysis of species richness, H’ and abiotic factors, Danau Baning-Sungai Ana-Jerora 1 was grouped in the same cluster while Danau BTN and Dusun Kerangas were in a separate cluster. This means that Danau Baning-Sungai Ana-Jerora 1 had proximity habitat characterized by highly dominant *N. mirabilis* in this areas. Whereas, Danau BTN was characterized by dominant *Nepenthes* hybrid and Dusun Kerangas was characterized by existence of *N. ampullaria*.

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