THE DISTRIBUTION OF THE CARNIVOROUS PLANT *NEPENTHES* (NEPENTHACEAE) IN MARAI PARAI, KOTA BELUD, SABAH, MALAYSIA

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ABSTRACT

Nepenthes (Nepenthaceae), a carnivorous plant, is notable for its character and carnivory constancy. This genus provides an excellent structure for studying the taxonomy and evolution of *Nepenthes* in relation to their functions and habitats. However, because of the complexity of *Nepenthes* evolution and taxonomy based on morphological traits, it is challenging to resolve these issues based on phylogenetic relationships. There are approximately 20 *Nepenthes* species in Sabah, seven of which are endemic and can be found in protected areas, such as Kinabalu Park. In this study, we examined *Nepenthes* species and their distribution patterns in Marai Parai, Kota Belud, Sabah. Elevation levels, humidity, and temperature were recorded to determine and investigate the relationship between the distribution and environmental factors of *the Nepenthes* species. *Nepenthes* species in Marai Parai were identified morphologically together with their distribution patterns, and a correlation analysis between elevation, humidity, and temperature was performed. There was no significant relationship between humidity and temperature with elevation; however, there was a significant relationship between humidity and temperature in Marai Parai. The expected findings could be applied as a reference in the future to increase the potential and management strategies for this carnivorous plant and to allow more research into how climate change affects the number of *Nepenthes* species and their spatial distribution patterns.

Keywords: *Carnivorous plant, distribution pattern, environmental factors, protected areas.*

INTRODUCTION

Carnivorous plants obtain supplementary nutrients which are scarce or unavailable in the soil by trapping and digesting animals. *Nepenthes* has carnivorous syndromes, where it must be able to absorb nutrients from dead animals juxtaposed to their surfaces, and thereby obtain some increment in fitness in terms of increased growth, chance of survival, pollen production, or seed set. The plant must have some unequivocal adaptation or resource allocation, the primary result being the active attraction, capture, and/or digestion of prey (Clarke & Moran, 2016).

Marai Parai is a small place located at the top on the saddle between two hills which very steep slopes where, the elevation of Marai Parai was from 900 m.a.s.l. up to 1,700 m.a.s.l. The forest condition is similar to that of Mount Tambayukon, where it consists of grassy (graminoid) vegetation and dense upper montane shrubs (Wood & van der Ent, 2012). These conditions allow some of plant species like Nepenthaceae and Orchidaceae to be found. Endemic species of *Nepenthes* can be found in ultramafic vegetation and soil. The last updated discovery of *Nepenthes* in Marai Parai was in 2005 by Romuald Anfraix. He discovered *N. edwardsiana*, *N. tentaculata*, *N. rajah*, and *N. burbidgeae* together with few Orchidaceae and Droseraceae species.

Marai Parai is considered is one of the ultramafic mountain that soils derived from ultramafic bedrock are characterised by relatively high concentrations of trace elements (Ni, Co, Cr, Mn), major cations imbalances (high Mg:Ca molar quotients) and nutrient deficiencies (K, P). The 'edaphic factor' relates to the influence of the soil physical and chemical properties on the ecology and plant distribution. Ultramafic soil has a lower stature, lower biomass, higher levels of endemism, and distinct species composition. Elevation plays a role in influences the distribution of plant species within the elevation range. Vegetation on ultramafic soils is often shorter than that on non-ultramafic soils because different locations have different overall heights and associated climatic effects (van der Ent et al., 2016).

METHODOLOGY

Study Site

The expedition started on 07th October 2023 to 13th October 2023. The starting point of this expedition is at Kiau Nuluh Basecamp (880 m a.s.l.), which then stops for a night at Nunuk Camp (1, 215 m a.s.l.), and continues all the way to the Marai Parai Camp (1, 652 m a.s.l.). All sampling was performed around

the Marai Parai Camp site with a starting elevation of 1, 500 to 1, 700 m a.s.l. 34 plots of *Nepenthes* population are discovered during expedition.

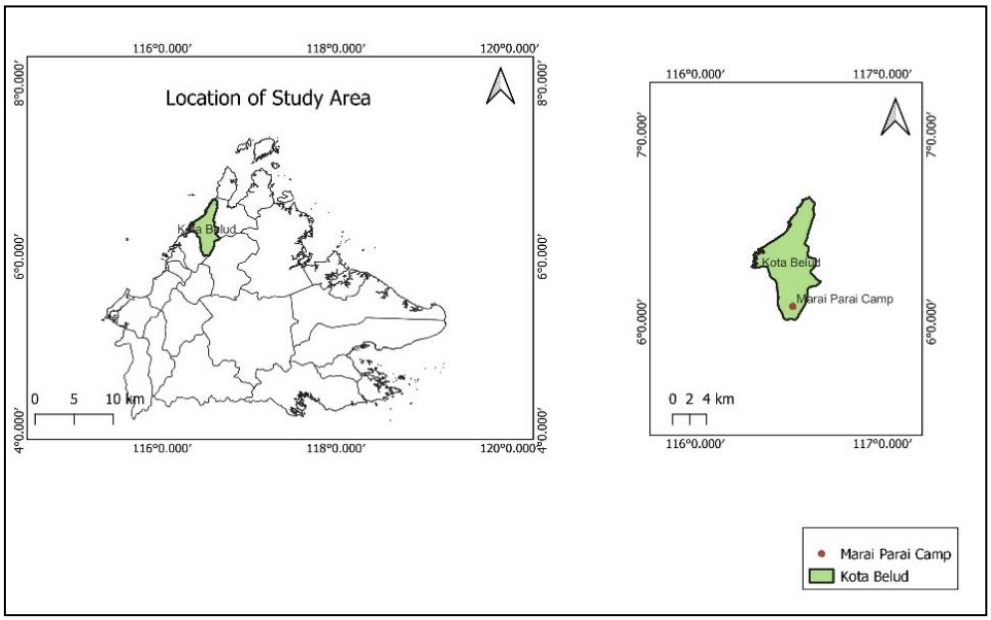

Figure 1. Location of study area.

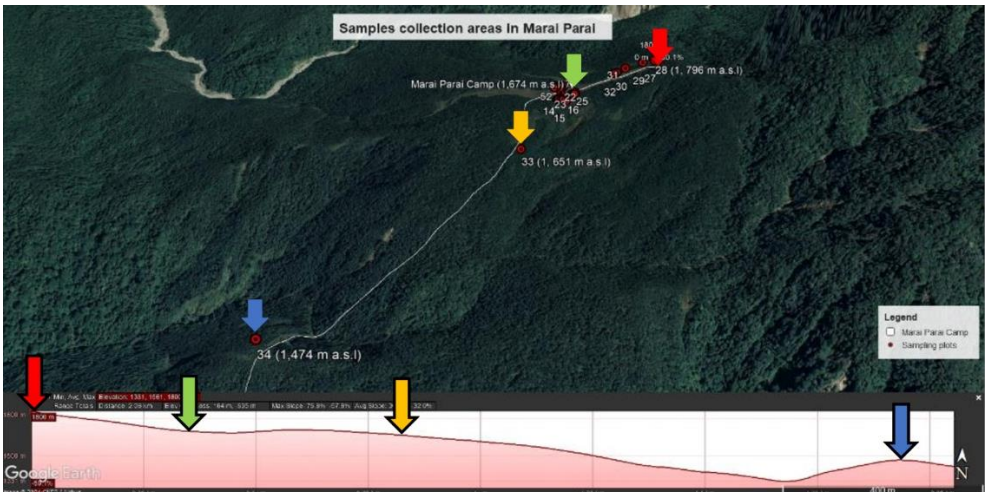

Figure 2. Sampling areas of Marai Parai.

*Notes: Red arrow = 1,796 m a.s.l.; Green arrow = 1,674 m a.s.l.; Orange arrow = 1,651 m a.s.l.; Blue arrow = 1, 474 m a.s.l.

Samples, and Data Collection

Random sampling was conducted based on the elevation level within 5 meters (m) radius circular plot of each *Nepenthes* species, approximately 5 m parallel

to the hiking trails. Approximately three to five young leaves of different *Nepenthes* species were collected that are brought back to the laboratory for the DNA identification are kept tightly in Ziplock bags with silica gel to help preserve the samples by rapidly drying them and preventing DNA degradation (Chase et al., 1991). Additional data was gathered and recorded, such as coordinates, elevation levels, humidity, temperature and other plant species-associated with *Nepenthes* plot discovered within a 10 m radius circular plot (Wahab et al., 2021).

Identification of *Nepenthes* Species and Samples Storage

Nepenthes and other plant species discovered at the Marai Parai were morphologically identified by samples collected and photographed with the help of Sabah Park guidance and ranger. We then referred to published books and journals, such as *Nepenthes* of Borneo by Clarke et al. (1997) and A Guide to The Pitcher Plants of Sabah by Clarke (2001).

The leaf samples taken to the laboratory were then crushed into powder using a mortar and pestle with liquid nitrogen. The powdered leaf samples were stored in a -80°C freezer for long-term storage. Later, these samples were used for molecular analyses, such as DNA extraction, Polymerase Chain Reaction (PCR), fragment analysis or sequencing, alignment, and phylogenetic analysis (Bunawan et al., 2017).

Data Analysis

R Studio software (Version 2023.12.1+402) was used for the statistical analysis of the correlation between elevation levels and microclimate data, specifically humidity (Rh%) and temperature (°C). A map of the study area was created using the Geographic Information System (GIS) software, QGIS (Version 3.26.3), along with Google Earth Pro.

RESULTS AND DISCUSSION

Nepenthes Species Distribution and Habitat in Marai Parai

Nepenthes species are highly adaptable and can grow from sea level, even within the spray zone, up to approximately 3,400 meters above sea level. These plants are generally categorized into two groups based on their elevation: lowland species (below 1,000 m a.s.l.) and highland species (above 1,000 m a.s.l.). Lowland species typically thrive in open habitats such as secondary bushes, roadside embankments, forest edges, swampy areas, heath forests, peat swamp forests, and gaps in lowland dipterocarp forests. In contrast, highland species are most commonly found in montane rainforests.

However, in rare cases, such as with *N. tentaculata*, they can also grow in gaps or open forest areas (Adam et al., 1992).

The distribution of plant species in Marai Parai is influenced by the unique forest environment, with the Nepenthaceae family being one of the key groups present (Anfraix, 2015). During a recent scientific expedition, 34 of *Nepenthes* populations were identified, revealing six distinct species (Plate 1: a to f), as detailed in Table 1 and illustrated in Figure 3. These six *Nepenthes* species were found at elevations ranging from 1,400 m a.s.l. to 1,800 m a.s.l. in the Marai Parai area. They are primarily located in open areas under direct sunlight, often growing in close proximity to one another such as *N. rajah* with *N. tentaculata* and *N. zakriana* with *N. rajah*. *N. edwardsiana* was first discovered near a campsite, growing on the ground at 1,654 m a.s.l., with two additional specimens found climbing large trees at elevations of 1,756 m a.s.l. and 1,776 m a.s.l. *N. stenophylla* was the only species found growing between rocks in an open area at 1,662 m a.s.l.

Table 1. *Nepenthes* species collected during scientific expedition with their elevation ranges, number of plots and locations discovered.

No.	*Nepenthes* species	Elevation levels ranges, m a.s.l.	No. of populations	Locations
1.	*N. burbidgeae*	1,400 – 1,600	2	Marai Parai and Kinabalu Sambau
2.	*N. edwardsiana*	1,500 – 1,700	3	Marai Parai
3.	*N. rajah*	1,500 – 1,600	15	Marai Parai
4.	*N. stenophylla*	1,500 – 1,600	1	Marai Parai
5.	*N. tentaculata*	1,500 – 1,700	8	Marai Parai
6.	*N. zakriana*	1,500 – 1,600	5	Marai Parai
Total populations			**34**	

The most commonly encountered species were *N. rajah* and *N. tentaculata*. *Nepenthes rajah* was predominantly found between 1,400 m a.s.l. and 1,700 m a.s.l., while *N. tentaculata* was located between 1,500 m a.s.l. and 1,700 m a.s.l. Both species are known for their resilience, thriving in harsh climates and conditions, such as hot and dry environments (Clarke, 2002). *N. burbidgeae* was observed at two elevation ranges: 1,400 m a.s.l. to 1,500 m a.s.l. and 1,500 m a.s.l. to 1,600 m a.s.l. Additionally, immature plants of possible natural hybrids, such as *N. rajah* × *N. zakriana* and *N. rajah* × *N. tentaculata*, were found between 1,500 m a.s.l. and 1,600 m a.s.l., indicating the potential discovery of new natural hybrids. Other plant species, including

Drosera sp. and wild orchids, were also found growing alongside *Nepenthes* in these areas (Table 2).

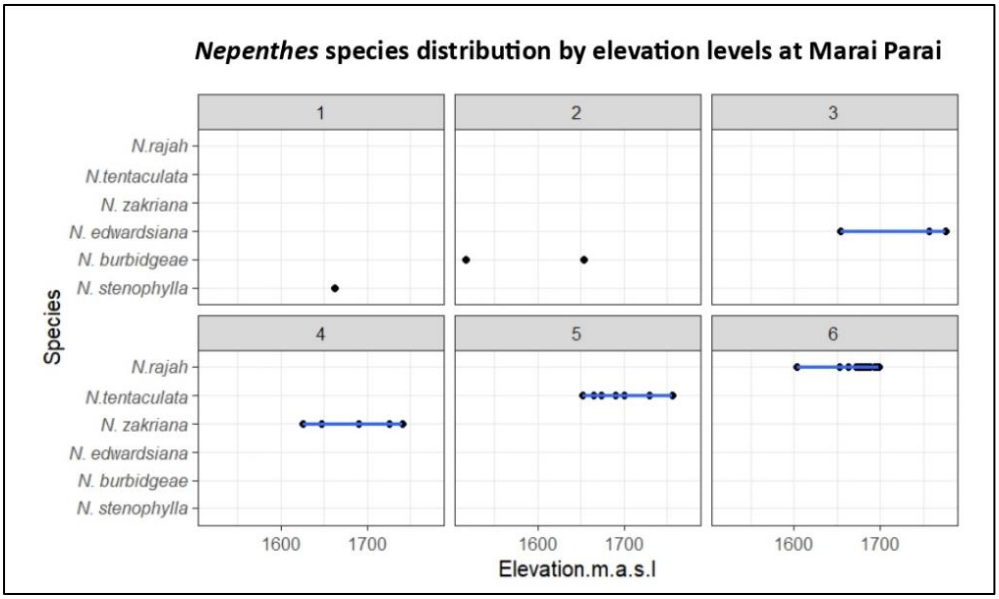

Figure 3. Distribution of *Nepenthes* species discovered based on elevation levels.

Table 2. Marai Parai forest types and associated plant species.

Forest types	Family	Plant species associate
Graminoid Shrub, Mossy Forest and Montane Forest	Acoraceae	*Acorus calamus* L.
	Droseraceae	*Drocera* sp. L.
	Eriocaulaceae	*Eriocaulon* sp. L.
	Gleicheniaceae	*Dicranopteris* sp. Bernh.
	Leucobryaceae	*Campylopus* sp. Brid.
	Melastomataceae	*Melastoma* sp. Blume
	Orchidaceae	*Dendrobium kinabaluensis* Ridl.
		Dilochia cantleyi (Hook.f.) Ridl.
		Spathoglottis gracilis Rolfe ex Hook. f.
	Pinaceae	*Pinus* sp. L.
	Polypodiaceae	*Melpomene* sp. A.R.Sm. & R.C.Moran

Microclimate Data on *Nepenthes* Distribution in Marai Parai

Climate plays a fundamental role in delimiting the niche of any given organism; *Nepenthes* is no exception. Figure 4 shows the mean relative humidity (Rh%) and mean temperature (°C) for the 34 populations of the

Nepenthes distribution in Marai Parai. The humidity was highly significantly related (r = -0.88, $p < 0.00$) to the temperature, where the higher the humidity, the lower the temperature in Marai Parai with the strong negative correlation between these variables. Graph a) shows a 95% confidence interval (CI), where the grey zone is narrowed close to the regression line of the mean relative humidity (Rh%) and mean temperature (°C), indicating a precise relationship between these variables.

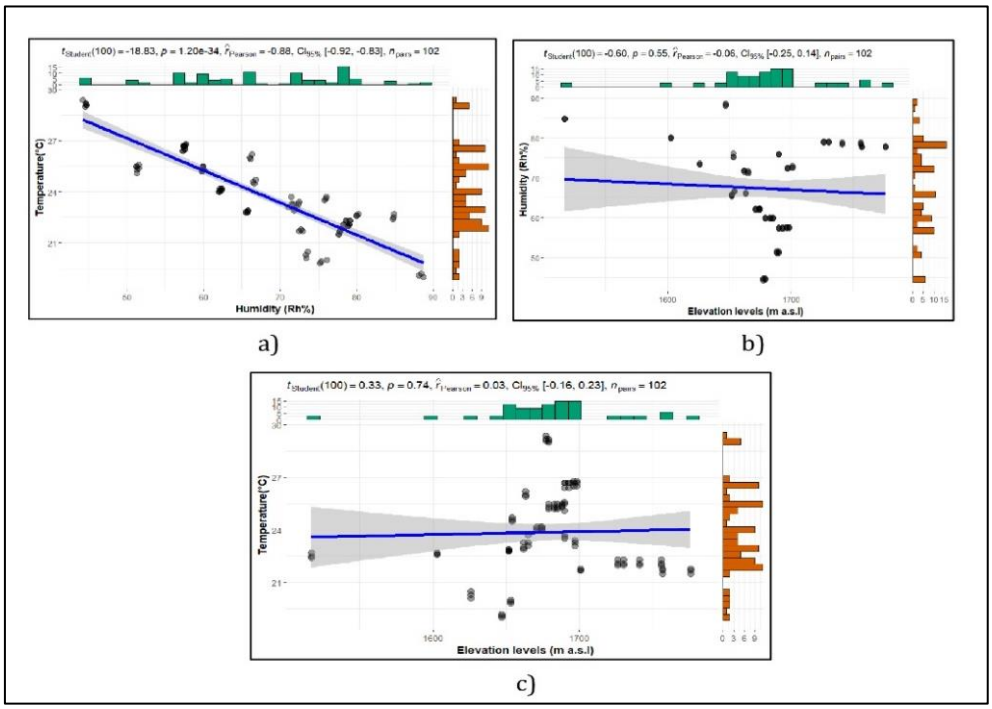

Figure 4. Microclimate mean data of Marai Parai. a) Humidity (Rh%) versus temperature (°C); b) Elevation levels (m a.s.l.) versus Humidity (Rh%); c) Elevation levels (m a.s.l.) versus temperature (°C).

According to Montesinos-Navarro et al. (2011), the higher the elevation levels, the lower the temperature; however, the results obtained from this study indicate that the temperature is not significantly related (p= 0.74) to the elevation levels in Marai Parai, where the higher the elevation levels, the higher the temperature and has extremely weak positive relationship (r = 0.03). Temperature does not affect *Nepenthes* growth in Marai Parai, because *Nepenthes* can withstand harsh environments in tropical montane forests (van der Ent et al., 2016). *Nepenthes* growing in this area might be influenced by the plant growth habits, light intensity, and moss cover. Many *Nepenthes* species tend to grow in clumps and live in open, stunted forests with nutrient-poor acidic soils that are seasonally soggy (Damit et al., 2017).

Humidity in Marai Parai also was not significantly related (p = 0.55) to the elevation levels, where the higher the elevation levels, the lower the humidity in Marai Parai with weak negative relationship (r = -0.06). Both graphs b) and c) show that the grey zone is wider, indicating that the relationship between elevation levels with humidity and temperature is less precise, and the outliers could influence the relationships. This might be due to the sudden light rain and direct exposure of sunlight at Marai Parai from 1,600 m a.s.l. to 1,700 m a.s.l. Climatic conditions in tropical montane habitats differ markedly in a number of respects from those encountered in the lowlands. As altitude increases, the conditions become cooler and wetter, and diurnal fluctuations in air temperature become much more extreme. However, during periods of clear sky, tropical montane forests are exposed to direct sun compared to lowlands because of the thinner atmosphere (Bruijnzeel & Veneklaas, 1998; Clarke & Moran, 2016).

CONCLUSION

In conclusion, Marai Parai hosts a rich distribution of *Nepenthes* species, with *N. rajah* and *N. tentaculata* being particularly widespread. The potential exists for new natural hybrid species to emerge, provided the natural environment remains undisturbed. While the study found no significant relationship between humidity, temperature, and elevation, there was a notable correlation between humidity and temperature. Future research will focus on the analysis of molecular and soil properties.

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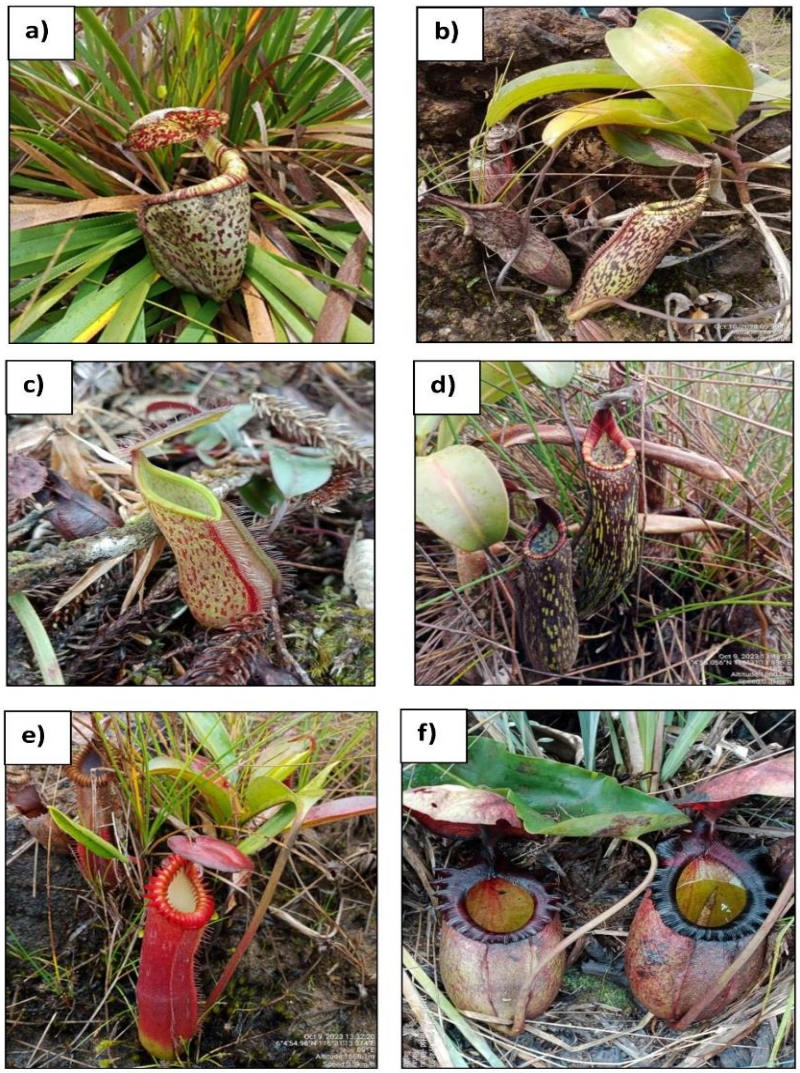
APPENDIX

Plate 1: Six distinct *Nepenthes* species found in Marai Parai.



a) *Nepenthes burbidgeae* Hook. f. ex Burb.
b) *Nepenthes stenophylla* Mast.
c) *Nepenthes tentaculata* Hook. f.
d) *Nepenthes zakriana* (J.H.Adam & Wilcock) J. H.Adam & Hafiza
e) *Nepenthes edwardsiana* H.Low ex Hook. f.
f) *Nepenthes rajah* Hook. f.