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Morphology and pitcher's color *Nepenthes* in Batu Lubang Sibolga Area, North Sumatra Province, Indonesia

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Abstract. *Tarigan MRM, Aziz S, Tanjung IF, Pary C, Adlini MN, Jayanti UNAD, Ardianto, Ulfa AY. 2023. Morphology and pitcher's color* Nepenthes *in Batu Lubang Sibolga Area, North Sumatra Province, Indonesia. Biodiversitas 24: 1953-1962.* The study's objective was to identify the size, color, and shape of a pitcher of *Nepenthes* found in the Batu Lubang Sibolga region. Purposive sampling is used as part of an exploratory approach in this study. Plot-based *Nepenthes* observation was conducted in the Sitahuis Sub-district, Central Tapanuli District, North Sumatra Province, Indonesia, to examine pitcher morphology and color. The results showed two species of *Nepenthes*, namely *N. gracilis* Korth and *N. eustachya* Miq, with two types of pitchers each, namely the lower and upper pitcher. The morphology of the *Nepenthes* pitchers has an almost similar shape but differs in the size of the pitcher circumference, where the lower pitcher is smaller than the upper pitcher. The bottom pitcher of *N. gracilis* has redwood (45%), and the upper pitcher is light green (55%), according to the proportion of observations of the color of the lower and upper pitchers of these two species. While the upper pitcher of *N. eustachya* is green with red dots (70%), the lower pitcher is light reddish green (30%). According to the study's findings, *Nepenthes* in the Batu Lubang Sibolga area required conservation intervention to preserve this species.

Keywords: Batu Lubang Sibolga area, morphology, *Nepenthes,* pitcher's color

INTRODUCTION

Nepenthes is one of the endemic plant species distributed throughout Indonesia. *Nepenthes* are widely distributed in Indonesia, with 32 species recorded in Kalimantan between 2005 and 2014, 29 species in Sumatra, ten Sulawesi, nine in Papua, four in Maluku, and two species in Java. (Handayani 2017; Cheek and Jebb 2013; Dančák et al. 2022; Tarigan et al. 2021). *Nepenthes* also spread from the east of Madagascar to New Caledonia, southern China, and several small remote islands in the Western Pacific and Malesiana (Gaume et al. 2016; Rizqiani et al. 2018; Mansur et al. 2021; Nerz and Koch 2018; Tarigan et al. 2021; Yulita and Mansur 2012).

Nepenthes is a plant that belongs to the carnivorous plant of the family Nepenthaceae. This plant has a pitcher in the leaf apex (Clarke and Moran 2015; Dančák et al. 2022; Bauer et al. 2012; Rizqiani et al. 2018; Robinson et al. 2019); a pitcher is a modification of the tip of the leaf (Gilbert et al. 2018; Schwallier et al. 2020). According to Bauer et al. (2012), almost all species of *Nepenthes* produce two kinds of pitchers, namely lower and upper pitchers. The lower pitcher is formed by sapling leaves or stems that are still rosettes. These pitchers are generally located near or attached to the ground. Sometimes the lower pitcher is located on the upper stem during the growth of the stem when still a rosette. The upper pitcher is produced by the leaves on mature stems or stems that have grown up. *Nepenthes* is unique because it has leaves that have been modified into the pitcher that function to attract, trap, and digest small animals such as insects as additional nutrients (Dančák et al. 2022; Bauer et al. 2015; Bazile et al. 2015; Buch et al. 2015; Pavlovič and Saganová 2015; Tarigan et al. 2021).

Nepenthes has different ways of attracting prey. According to Bauer et al. (2015), Farré et al. (2015), and Kocáb et al. (2021), *Nepenthes* uses nectar as a food source for visitor insects. The *Nepenthes* pitcher also gives off a certain scent to attract prey (Gaume et al. 2016; Tarigan et al. 2021). In addition, *Nepenthes* also uses the form of the pitcher (Gaume et al. 2016), pitcher's color (Pavlovič & Saganová 2015; Gaume et al. 2016), and environmental factors to attract prey (Baby et al. 2017; Vong et al. 2021).

The pitcher's shape, size, and color are important in attracting prey (Gaume et al. 2016; Peng and Clarke 2015; Stephens et al. 2015). However, Buch et al. (2015) and Gilbert et al. 2018 reported no relationship between pitcher size and color and prey capture. Furthermore, Hale et al. (2020) found no correlation between species richness and pitcher color in *Sarracenia purpurea*. Furthermore, Foot et al. (2014) reported that a red coloration did not meet a prey attraction function or serve as advantageous camouflage in

Drosera rotundifolia (Droseraceae). Besides that, Dančák et al. (2022) reported that prey was attracted to the red pitcher of *N. pudica, N. hirsuta, N. hispida, N. leptochila*.

Nepenthes are fairly common in Sibolga, particularly in the Batu Lubang region, but nothing is known about their variety. The form and color of the pitcher can be used to identify the variety of *Nepenthes*, while the pigment produced by each pitcher causes the pitcher's color variance (Handayani and Hadiah 2019). The purpose of this study is to describe the size, color, and shape of the *Nepenthes* pitcher found in the north Sumatra province's Batu Lubang Sibolga region. Therefore, further research is anticipated to benefit from the findings of this study.

MATERIALS AND METHODS

Study area

This research was conducted using *purposive sampling,* where the species of *Nepenthes* were found. *Purposive sampling* is a quadratic method to determine the presence of species in a community; this method is a vegetation analysis technique using sample plots or strips (Gay et al. 2012). This research was carried out from March to April 2022. The research location was around the Batu Lubang Sibolga area, Sitahuis Sub-district, Central Tapanuli District, North Sumatra Province, Indonesia (Figure 1). Observations were made on six plots measuring 10 x 10 m^2 to observe the morphology and color of the pitcher's organs.

The Batu Lubang Sibolga area is a tunnel that is quite phenomenal. This tunnel is located on the Tarutung-Sibolga Cross Road, in Simaninggir Hamlet, Bonandolok Village, Sitahuis Sub-district, Central Tapanuli District, North Sumatra Province. The distance between Sibolga City and Batu Lubang is around ± 10 km. The distance between the city of Medan to the Batu Lubang area is about ± 335 km. The location has a relatively rocky and wavy topography with a soil pH of 3-4. The average air temperature in the Batu Lubang area is 24-28°C during the day and drops to 15-20°C at night, humidity is around 69.9-84.5%, and the average rainfall is 309.98 mm/year. Batu Lubang is a term familiar to the people of Central Tapanuli District, consisting of two stone tunnels that must be passed while crossing the Sibolga Tarutung road. This stone Lubang was built because, in 1930, of the forced labor from Dutch colonialism in Indonesia. The Dutch forced the people to carve two giant stones to facilitate transportation to Tarutung, North Tapanuli District, North Sumatra Province. It also transported natural products from Batak soil that the Dutch wanted to take. The other tunnel measured about 10 meters. The research location can be seen in Figure 1.

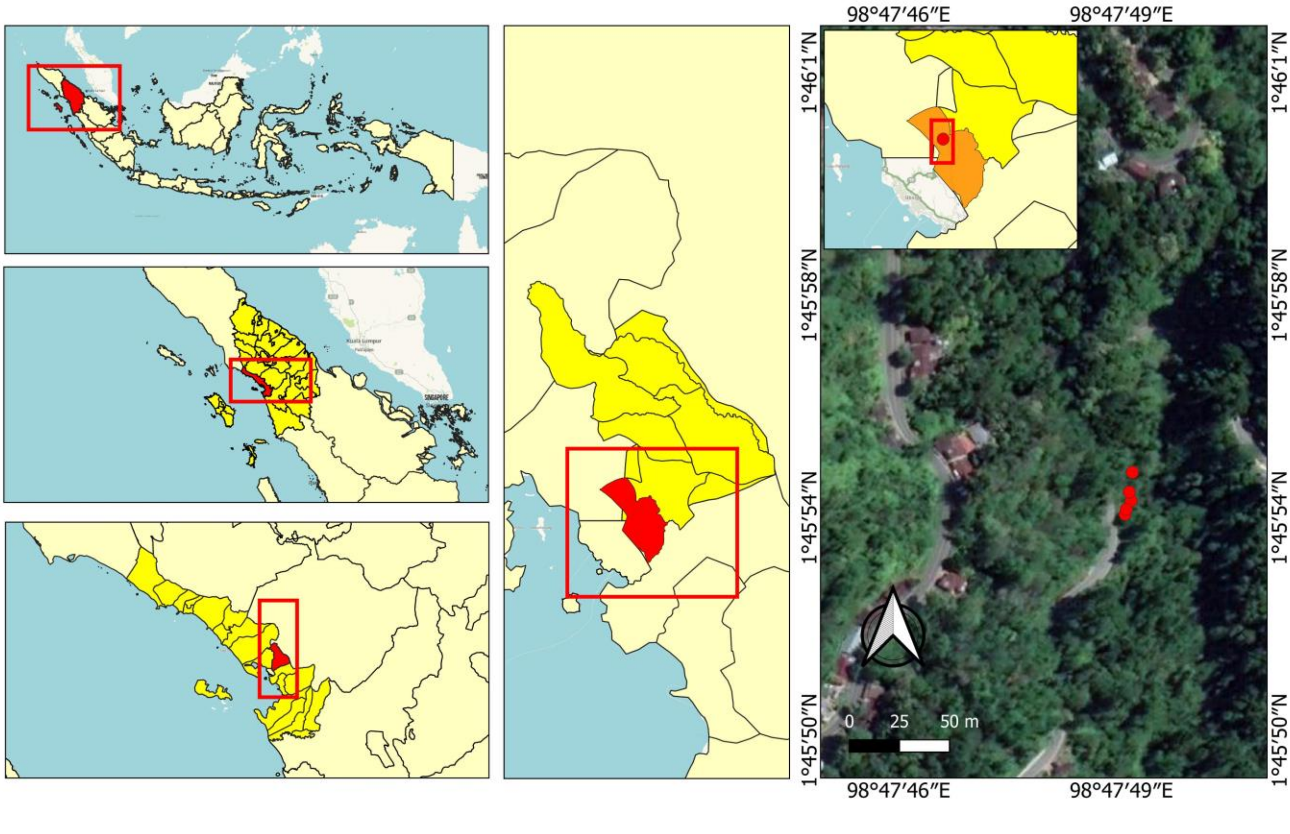

Figure 1. Map of *Nepenthes* location in Batu Lubang Sibolga Area, North Sumatra Province, Indonesia

Procedures

The pitcher morphology observation was carried out on 57 samples (27 lower and 30 upper pitchers) visually or with a camera. In contrast, the measurements of the pitcher and its parts were done using a ruler or tape measure. The pitcher morphology observation was carried out by measuring and recording the parts of the pitcher as follows: the tendency length and the length of the tendrils were measured from the tip of the lamina to the lowest part of the pitcher's body. Pitcher height; measuring the height of the pitcher starts from the lowest part of the pitcher's body (at the point of attachment of the tendrils) to the end of the peristome. The upper and lower pitchers; the measurement of the upper circumference of the pitcher is measured at the largest part of the pitcher's upper body, while the measurement of the lower circumference of the pitcher is measured at the largest part of the lower body of the pitcher. Wingspan; wingspan measurement starts from the middle, lower, and upper of the pitcher's body. Mouth length and width; the mouth length is measured at the longest part of the mouth, while the mouth width is measured at the widest part of the mouth and the length and width of the pitcher cover. The pitcher lid length is measured at the longest part of the lid, while the lid width is measured at the widest part.

The color could be seen on every pitcher area (vine, pitcher body, wing, peristome, and cover). Primary colors come first in the process of color observation, which is subsequently followed by secondary colors. In this study, the color that covers the pitcher most is called the primary color, while the color that covers the pitcher least is called the secondary color. If a section of the pitcher is covered by only one dominant color, the color of that section of the pitcher is named a single color, such as green or dark red. If there is more than one color, the pitcher is named after the color combination, such as purplish red. After that, the prey that entered the *Nepenthes* pitcher was identified. The family of preys was identified in the Animal Systematics Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Sumatra Utara (USU), Medan, North Sumatra, Indonesia. In this laboratory, the main characteristics of each prey specimen were determined. Then, perform environmental parameter measurement activities such as air temperature, soil pH, and humidity.

RESULTS AND DISCUSSION

***Nepenthes* abiotic environmental data**

Based on the research results conducted in the Batu Lubang Sibolga area, North Sumatra Province, there were two *Nepenthes* plants, namely *Nepenthes gracilis* Korth and *Nepenthes eustachya* Miq. *Nepenthes* environmental data results *Nepenthes* in the area can be seen in Table 1.

Table 1 shows the results of observations of environmental factors in the habitat of *N. gracilis* and *eustachya* in Batu Lubang Sibolga with six plots, namely plot 1 with temperature measurement: 22ºC, soil pH 5.3, humidity 92%, plot 2 (25ºC, 5.5, 93%), plot 3 (25ºC, 5.8, 91%), plot 4 (23ºC, 5.8, 90%), plot 5 (23ºC, 5.4, 92%) dan plot 6 (23ºC, 5.2, 91%). This location's temperature and humidity conditions are within the normal range of growth of *Nepenthes*. Nainggolan et al. (2020) stated that *Nepenthes* could live in an air temperature range of 20-32ºC and air humidity ranging from 67-93%. Rizki et al. (2021) also revealed that *Nepenthes* lives at an air temperature of 28-38ºC and an air humidity of 62-98%. At the same time, this location's soil is acidic and poor in nitrogen. This habitat follows the opinion of Cheek et al. (2019), which states that *Nepenthes* can generally live and develop in large numbers on nutrient-poor soils, especially nitrogen deficiency.

Morphological parameters *Nepenthes*

Pitcher morphology N. gracilis and N. eustachya.

The results of observations showed that these two species of *Nepenthes* produced two kinds of pitcher, namely the lower and upper. These two types of pitchers have almost the same shape: the lower is rounded, then cylindrical towards the upper, then widens to the peristome (lips). However, the sizes and colors of the two types of pitchers vary. The lower pitcher is generally produced by saplings, young plants, or stems that are still rosettes. Mature plants produce the upper pitcher or stem whose segments have elongated. The lower pitcher is generally smaller than the upper. The pitcher morphology of *N. gracilis* and *N. eustachya* is described as follows.

The morphology of the pitcher of *N. gracilis* consists of 2 parts: the lower and upper pitcher. (i) The lower pitcher characteristic of *N. gracilis* with tendrils 0.4-7 cm long, straight, mostly reddish brown. The lower pitcher is ovoid at the lower and cylindrical at the upper the pitcher's height is 2.2-7 cm. The upper circumference is 1-7 cm, and the lower is 2.2-7 cm. The lower pitcher usually has a pair of wide wings measuring 0.2-0.3 mm. The mouth of the pitcher is round to ovoid, slightly oblique, 0.7-1.7 cm long, and 0.6-1.6 cm wide. The peristome is narrow, and the upper surface is flat; the inner edges of the teeth are slightly rough, while the outer edges are rather smooth. The lid is round to ovoid, 0.7-1.7 cm long, and 0.6-1.7 cm wide. At the base of the pitcher lid is a spur 0.1-0.7 cm long.

Table 1. *Nepenthes* abiotic environmental data in Batu Lubang Sibolga Area, North Sumatra Province, Indonesia

Type of *Nepenthes*	Parameters	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
N. eustachya & N. gracilis	Air temperature	22°C	25°C	25°C	23°C	23°C	23°C
	Soil pH	5.3	5.5	5.8	5.8	5.4	5.2
	Humidity (%)	92%	93%	91%	90%	92%	91%
	Coordinate	1°45'54.74" S 98°47'49.38" E	1°45'54.53" S 98°47'49.34" E	1°45'54.42" S 98°47'49.33" E	1°45'54.14" S 98°47'49.28" E	1°45'54.06" S 98°47'49.26" E	1°45'54.28" S 98°47'49.36" E
	Height (m asl)	340 m asl	338 m asl	328 m asl	327 m asl	315 m asl	310 m asl

(ii) Upper pitcher characteristic *N. gracilis*. The upper pitcher tendrils are 8.3-20 cm long, straight, and mostly yellowish. The upper pitcher of *N. gracilis* is ovoid at the lower and cylindrical at the upper, 4.2-12 cm high. The upper circumference of the pitcher's body is 2.2-8 cm, and the lower is 4.2-12 cm. A pair of wings on the upper pitcher is reduced its shape only resembles a longitudinal line from below the peristome to the base of the pitcher's body. The mouth is round to ovoid, slightly slanted, 0.8-2.7 cm long, and 1.2-2.7 cm wide. The peristome is narrow, the upper surface is flat, and the inner edges of the teeth are slightly rough, while the outer edges are rather smooth. The lid of the pitcher is round to ovoid, 1.3-7 cm long, and 0.7-3 cm wide. At the base of the pitcher lid is a 0.1-2 cm long spur.

The morphology of the pitcher of *N. eustachya* consists of 2 parts: the lower and upper pitcher. (i) The lower pitcher characteristic of *N. eustachya* has a lower pitcher tendril 0.4-8 cm long, straight, and mostly yellowish red. The lower pitcher is shaped like a wasted jug with a wide mouth. The pitcher's height is 5-8 cm. The upper circumference of the pitcher is 1-8 cm, and the lower is 2.2-8 cm. The lower pitcher usually has a pair of broad wings measuring 0.2-0.5 mm. The mouth is orbicular in shape, the peristome is tight and very narrow, 3-6 cm long and 3-8 cm wide. The lid of the pitcher is orbicular in shape, 3-6 cm long, and 3-8 cm wide. At the base of the pitcher lid is a 0.3-0.7 cm long spur. (ii) The upper pitcher characteristic of *N. eustachya* with upper pitcher tendril length is 10.5-25 cm, straight, brownish yellow. The upper pitcher's waist is cylindrically shaped with a wide mouth height of 8-15 cm. The upper circumference of the pitcher is 2.5-10 cm, and the lower is 4.5-15 cm. The mouth of the pitcher is orbicular in shape, slightly oblique, 1.2-2.8 cm long, and 1.5-2.6 cm wide. The peristome is narrow, with a flat upper surface and wavy edges. The lid of the pitcher is orbicular in shape, 6-12 cm long, and 5.8-8.5 cm wide. At the base of the pitcher lid is a spur 0.2-0.6 cm long. (iii) Based on the morphological measurements of the lower and upper pitchers of *N. gracilis* and *N. eustachya*, the lower pitcher sizes were smaller than the upper pitcher. That includes the size of the lower pitcher, most smaller than the upper pitcher. This result is different from the size of the lower ring in other types, where the lower circumference of the upper pitcher is usually smaller. That is due to the number of plants found mostly in saplings or rosette plants that produce small and slender pitchers. In some *Nepenthes*, the size of the lower circumference of the lower pitcher is generally larger than the upper. At least two reasons are considered strong in supporting this statement, namely the location and function of the lower pitcher. The first reason is that the lower pitcher is often attached to the ground. Despite its larger size, the pitcher remains strong when strong winds hit it. The second reason is the function of the lower pitcher to catch insects that live on the ground surface. Therefore, the larger pitcher size can accommodate more insects (Buch et al. 2015; Dančák et al. 2022; Tarigan et al. 2021; Wang and Zhou 2014). On the other hand, the upper pitcher size is generally smaller so that it is lighter so that if exposed to the wind, the pitcher will not fall easily (Cheek et al. 2019; Handayani and Hadiah 2019). Based on the measurements of mouth length, mouth width, cap length, and cap width in *N. gracilis* and *N. eustachya*, it was found that there were variations in the size of the mouth and lid of the pitcher. The mouth of the lower pitcher of *N. gracilis* and *N. eustachya* was narrower than the upper following its function, the lower pitcher is to catch insects on the ground (Dančák et al. 2022; Mansur et al. 2022). For example, the bug will crawl up the pitcher to reach the top (mouth or lid) (Gaume et al. 2016). Although the mouth and lid are small, insects can still access the pitcher's upper portion (Handayani and Hadiah 2019). On the other hand, the pitcher's large mouth enables more capture because the upper pitcher is used to catch flying insects (Gaume et al. 2016). The upper pitcher's lid was larger and wider than the one on the lower. It generates nectar on the lower part of the lid of the top pitcher, which is utilized to draw insects (Bauer et al. 2015). The lower surface of the lid will likewise be wider if the lid is wider (Peng and Clarke 2015). The amount of cover surface has an impact on the yield of nectar generated (Rizqiani et al. 2018). As a result, the capture will also increase as the amount of nectar produced increases the number of visiting insects (Handayani 2017).

Pitcher's body color of *N. gracilis* and *N. eustachya*

The most interesting part of the pitcher's organ is the pitcher's body. This section has different shapes, colors, and sizes for each type of *Nepenthes* (Handayani and Hadiah 2019; Schwallier et al. 2020; Tamizi et al. 2020). The pitcher's inside body is divided into two parts, namely the wax zone and the digestive zone (Wang and Zhou 2014). The wax zone is the upper part of the pitcher opening (inner pitcher body), directly under the lid, until it borders the digestive zone (Schwallier et al. 2020). This part contains cells covered by slippery wax so that prey falling into the pitcher hole is difficult to climb up again. Beneath the waxy zone is the digestive zone, filled with fluids that contain enzymes to kill and destroy prey (Wang et al. 2018). Finally, the pitcher's outside body is covered in various colors (Biteau et al. 2013; Dkhar et al. 2020; Scharmann et al. 2013; Wang and Zhou 2014). The results of observing the color of the pitcher body on the lower and upper pitcher are presented in (Figure 2).

The lower and upper pitchers are shown on *N. gracilis*. The lower pitcher's (6 types) *N. gracilis* pitcher color variants are superior to those of the upper pitcher (5 types). The upper pitcher of *N. gracilis* is light green, while the lower pitcher is redwood. There are also two different varieties of pitchers, known as the lower and higher, based on observations of the *N. eustachya* pitcher. The *N. eustachya* pitcher's color variety in the upper pitcher was greater (5 types) than in the lower (3 types). The lower pitcher of *N.eustachya* is light reddish green, while the upper pitcher is green with red spots (Figure 2).

Figure 3 shows observations as a percentage of the color of the lower and upper pitchers of *N. gracilis* and *N. eustachya*, which are the lower pitcher of *N. gracilis* with the redwood (45%) and the upper pitcher is light green

(55%). While the lower pitcher of *N. eustachya* is light reddish green (30%), and the upper is green with red spots (70%).

Table 2 summarizes observations of 168 prey belonging to three families (86 trapped in the *Nepenthes* lower pitchers and 82 trapped in the upper). Culicidae was found in the lower pitchers of *N. gracilis* and the lower and upper pitchers of *N. eustachya*. Next, Formicidae was found in the lower pitchers of *N. gracilis* and the lower pitchers of *N. eustachya*. Finally, Rhyparochromidae was found in the lower and upper pitchers of *N. gracilis* and the lower and upper pitchers of *N. eustachya*. Three types of prey families are found in *N. gracilis*, and *eustachya* are the main prey of *Nepenthes.*

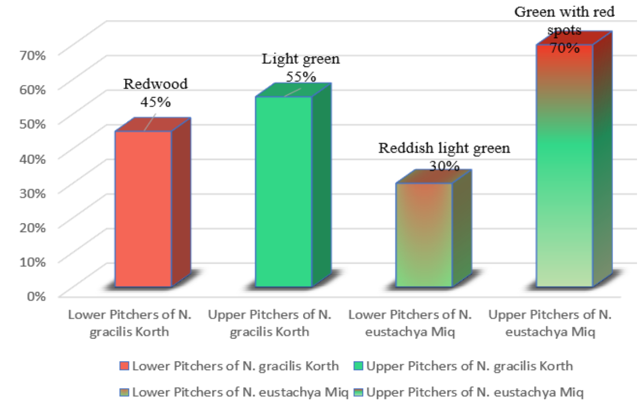

Figure 3. The percentage of observations of the color of the lower and upper pitcher of *N. gracilis* and *N. eustachya*

A B C

Figure 4. Preys trapped in the lower and upper pitchers of *Nepenthes.* A. Culicidae (lower pitcher: *N. gracilis*, lower and upper pitchers: *N. gracilis* and *N. eustachya*); B. Formicidae (lower pitcher: *N. gracilis*, lower pitcher: *N. eustachya*); C. Rhyparochromidae (lower dan upper pitchers: *N. gracilis*, lower and upper pitchers: *N. eustachya*)

Table 2. Comparison of the number of prey found in *Nepenthes* lower and upper pitchers

Family of preys	Species of *Nepenthes*	Number of preys	
		Lower pitcher	Upper pitcher
Culicidae	*N. gracilis*	12	-
	N. eustachya	18	22
Formicidae	*N. gracilis*	21	-
	N. eustachya	25	-
Rhyparochromidae	*N. gracilis*	4	32
	N. eustachya	6	28
Total		86	82

(A1) (A2) (B1) (B2)

Figure 2. Pitcher body color variations *N. gracilis* (a lower pitcher); (A1) redwood, *N. gracilis* (an upper pitcher); (A2) light green. Body color variation of pitcher *N. eustachya* (a lower pitcher); (B1) reddish light green, *N. eustachya* (an upper pitcher); (B2) green with red spots

Table 3. Prey found in *Nepenthes* lower and upper pitchers

Family of preys	Description
Culicidae	The culex specimen measures 0.5 cm in length and is all black. This Culex specimen was eventually identified as a member of the Culicidae family, which is typically cosmopolitan in appearance and ranges from 0.6-3 cm, but some are enormous at 5-6 cm in length.
Formicidae	The Hymenoptera specimen measures 0.8 cm long and has a black thorax-head and a bright red abdomen. The specimen was subsequently assigned to the Formicidae family, which typically has a body length of 0.7 to 4 cm with a color range of black to reddish.
Rhyparochromidae	The specimen has a body length of 1-3 cm and a dark brown to black coloration. Species from the Rhyparochromidae family are frequently called dung-colored aphids since these arthropods are ground-dwelling yet fly in search of food.

There are three prey families found in the lower and upper pitchers of *Nepenthes*. The body of the prey that was discovered dead is depicted in Figure 4. Culicidae species usually live in plants, whereas Formicidae species have a mutualistic symbiosis with *Nepenthes*. All Culicidae specimens were discovered in their larval and live stages. They remained in the pitcher fluid, with some demonstrating a larval developmental stage for many days. This finding is consistent with Bittleston et al. (2016), who observed a variety of prey in *Nepenthes* in the form of whole individuals, larvae, pupae, and individual body parts like antennae and wings. Since that *Nepenthes* can also act as a habitat for these invertebrates, it can be inferred that not all prey in *Nepenthes* pitchers will likely become prey (food). In addition, adult Culicidae, in particular, employ pitchers as mini-habitats for egglaying and larval breeding.

Discussion

Based on the results of research conducted in the Batu Lubang Sibolga area, North Sumatra Province, there were two types of *Nepenthes* plants, namely *N. gracilis* and *N. eustachya*. Observation of the physical condition of the *Nepenthes* environment was carried out using the plot method, which consisted of plots 1 to 6 (Table 1). The parameters measured were temperature, pH, and humidity. The temperature factor affects the growth of *Nepenthes*. According to Nainggolan et al. (2020) a good air temperature for *N. tobaica*, *N. ampullaria*, *N. gracilis*, *N. rhombicaulis*, *N. eustachya*, *N. reinwardtiana* x *spectabilis* is 20-32ºC. This research found that the air temperature in the Batu Lubang Sibolga area ranges from 22-25ºC; this means that the temperature in Batu Lubang Sibolga Area is the optimal temperature for *N. gracilis* and *N. eustachya* growth. On the other hand, soil pH is also an environmental factor that affects *Nepenthes'* growth. The optimal pH for *Nepenthes* growth is 5-7.5 (Rizki et al. 2021). The soil pH of the Batu Lubang Sibolga area is measured using a universal pH indicator. This study results, the pH of Batu Lubang Sibolga area soil ranges from 5.2 to 5.8. *Nepenthes* generally grows in fairly high humidity. According to Handayani (2017), good humidity for the growth of *Nepenthes* is 34-80%, whereas according to Nainggolan et al. (2020), optimal humidity for *Nepenthes* is 67-90%. In this study, the humidity in the Batu Lubang Sibolga area ranges from 90-93%. This humidity is very good, especially for *N. gracilis* and *N. eustachya* growth which prefer shade and high humidity.

This study indicates that the lower pitcher's size is generally smaller than the upper, including the size of the lower circumference of the bag on the lower pitcher, which is mostly smaller than the upper pitcher. This result is somewhat different from the size of the lower circumference in other types, where the lower circumference of the upper pitcher is usually smaller. That is because the number of plants found were mostly still in the form of saplings or rosette plants, which produced small and slender pitchers (Cheek 2015). In several *Nepenthes* types, the lower pitcher's lower circumference is generally larger than the upper circumference (Handayani & Hadiah 2019). Moreover, at least two reasons are considered strong in supporting this statement: the lower pitcher's location and function. The first reason is the location of the lower pitcher is often attached to the ground. Therefore, even though it is larger, the bag remains strong if strong winds hit it. Reason secondly, the function of the lower pitcher is to catch insects that live on the ground (Dančák et al. 2022). Therefore, a larger pitcher size can accommodate more insects (Gaume et al. 2016). Conversely, the size of the upper pitcher is generally smaller so that it is lighter; when the wind blows, the pitcher does not fall easily (Schwallier et al. 2020).

The samples were collected in two rock canopy structures, open space areas and inside rock canopy. The open space area is classified as light green and indicated as an open area lacking shade. We discovered a green with red spots and light reddish green in the open space area. However, the pitcher inside the rock canopy tends to be darker and redwood in the body (Figure 3). Harapan et al. (2022) mentioned that the light intensity strongly affected the color in *Nepenthes*.

Variations in the pitcher color are caused by the different colors formed by each pitcher (Handayani and Hadiah 2019). Differences in growing locations cause the difference in color variation of the pitcher color variation differences (Gilbert et al. 2018). The Batu Lubang Sibolga pit is where *Nepenthes* grows because this location has high humidity in this place, *Nepenthes* grows on open rocky cliffs. The growing location also affects the color types and the percentage of colors produced. Therefore, the more varied the places where it grows, the more varied the colors appear. The appearance of colors related to the growing location can be observed in the colors that appear on the tendrils, the pitcher's body, the pitcher's cover, and the pitcher's wings (Harapan et al. 2022). This exposure aligns with the obtained field observations that the *N. gracilis* and *N. eustachya* types have different pitcher colors. The percentage of light green in the upper pitcher of *N. gracilis* was higher than the redwood in the lower pitcher of *N. gracilis*. While the percentage of green with red spots in the upper of *N. eustachya* was higher than the light reddish green in the lower pitcher of *N. eustachya* (Figure 3). The light green color in the upper pitcher indicates chlorophyll's presence in the pitcher's body. The presence of chlorophyll in the body of the upper pitcher is because this part is still modified as a leaf to develop into a body whose main task is to carry out photosynthesis (He and Zain 2012). That is because the role of the upper pitcher with a brighter color tends to carry out photosynthesis rather than attract prey. Furthermore, the tendrils' role in photosynthesis is because it grows as of the leaf's mid-bone, where the leaves are tasked with photosynthesis (Dávila-Lara et al. 2021). In addition, the position of the *Nepenthes'* upper pitcher is directly exposed to sunlight. This presentation aligns with the statement of Kocáb et al. (2021), who revealed that the green color is closely related to the chlorophyll content, which plays a role in photosynthesis. Furthermore, Croft and Chen (2017) also revealed that chlorophyll is responsible for the appearance of the green color and is the main pigment that plays a role in photosynthesis.

Meanwhile, the lower pitcher is closely related to the anthocyanin content in plant organs. Dark colors, such as redwood, are more abundant in the lower pitcher tendrils, indicating that this section plays a greater role in attracting prey than in photosynthesis. The lower pitcher is generally located or attached to the ground surface and invites visitor insects on the ground surface to recognize the pitcher more. In addition, the position of the *Nepenthes* pitcher, which is slightly exposed to sunlight, also makes the pitcher slightly darker.

In nature, *Nepenthes* live in the open, in soil with poor nutrients and high humidity (Nainggolan et al. 2020). The observations in the field showed that *N. gracilis* and *N. eustachya* Korth grew in closed areas or areas with a thick canopy of plants. Almost all the pitchers' colors were dark, while in the open, the pitchers and leaves varied more due to the red pigment (anthocyanin). This exposure is aligned with the research of Handayani and Hadiah (2019) showed that light intensity affects the formation of anthocyanin pigments. Anthocyanins are the most common plant pigment that colors flowers, conferring orange, red, pink, and blue colors (Del Valle et al. 2019). In addition, anthocyanins are signs of nectar in parts that produce many of these pigments. That is proven by the research of Setiawan et al. (2022), who found a nectar source in the pitcher body of *N. bicalcarata*. Visitor insects obtain nectar from *Nepenthes*, while *Nepenthes* obtains a source of food from prey that falls into the pitcher hole (Handayani 2017). Research Dávila-Lara et al. (2021) also revealed that a bright color indicates the presence of anthocyanin and its content, which is higher than the chlorophyll content, indicating that the pitcher wings play a bigger role in attracting prey than in photosynthesis. The formation of more anthocyanins than chlorophyll is thought to be closely related to the nectar produced by the lower surface of the bag lid. That follows research conducted by Handayani and Prize (2019) which revealed that *Nepenthes* nectar is only found on the lower surface of the pitcher lid. Therefore, *Nepenthes* direct insect visitors to nectar sources by forming bright colors on the upper surface of the pitcher lid (Handayani 2017). That will make it easier for visiting insects to find nectar sources. Therefore, the more insects that come, the greater the possibility of plants getting prey (El-Sayed et al. 2016). The position of the bag cover in this type is right above the bag hole so that if an insect slips while taking the nectar, the insect will immediately fall into the pitcher hole (Bauer et al. 2012).

The formation of anthocyanins in the pitcher, including the body of the pitcher, is not yet known with certainty whether its function is to attract prey or only as an adaptation of plants that grow in nitrogen-deficient soil; this still requires further research (Brearley 2021; Dávila-Lara et al. 2021; Gaume et al. 2016). According to Yang et al. (2022) and Albert et al. (2015) the formation of anthocyanins in leaves is closely related to plant lack of N and P elements. Therefore, the formation of anthocyanins in *Nepenthes* pitcher is thought to be due to a deficiency of N and P elements because *Nepenthes* pitcher prefers to grow in open areas that are poor in nutrients (Bauer et al. 2015; Brearley 2021; Dkhar et al. 2020; Mansur et al. 2021; Scharmann et al. 2013). Besides that, Handayani and Hadiah (2019) state that red pigment formation is a plant response to environmental stress. Therefore, anthocyanins indicate nectar's presence in the pigment-producing part. This is proven by research by Setiawan et al. (2022) and Scharmann et al. (2013), who found the source of nectar in the pitcher's body of *N. bicalcarata*. Schöner et al. (2017) also found the nectar source in the pitchers' body of *N. hemsleyana.* Visitor insects get nectar from the pitcher of *Nepenthes.* On the other hand, the *Nepenthes* pitcher gets food from prey that falls into the hole of the pitcher. Another exposure revealed that, according to Buch et al. (2015), Handayani (2017), Gilbert et al. (2018), and Tarigan et al. (2021), the pitcher serves as a passage for insects or small animals that are on the ground at the upper of the pitcher, for example, lips, closing the pitcher. Furthermore, various colors in the pitcher indicate that this part also plays a role in photosynthesis or attracting prey.

That implies terrestrial pitcher plays more role in photosynthesis and capturing prey than aerial pitcher (He and Zain 2012). The body pitcher's green color shows chlorophylls' presence (Handayani and Hadiah 2019). The presence of red, purplish, and brownish-dark red in the pitcher body indicates the presence of anthocyanin (Sheridan et al. 2021). This pigment was found on the pitcher's body and most other parts (Dávila-Lara et al. 2021). As a pitcher is the further leaf growth, it naturally functions for photosynthesis (Scharmann et al. 2023; Del Valle et al. 2019). Although the pitcher body produces nectar, it is not the main nectar producer of the plant. Insects visit the pitcher for the pitcher's body color, eventually slipping and falling into prey (Handayani and Hadiah 2019). However, further research is required to observe whether pitcher color does function to lure prey or is merely an adaptive behavior of the plant growing on soil lacking nitrogen. Jürgens et al. (2015) stated that anthocyanin accumulation could be used as an indication of symptoms of nitrogen or phosphorus deficiency.

This observational data illustrate that the lower pitcher plays a more important role in attracting prey, while the upper pitcher plays a role in photosynthesis. Prey is found in the lower and upper pitchers of *Nepenthes gracilis* and *eustachya,* namely Culicidae, Formicidae, and Rhyparochromidae (Table 2). Preys are trapped in *Nepenthes* pitchers for various reasons, including that *Nepenthes* plants occasionally prey on insects belonging to these family groups. Simultaneously, Culicidae, Formicidae, and Rhyparochromidae are present in *Nepenthes* pitchers due to their close association and their UV color trapping mechanism and color pitcher darkens the lips of the plant's pitchers while lightening its body (Tarigan et al. 2021). The peristome condition strongly influences the prey trapped in the pitcher (Harapan et al. 2022). The prey is attracted to the peristome by the nectar-secreting gland (Bauer et al. 2012). The wettable peristome could cause the prey to slip easily into the pitcher. Such conditions would make *Nepenthes'* trapping strategies more efficient and increase incoming insects (Harapan et al. 2022). In the open area, we assumed that the nectar fluid would evaporate shortly and the peristome would become drier than the area shaded by canopy cover (Patel 2014). We suggest this is one reason the shaded area has more contained prey in the pitcher than the open area. In many pitcher types (*N. mirabilis* and *N. rafflesiana*), the peristome are colored bright and producing nectar to attract prey. The bright color is considered a "sign" that the part produces nectar that can be used as a food source for visiting insects (Patel 2014). Bauer et al. (2015), Tarigan et al. (2021), and Thorogood et al. (2018) reported that the peristome produces nectar, especially the interior that bends toward the pitcher's opening. The risk faced by visitor insects that take nectar in this section is very large because it directly faces the pitcher hole. If the tipping insect slips, it immediately falls into the hole of the pitcher to the digestive zone to become the prey of the pitcher (Buch et al. 2015; Ravee et al. 2018).

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