



Faculty of Resource Science and Technology

Genus *Nephelium* L. (Sapindaceae) in Borneo: Distribution of the Species and its Flowering-Fruiting Pattern Based on the Specimens from Naturalis Biodiversity Center (NL)

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Bachelor of Science with Honours
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A thesis submitted in partial fulfilment of the Requirement of The Degree Bachelor of
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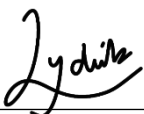
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Gratitude to the God for the blessing and grace so that this Final Year Project report entitled “Genus *Nephelium* L. (Sapindaceae) in Borneo: Distribution of the Species and its Flowering-Fruiting Pattern Based on the Specimens from Naturalis Biodiversity Center (NL)” can be completed.

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Author

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ABSTRACT

Nephelium L. is a genus belonging to the family Sapindaceae that is widely distributed in the Southeast Asia region and Borneo is known to be the center of diversity of this genus. The study of *Nephelium* species distribution and flowering-fruiting pattern in Borneo is not much studied yet. Therefore, based on herbarium specimen collections in Naturalis Biodiversity Center (NL), the distribution and the flowering-fruiting pattern of 16 *Nephelium* species in Borneo were studied. Distribution maps were generated by ArcView GIS 3.3 software based on specimen's longitude and latitude coordinates. Flowering and fruiting season pattern of each species was assessed based on the collection date of the specimens stated on the labels. From the distribution maps produced, it was found that each species has different distribution. Sarawak and Sabah recorded the most diverse *Nephelium* species. *Nephelium maingayi*, *N. ramboutan-ake*, and *N. uncinatum* were found to be the species with the widest distribution in Borneo and also recorded to be flowering and fruiting all year round. From this study, it shows that a distribution and flowering-fruiting pattern study of *Nephelium* species is possible to be done by using digital data from Naturalis Biodiversity Center. To support this study and supplement the information, a comparison with another herbaria is suggested.

Key words: Borneo, distribution, flowering and fruiting pattern, *Nephelium*

ABSTRAK

Nephelium L. adalah genus dari keluarga Sapindaceae yang tersebar luas di rantau Asia Tenggara dan Borneo dikenali sebagai pusat kepelbagaian. Kajian tentang taburan spesies *Nephelium* dan corak berbunga-berbuah di Borneo masih belum banyak dikaji. Oleh itu, berdasarkan koleksi spesimen herbarium di Naturalis Biodiversity Center (NL), taburan dan corak pembungaan 16 spesies *Nephelium* di Borneo telah dihasilkan. Peta taburan spesies telah dijana menggunakan perisian ArcView GIS 3.3 berdasarkan koordinat longitud dan latitud spesimen. Manakala corak musim berbunga dan berbuah bagi setiap spesies dinilai berdasarkan tarikh pengumpulan spesimen pada label spesimen. Daripada peta taburan yang dikaji, didapati setiap spesies mempunyai taburan yang berbeza. Sarawak dan Sabah direkodkan mempunyai kepelbagaian spesies paling tinggi. *Nephelium maingayi*, *N. ramboutan-ake*, dan *N. uncinatum* adalah spesies-spesies yang mempunyai taburan paling luas di Borneo dan juga direkodkan berbunga dan berbuah sepanjang tahun. Daripada kajian ini, terbukti bahawa kajian taburan dan corak pembungaan spesies *Nephelium* boleh dilakukan dengan menggunakan data digital dari Naturalis Biodiversity Center. Untuk menyokong kajian ini dan menambah maklumat, perbandingan dengan herbaria lain dicadangkan.

Kata kunci: Borneo, corak berbunga dan berbuah, *Nephelium*, pengedaran

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CHAPTER 1

INTRODUCTION

Nephelium L. is one of the economically important genera that is known for its tropical edible fruit such as rambutan. It is a genus belonging to the family Sapindaceae and order Sapindales that consists of 22 known species. *Nephelium* is mainly distributed in the Southeast Asia region from Yunnan (Southwestern China) and Assam (Northeastern India) to Hainan, Peninsular Malaysia, Borneo, Indonesia, and Philippines. Borneo island is reported to be the center of diversity of the *Nephelium* species. This genus is described as medium-sized to tall trees that grow in rainforests at low to medium altitudes and sometimes in deciduous or savannah forests (Leenhouts, 1986).

Nephelium became popular for its fruits due to their unique appearance with bright red color, hairs, and sweet edible flesh (aril). The well-known species of this genus is *Nephelium lappaceum* L. which refers to the rambutan in Malaysia and Indonesia. There are 61 cultivars developed from *N. lappaceum* in Malaysia and the recommended cultivars are widely cultivated in the orchards and home gardens (Department of Agriculture [DOA], 2021). Another popular but rarely cultivated species of this genus is *Nephelium ramboutanake* (Labill.) P. W. Leenhouts or commonly called as pulasan in Malaysia or kapulasan in Indonesia. Some other wild species with edible fruits that can be found in the local markets are *Nephelium cuspidatum* Bl., *Nephelium maingayi* Hiern, *Nephelium hypoleucum* Kurz and *Nephelium uncinatum* Radlk. ex. P. W. Leenhouts (Salma et al., 2015). Besides providing edible fruits for humans, the fruits of *Nephelium* are also ecologically important in the wild as a food source of monkeys and fruit bats (Leenhouts, 1986).

Although *Nephelium* is a well-known genus with some notably important species, most of the species are still under-studied and considered as threatened species (Salma et al., 2015). The cultivation of *Nephelium* species these days is still limited to a few species with

N. lappaceum as the most widely cultivated species. Other wild species might also have the potential to be cultivated as profitable local fruit crops or other purposes such as germplasm resources to develop new cultivar and source of timber (Anggraheni & Mulyaningsih, 2018). *Nephelium hamulatum* Radlk., *N. costatum* Hiern, and *N. papillatum* P. W. Leenhouts are considered as vulnerable species while *N. aculeatum* P. W. Leenhouts is a critically endangered species (International Union for Conservation of Nature [IUCN], 2021). Most of these species are endangered and rapidly declining due to deforestation, urbanization, and land conversion (Salma et al., 2015). Therefore, considering the ecological importance and economical potential of it, a further and deeper study of this genus is needed.

1.1 Problem Statement

The genus *Nephelium* is not significantly studied yet and the distribution for each species is still not clear. The most comprehensive studies on this genus were published by Leenhouts (1986) that focused on the taxonomy and Salma et al. (2015) that focused on the diversity and distribution. Other papers published are mostly focused on more popular or cultivated species such as *N. lappaceum* and *N. ramboutan-ake* (Windarsih & Efendi, 2019; Djuita et al., 2017). While the distribution and flowering or fruiting pattern of each *Nephelium* species has not much studied yet especially for Borneo. As Borneo is considered as the center of biodiversity of this genus, a comprehensive study especially on the genus *Nephelium* in Borneo is important to be conducted. In this study, specimen collections of 16 *Nephelium* species from Naturalis Biodiversity Center (NL) herbarium that is based in the Netherlands were observed.

Therefore, the objectives of this study were: 1) To determine the distribution of each *Nephelium* species found in Borneo and 2) to determine the flowering and fruiting pattern of *Nephelium* species in Borneo.

CHAPTER 2

LITERATURE REVIEW

2.1 Sapindaceae

Sapindaceae or also known as soapberry family is a large family under the order Sapindales that consists of around 140 genera and 1,630 species (Utteridge & Bramley, 2015). This family is widely distributed in the world especially in the pantropical and temperate regions. It was first described by Jussieu in 1789 in his *Genera Plantarum* as a distinct family from Aceraceae (Acevedo-Rodríguez et al., 2010).

Sapindaceae are trees, shrubs, or lianas with tendrils on the inflorescence, and rarely as herbs. Most Sapindaceae have compound leaves, rarely simple, with alternate arrangement, and serrate or entire margins. The inflorescences are terminal, axillary, paniculate, racemose, or thyrsoid, while the flowers are usually functionally unisexual, rarely bisexual, actinomorphic or zygomorphic, monoecious or dioecious, and with superior ovary. The fruits are drupes, berries, capsules, or samaras, and often 2-3 lobed or winged. Seeds are globose to obovoid, often with fleshy arillode or sarcotesta such as shown in lychee and rambutan fruits (Utteridge & Bramley, 2015; Adema et al., 1994).

Sapindaceae is considered as an economically important family as it consists of many important species in the world either globally or locally. It is especially well known for its tropical edible fruits such as lychee (*Litchi chinensis* Sonner.), longan (*Dimocarpus longan* Lour.), rambutan (*Nephelium lappaceum*), and pulasan (*N. ramboutan-ake*) (Adema et al., 1996). In Jamaica, *Blighia sapida* Koenig or known as ackee is widely consumed but it is highly toxic when eaten unripe. Other than that, the genus *Paullinia* L. is known for its versatile species that were reported to be used as medicines, caffeine beverages, binding and weaving material, and for fish and arrow poisoning. This family also includes *Acer* L. or

maples that are usually recognized for its palmately lobed leaves that consists of many species of maple trees (Acevedo-Rodríguez et al., 2010).

2.2 Genus *Nephelium* L.

2.2.1 General Characteristics of Genus *Nephelium*

Nephelium L. is a genus that consists of about 22 species and belongs to the family Sapindaceae. This genus is a medium to tall sized tree and rarely found as shrubs. Most species are dioecious while some are monoecious. The leaves are compound, spirally arranged, paripinnate, and without stipules. Leaflets are arranged alternately (rarely opposite) and almost always hairy above on the midrib. Inflorescences are axillary, pseudoterminal, or terminal thyrses. Flowers are actinomorphic. The calyx is cup-shaped, 4 or 6-merous, valvate or sometimes slightly imbricate, entire, and without glands. The corolla is always shorter than calyx, 0 or 4 to 6, entire, clawed, and hairy on both sides. Fruits are 1 or 2-lobed with short to inconspicuous stipe, ellipsoid to subglobular, hairy at first and soon glabrescent, sometimes remaining densely puberulous, and with warty to spiny epicarp. The seeds are completely covered by edible sarcotesta (Leenhouts, 1986; Acevedo-Rodríguez et al., 2010) (Figure 1).

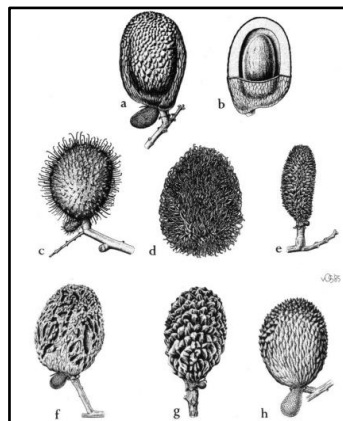


Figure 1. Fruits of *Nephelium*; (a & b. *Nephelium compressum* Radlk.; c. *N. uncinatum* Leenh; d. *N. meduseum* Leenh; e. *N. laurinum* Blume; f. *N. daedaleum* Radlk.; g. *N. juglandifolium* Blume; h. *N. hypoleucum* Kurz) (adapted from Leenhouts, 1986)

2.2.2 Distribution of *Nephelium*

The genus of *Nephelium* was assumed to be originated in the Indo-China-Indonesia region and distributed in the Southeast Asian countries. It was reported that five *Nephelium* species were found in the Indo-China region (Cambodia, Laos, Myanmar, Thailand, Vietnam), 13 in Peninsular Malaysia, eight in Sumatra, 16 in Borneo, four in the Philippines, three in Java, and one in Sulawesi. The distribution of the genus according to Leenhouts (1986) is shown in Table 1 and Figure 2. Borneo is considered as the center of diversity of this genus as there were 16 species found and eight of them were reported to be endemic species (Leenhouts, 1986).

Table 1. Distribution of *Nephelium* Species (Adapted from Leenhouts, 1986)

Species	Distribution
<i>N. aculeatum</i>	Borneo (Sabah, Malaysia)
<i>N. compressum</i>	Borneo (Sarawak, near Kuching)
<i>N. costatum</i>	Malaya
<i>N. cuspidatum</i>	Burma (Myanmar), Thailand, Cambodia, Vietnam, Malaya, Sumatra (Indonesia), W. Java (Indonesia), Borneo, and Palawan (The Philippines)
<i>N. daedaleum</i>	Borneo
<i>N. hamulatum</i>	Malaya
<i>N. havilandii</i>	Borneo
<i>N. hypoleucum</i>	Burma (Myanmar), Thailand, and Indo-China
<i>N. juglandifolium</i>	Malaya, Sumatra (Indonesia), and Java (Indonesia)
<i>N. lappaceum</i>	Yunnan, Hainan, the Indo-Chinese Peninsula, Malaya, Sumatra (Indonesia), Java (Indonesia), Borneo, the Philippines, and Sulawesi (Indonesia)
<i>N. laurinum</i>	Malaya, Sumatra (Indonesia), and Borneo
<i>N. macrophyllum</i>	Borneo
<i>N. maingayi</i>	Malaya, Sumatra (Indonesia), and Borneo
<i>N. meduseum</i>	Borneo
<i>N. melanomiscum</i>	Borneo and the Philippines (Mindanao)
<i>N. melliferum</i>	Thailand, Vietnam, and Malaya
<i>N. papillatum</i>	Borneo (Sabah, Malaysia)
<i>N. ramboutan-ake</i>	Assam (India), Burma (Myanmar), Malaya, Sumatra (Indonesia), Java (Indonesia) (doubtful), Borneo, the Philippines, and the Moluccas (Maluku islands, Indonesia)
<i>N. reticulatum</i>	Borneo
<i>N. subfalcatum</i>	Malaya, Sumatra (Indonesia), and Borneo
<i>N. uncinatum</i>	Malaya, Sumatra (Indonesia), and Borneo

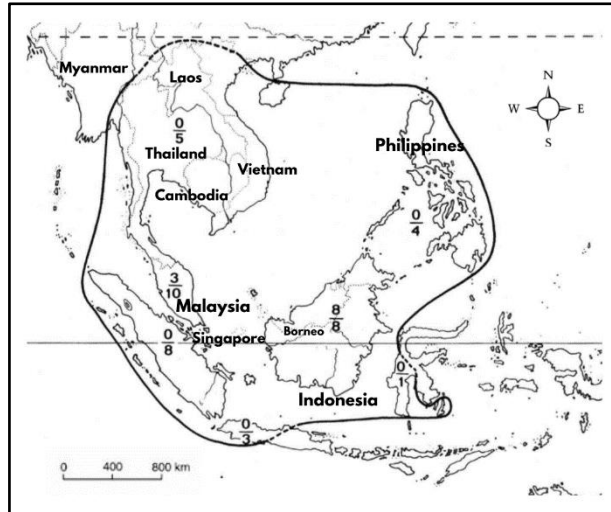


Figure 2. Distribution of *Nephelium* (number of endemics are above and number of non-endemics are below the hyphen) (adapted from Leenhouts, 1986)

2.2.3 Systematics of *Nephelium*

Nephelium is closely related to *Xerospermum* Blume, *Cubilia* Blume, *Dimocarpus* Lour., *Otonephelium* Radlk., *Litchi* Sonn., and *Pometia* J. R. Forst. & G. Forst. It was reported that a reasonable cladistic analysis on the genus *Nephelium* is impossible due to the lack of phylogenetic series. There are at least four reliable phylogenetic series based on the flower characteristics such as coalescence of the calyx from free to nearly completely connate sepals, reduction of the corolla (5-0), reduction of the number of stamens (8-4), and reduction of the pistil from 2(-4)-merous to 1-merous. Based on these series it was determined that the most primitive species are *N. compressum* Radlk. and *N. havilandii* P. W. Leenhouts. Fairly primitive species are *N. costatum*, *N. daedaleum* Radlk., *N. hypoleucum*, *N. laurinum* Bl., *N. macrophyllum* Radlk., *N. meduseum* P. W. Leenhouts, and *N. melliferum* Gagnep. Central group consists of *N. cuspidatum*, *N. hamulatum*, *N. juglandifolium* Bl., *N. lappaceum*, *N. ramboutan-ake*, and *N. reticulatum* Radlk. Rather advanced group are *N. melanomiscum* Radlk. and *N. subfalcatum* Radlk., connected with the latter is *N. uncinatum*, and highest evolved species with the most reduced flower is *N. maingayi* (Leenhouts, 1986).

2.2.4 Flowering and Fruiting Pattern of *Nephelium*

Nephelium species are mostly cross pollinated as most of the species are known as dioecious plant. The flowers are pollinated by insect and bird, while the seeds are dispersed by monkeys, bats, and some species by water (Leenhouts, 1986). Rambutan or *N. lappaceum* was reported to be flowering once a year in general but may flower twice a year depending on the genotypes, soil, and agro-climatic conditions. The flowering period usually occur in the dry season and lasts for about two to three weeks (Chakraborty et al., 2018). Table 2 shows the flowering and fruiting pattern of *Nephelium* species.

Table 2. Flowering and Fruiting Pattern of *Nephelium* Species (adapted from Leenhouts, 1986)

Species	Flowering Time	Fruiting Time
<i>N. aculeatum</i>	August	-
<i>N. compressum</i>	March	December
<i>N. cuspidatum</i>	November-March	May-September
<i>N. daedaleum</i>	May, September	June, August, September, November
<i>N. havilandii</i>	October	February, November
<i>N. macrophyllum</i>	-	September
<i>N. maingayi</i>	January-April, July-October	January-April, August-November
<i>N. meduseum</i>	January and October	-
<i>N. melanomiscum</i>	October	January
<i>N. papillatum</i>	November	-
<i>N. ramboutan-ake</i>	February-April, July-September	May-July, October-December
<i>N. reticulatum</i>	April, May, July, August, October	January
<i>N. subfalcatum</i>	August	December-February
<i>N. uncinatum</i>	April-June, August-October, December	December, March
<i>N. costatum</i>	March and April	August
<i>N. hamulatum</i>	October	Jan, June, July
<i>N. hypoleucum</i>	December-February	February-June
<i>N. juglandifolium</i>	February, July-August	July
<i>N. laurinum</i>	March-August	January
<i>N. melliferum</i>	March, June, December	April-July
<i>N. reticulatum</i>	May, July, August, October	January

2.2.5 Uses and Economic Importance of *Nephelium*

The most economically important and widely cultivated species of *Nephelium* is *N. lappaceum* or commonly known as rambutan. Rambutan is a well-known edible tropical fruit that can be consumed as fresh fruit or processed as canned fruit, juice, jellies, or jam (Sirisompong et al., 2011). The edible fruit flesh of the rambutan is called aril. It is translucent to white, juicy, sweet, and reported to be nutritive and rich in sugar, vitamins, and minerals. Besides as a food source, the seed contains some chemicals that can be utilized as antioxidant and anti-hyperglycemic agents and its oil extract can be used to make soap. While for medicinal purposes, the root extract is used to cure fever and the bark extract can cure tongue disease. In addition, the whole tree itself is aesthetically pleasing so that it can be used as a landscaping tree (De & Bhattacharjee, 2008).

It was also reported that *N. ramboutan-ake* (pulasan) and *N. cuspidatum* (kalambuko) are also edible and cultivated in Malaysia. Some other edible wild species are *N. juglandifolium*, *N. maingayi*, *N. meduseum*, *N. melanomiscum*, *N. reticulatum*, *N. uncinatum*, *N. daedaleum*, and *N. laurinum* (Djuita et al., 2017).

2.3 Naturalis Biodiversity Center (NL)

Naturalis Biodiversity Center (NL) or in Dutch called as *Nederlands Centrum voor Biodiversiteit Naturalis* is a national museum that is located in Leiden, Netherlands. It is a museum of natural research history and a research center that was born from the establishment of the National Museum of Natural History by King Willem I in 1820. In 2010, it combined with the Zoological Museum Amsterdam of the University of Amsterdam and the Dutch National Herbaria which collect herbarium specimens from the universities of Leiden, Wageningen, and Utrecht. The combinations of those three institutes were named

Nederlands Centrum voor Biodiversiteit and later in 2012 changed into Naturalis Biodiversity Center (NL) (Oever & Gofferje, 2012).

More than 40 million objects were collected and categorized into botany, geology, vertebrates, invertebrates, entomology, books, and type catalogs. There are around 5.5 million botanical specimens which were collected from Southeast Asia, tropical America, tropical Africa, and the Netherlands. The herbarium specimens of NL were combined from three herbaria such as Leiden that focused on Southeast Asia region especially Indonesia and New Guinea, Utrecht that focused on tropical America, and Wageningen that focused on tropical Africa. All of the specimens have been digitized and can be accessed freely at the BioPortal database of Naturalis Biodiversity Center (Naturalis Biodiversity Center, n.d.).

2.4 Borneo Island

Borneo is considered as the third largest island in the world. Figure 3 shows the map of Borneo Island. It is in Southeast Asia and surrounded by the South China Sea to the northwest, Sulu Sea to the northeast, Celebes Sea to the east, and Java Sea to the south. Borneo is constituted of three countries such as Indonesia, Malaysia, and Brunei. Kalimantan is the largest region of Borneo Island which belongs to Indonesia. Kalimantan is divided into five provinces of East Kalimantan, West Kalimantan, Central Kalimantan, North Kalimantan, and South Kalimantan. The northwest and northern part of Borneo belongs to East Malaysian region and comprised of the states of Sabah and Sarawak. Brunei is located between Sarawak and Sabah (Britannica, 2021).

Borneo is located in the equator line therefore the climate is hot and humid with annual average rainfall around 150 inches. Most parts of Borneo are largely mountainous, while some parts are lowland such as in Central Kalimantan and Sarawak (Britannica, 2021). Borneo has been recognized as the world's biodiversity 'hotspot' by WWF as Borneo is still

largely covered with rainforest that is rich in floral and faunal diversity. It was reported that 55% or 40 million hectares of Borneo is covered by forest and 31% of it is protected (World Wildlife Fund [WWF], 2017). The rainforest is very rich with extensive stands of teak, oak, conifers, and Dipterocarpaceae family. Borneo is estimated to be the home of 6% flora and fauna of the world including protected or endemic species such as orangutan, *Rafflesia arnoldii* R. Br. which is the largest flower in the world, endemic mammals such as Bornean clouded leopard (*Neofelis diardi* G. Cuvier), proboscis monkey, and many more plant, birds, insects, and fish species (Britannica, 2021). However, it was reported that the natural forest area of Borneo is declining rapidly due to deforestation and land conversion for agricultural purposes. As in 2016, more than 7 million hectares of rainforest had been converted into oil palm plantation and 6 million hectares were converted into pulpwood plantation (WWF, 2017).



Figure 3. Map of Borneo Island (adapted from Britannica, 2021)

CHAPTER 3

MATERIALS AND METHODS

The study of *Nephelium* was carried out based on the specimen collections of Naturalis Biodiversity Center (NL) that were accessible online at <https://bioportal.naturalis.nl/>. There were 16 species of *Nephelium* with a total number of 396 specimens in NL that were collected from Borneo. The species name, collection number, collector, date, locality, site coordinates, and any other additional information were recorded for each sample (Appendix 1).

The distribution of *Nephelium* species was determined from the locality and site coordinates from all specimens of each species. Data dictionary was created for attributes of collection ID, species ID, species name, country, province, state, district, date collection, collector name, and specific location of each specimen to minimize spatial database size and ensure standard representation of specimen data. Spatial database comprising of each specimen's longitude location, latitude location, and attributes were compiled using ArcView GIS 3.3 (ESRI, 2002). Subsequently, distribution map of each *Nephelium* species was generated from the database using the same software. Descriptive discussion of species distribution is produced for each map. Description of data was done from the map produced.

Flowering and fruiting season pattern was assessed based on the collection date of the specimens for each species. The availability of flower and fruit in each specimen was recorded by observing the specimen and reading the specimen label. Bar chart showing the flowering and fruiting pattern for each species was created using Excel Spreadsheet.

CHAPTER 4

RESULTS

From 1351 specimens of *Nephegium* species recorded in Naturalis Biodiversity Center database, a total of 396 specimens were collected from Borneo. 106 specimens in this study were collected after 1986. There were 16 *Nephegium* species recorded from Borneo and all the 16 species can be found in the Naturalis Biodiversity database. The number of specimens collected for each species varied from less than 10 to more than 100. Table 3 shows the list of 16 species found in Borneo along with its number of specimens collected from the NL database. This table includes all specimens collected in Borneo with specific location and without specific location (only stating region in Borneo as its collection locality).

Table 3. *Nephegium* species collected in Borneo with its number of specimens

Species	Number of Specimens			
	Kalimantan	Sarawak and Sabah	Brunei	Borneo (Country not specified)
<i>N. aculeatum</i> P. W. Leenhouts	-	4	-	-
<i>N. compressum</i> Radlk.	-	1	-	3
<i>N. cuspidatum</i> Bl.	6	13	-	-
<i>N. daedaleum</i> Radlk.	1	15	-	1
<i>N. havilandii</i> P. W. Leenhouts	2	3	-	-
<i>N. lappaceum</i> L.	10	9	3	1
<i>N. laurinum</i> Bl.	2	-	-	-
<i>N. macrophyllum</i> Radlk.	-	3	-	1
<i>N. maingayi</i> Hiern	28	58	9	1
<i>N. meduseum</i> P. W. Leenhouts	1	8	3	-
<i>N. melanomiscum</i> Radlk.	2	4	1	1
<i>N. papillatum</i> P. W. Leenhouts	-	2	-	1
<i>N. ramboutan-ake</i> (Labill.) P. W. Leenhouts	26	89	4	2
<i>N. reticulatum</i> Radlk.	8	9	-	-
<i>N. subfalcatum</i> Radlk.	-	9	3	-
<i>N. uncinatum</i> Radlk. ex. P. W. Leenhouts	18	28	3	-
Total	104	255	26	11

Nephegium ramboutan-ake has the highest number of specimens collected while *N. laurinum* has the least number of specimens collected which were just three specimens.