Distribution and Nutritional Status of Free Ranging Sumatran Rhinoceros (*Dicereorhinus sumatrensis harrisoni Groves 1965)* in the Tabin Wildlife Reserve, Lahad Datu, Sabah, Malaysia.

S.Thayaparan.

Institute for Tropical Biology and Conservation
University Malaysia Sabah
Sabah.

2006

The Sumatran rhinoceros is the descendant of the woolly rhinoceros which is the oldest living rhinoceros species today. It is the only species found in Malaysia. The wild population of Sumatran rhinoceros in Malaysia was estimated to be 100-150 in 2001 (Zainal, 2001) and the population may have progressively dwindled in this millennium since sightings of this animal in the forest are rare.

Since the Sumatran rhinoceros is on the verge of extinction, the Sabah Wildlife Department is conducting a long-term study for the conservation of the Sumatran rhinoceros in Sabah, Borneo (Ambu, 1995). One of their strategies is to breed these animals *ex situ*. However, before achieving a successful captive breeding program, there is the necessity for thorough research on several aspects. Those are the nutrition needs, health aspects and feeding habit of the Sumatran rhinoceros.

2.2 Description of the Sumatran rhinoceros.

The Sumatran rhinoceros is the smallest and the most primitive of the rhinoceros species existing in the world (Van Strien, 1974; Borner, 1979). They are hairy; two horned with distinctive odd-toed ungulate feet. The three toed foot of the rhinoceros measures from 1.2 m to 1.4 m at shoulder height. It has a head and body length from 2.2 m to 2.6 m (Van Strien, 1974; Hubback, 1939), and weights from 900kg to 1000kg (Van Strien, 1974).

The anterior horn of a male rhinoceros measures at an average of 19cm and rarely exceeds 30 cm in length, while the posterior horn averages at 7.6cm (Van Strien, 1974; Hubback, 1939). The anterior horns of females average at 7.6 cm, while the posterior ones are small knob-like structures. This rhinoceros is also characterised with two distinct folds on its body, which makes the Sumatran rhinoceros body being segmented into three parts (Figure 2.2). The first segment is

encircling the trunk just behind the front-legs and the second part over the belly and flank (Van Strien, 1974). The skin structure is rough.

The general colouration of the Sumatran rhinoceros varies from light buff to brown to dark brown (Hubback, 1939), but in the field the coloration of the skin is largely the colour of the mud as shown in figure 2.2 (Van Strien, 1974). The younger animals have a coat of long, thick and light brown soft hairs, but in adults the thickness of the hairs are reduced and decolourised to short black bristles, except on the ears and at the tip of the tail where they remain long.

2.3 Distribution

Historically Sumatran rhinoceros were found far north of Bhutan, India , Down South of Myanmar, Thailand, Peninsular Malaysia, the Islands of Sumatra and Borneo (Choudhury, 1997) (Figure 2.3). Today, the species is found to be struggling for survival in a few pockets of forest in the Peninsular Malaysia, Sumatra and Borneo (Khan, 1989)

The species in Sumatra and Peninsular Malaysia is scientifically known as *D. s. sumatresis* (Khan et al, 1995). It is believed that the estimated 197-274 (estimated at the 1993 PHVA and AsRSG Meeting) (Foose and Van Strien, 1997) individuals in Sumatra are confined in the Gunung Leuser, Way Kambas Barisan Selatan, North Aceh and Kerinci-Seblat in the west. Foose and Van Strien (1997) stated that an estimation of around 75-100 individuals are distributed in areas of Belum, Gunung Inas and Ulu Selama in the north, Taman Negara in the centre of the Malaysian Peninsular and Endau Rompin in the southern part of Johore towards its border with Negeri Sembilan.

In the island of Borneo, an estimated individual approximately 50 to 70 individuals are found in Tabin and Danum Valley (Foose and Van Strien, 1997; Boonratana, 1997). A survey conducted by SOS rhino in Borneo over a period of four years from 2001 until 2004 identified a minimum of 35 Sumatran rhinoceros individuals in Tabin Wildlife Reserve (TWR) (Bosi and Schaffer, 2005). The possibility of a few survivors and existence of Sumatran rhinoceros in Kalimantan is being explored and questioned (Foose and Van Strien, 1997). All this shows the importance to conserve the sub species. Efforts should be taken especially in confirmed locations and in Sabah specifically the study's focus area were in TWR and Danum Valley (Ambu, 1995).

The over view of the current numbers and target populations of Sumatran rhinoceros species by country as reported by Asian Rhino Action plan, 1997 is presented in table 2.1 below. Target population: The group of individual (usually those at high risk) whom program interventions are designed to reach the number to prevent the species from its existence.

Table 2.1: Current and Target Population of Sumatran rhinoceros

	Sumatran Rhino (*Dicerorhinus sumatrensis*)			
Country	Current population	Target population	Current number/size km^2 Areas	Target Number/size km^2 Areas
Indonesia	<200	2,000	5/22,000	5/30,000
Malaysia				
Peninsula	<100	400	4/8,000	4/10,000
Sabah	<75	200	2/2,000	4/4,000
Sarawak		100	1/600	1/1,000
Thailand		200	2/	2/2,000
Myanmar		200	2/	2/2,000
Laos		200	2/	2/2,000
Total	<400	3,300	10/37,000	20/50,000

Source: Status Survey and Action Plan, 1997

2.4 Ecological Distribution

The Sumatran rhinoceros is found mainly near water in forested areas, often in hilly area, where it enables it to climb to higher area depending on the weather and climate. It appears to favour secondary forest where the upper canopy is broken and where smaller shrubs and vines are available in abundance (Van Strien, 1974; Colin and Kurt, 1972). Sumatran rhinoceros spends most of the day time in wallows, a shady and cool place for it to cool itself. The rhinoceros movement pattern can be linked to the weather condition. It prefers to stay in hilly area during rainy season where the lowlands are flooded. In the hot season it favours to stay in the lowlands wherever the water resources are available.

The Sumatran rhinoceros is solitary except for the nursing period where they spend with their mother and becomes a great wanderer at later stages (Van Strien, 1986). Females have relatively stable home ranges compared to the males, which have large and partially overlapping home ranges with the other females. In breeding animals the size of the home range of a female is around 10-15 sq km comparatively smaller than non-breeding period or mating season (Van Strien, 1986). The male Sumatran rhinoceros behaviours are more nomadic and wander large home ranges along stream beds and game trails, which is approximately 25 sq km.

Source: http://www.rhinos-irf.org/rhinoinformation/sumatranrhino

Figure 2.3: The Past and current Distribution of Sumatran rhinoceros.

2.5 Legal status of Study Animal.

The rhinoceros population notices a drastic decline in the South East Asia, primarily due to a combination between reduction in habitat and over exploitation. The rapid

decrease in range and numbers of Sumatran rhinoceros population in Sumatra and Malaysia is attributed chiefly to fragmentation of its habitat through indiscriminate forest clearance and due to poaching, stimulated by the illegal exotic trade market which pays very lucrative payback for its horns, hooves and other parts (Rabinowitz, 1994).

The subspecies *D. s. harrissoni* , is found in Borneo and is the most endangered of the subspecies (Khan *et al*, 1995). The following table 2.2 from Asian Rhino Action Plan, 1997 explains the IUCN Red list categories. The results appear in Table 2.2, indicating that of the seven taxa maximally recognised: one is probably extinct, four are critically endangered, and two are endangered. In terms of the three species, two are critically endangered, and one is endangered. Therefore trading of animal or its parts is illegal and banned except for non-commercial conservation reason, such as exchange of rhinoceros for captive breeding purposes. In Sabah, Sumatran rhinoceros is categorised as a "protective animal" under the Fauna Conservation Ordinance 1963 and its subsequent amendments (Boonratana, 1987)

Table 2.2: Status of Asian rhinoceros.

Assessment of Asian rhino species by IUCN Red List Criteria							
	Javan Rhino		Sumatran Rhino			Indian Rhino	
	Rhinoceros sondaicus sondaicus **JAVA**	*Rhinoceros sondaicus annamiticus* **VIETNAM**	*Dicerorhinus sumatrensis sumatrensis* **SUMATRA, MALAYSIA**	*Dicerorhinus sumatrensis harrissoni* **BORNEO**	*Dicerorhinus sumatrensis lasiotis* **MYANMAR, THAILAND**	*Rhinoceros unicornis* **Eastern pop ASSAM, W.BENGAL**	*Rhinoceros unicornis* **Western pop. NEPAL**
A. Population reduction	VU	CR?	CR	CR	-	VU	VU
B. Extent of occurrence.	EN	EN	EN	EN	-	EN	EN
C&D. Population estimate	CR	CR	CR	CR	-	VU	VU
E. Probability of extinction	EN?	CR?	EN?	CR	-	VU	VU
Overall rating	CR	CR	CR	CR	EX?	EN	EN

*Revised IUCN Categories and Criteria, approved by the 40th Meeting of the IUCN Council, 30 November 1994

EX= Extinct CR= Critically Endangered EN= Endangered VU= Vulnerable

Source: Status Survey and Action Plan, 1997

The decreasing number of this species in Borneo is attributed to several factors as mentioned earlier. The low number of the species coupled with their solitary behaviour and long gestation period (15 months) (Schaffer, 2001) hampers the survivability of the species in the wild. The extensive habitat destruction from logging and deforestation for Palm oil industry and development poses a great threat and has contributed greatly in reducing the amount of suitable habitat. The rhinoceros prefers undisturbed and quiet surrounding. The animals are isolated into the small patches of pocketed forest, which prevents them from meeting each other to mate at correct time (mating season). Schaffer et al, 2001 mentioned that the animal oestrus period lasts for only 24 hours, since the density of the animal is low and greatly scattered; possibility of meeting for mating purpose at the correct time is very low.

2.6 Tabin Wildlife Reserve (TWR)

SOS Rhino (Borneo) a Non- Profit Organisation has made several surveys and managed to establish the distribution of the rhinoceros in TWR (Bosi and Schaffer, 2005). Tabin Wildlife Reserve was gazetted in early 1984 and covers an area of approximately 1205 sq. km (Maryati et al, 1999). It is situated in the middle of the Dent Peninsular on the east coast of Sabah, to the north east of Lahad Datu town.

2.7 Signs of Sumatran rhinoceros in forest

Apart from knowledge based on direct observations of individuals, manual tracking of rhinoceros allows observation for a more detailed understanding of the animal behaviour through the interpretation of tracks and signs. This method offers more hands on details to be obtained that would otherwise remain unknown, especially on the behaviour of rare or nocturnal animals that are not often seen (Flynn and Abdullah, 1983). Furthermore, tracks and signs offer information on undisturbed

natural behaviour. Direct observations often influence the rhinoceros behaviour. It can sense the presence of the observer in the field. Therefore tracking is a non-invasive method of information gathering, in which potential stress caused to rhinoceros can be minimised. Indirect observation helps to identify rhinoceros presence in Tabin Wildlife Reserve. Its foot prints, wallows, rub, bite marks and certain mud smears on trees or saplings along the path indicates a rhinoceros presence in the area (Van Strien, 1974).

2.7.1 Rhinoceros Foot print

The physical descriptions of the rhinoceros foot are flat and bare with three rounds toes. The skin under the foot seems to be soft. The colour of the nail is blackish. When the rhinoceros is walking, the print of the hind foot almost completely overlaps the forefoot print. The hind foot is narrower than the fore foot and the toe nails are generally slightly larger (Hubback, 1939). Since the sole is rather elastic the width of the print varies considerably depending on soil conditions. Strickland (1967) found a difference of almost two cm between tracks in soft mud and those left in hard sand. Borner (1979) found an average variation of 1.4cm in tracks. Most authors gave the maximum width of the track from edge of lateral toe to edge of medial toe.

A rhinoceros foot print study was conducted in Sepilok using the two captive rhinoceros indicated clearly that front hoof print wider width was larger than hind food width (Bosi, 2005). The report was clearly indicating that the mean value of the print measurement from cement and soil does not give big mean difference. By measuring more prints it can differentiate the individual in the field (Flynn and Abdullah, 1983; Abdullah, 1985)

2.7.2 Wallows

The presence of fresh wallows is a one of the great indicator of the presence of rhinoceros in a particular area (Mokhtar et al, 1990). It creates wallow to cool their body (Figure 2.4) during the hot period of the day, and also another significant mud covered on the body of the rhinoceros acts as a protection shield. It gives the protection against flies and ecto-parasites like ticks and leeches (Van strien, 1986). After wallowing the rhinoceros spends time to rub its surface of the body against tree trunks, or stumps (figure 2.5). Most of the wallows are big in size approximately two meters to ten meters in diameter.

Source: http://www.sosrhino.org

Figure2.4: Sumatran Rhinoceros wallowing in the mud.

Source:http://www.sosrhino.org

Figure 2.5: Sumatran Rhinoceros rubbing itself on tree trunks

2.7.3 Rub and biting marks

Biting on tree trunk is one of the behaviour of the rhinoceros in their trail. While following their path they rub their horn on the tree trunks. Marks made along the trails may help in sexual attraction among their species, as signs that the rhinoceros is on familiar place (Van Strien, 1986) and indirect communication or leaving signals for other rhinoceros.

Source: http://www.rhinos-irf.org/rhinoinformation/sumatranrhino

Figure 2.6: Browsing habit of the Sumatran Rhinoceros.

2.8 Spoor Analysis and Population Determination

The future of wildlife conservation depends to the extent on ability to develop non-invasive, cost-effective, and sustainable methods of censussing and monitoring endangered species. There are many techniques that are being used and implied for conservation purposes such as radio-collaring, tagging, camera trapping and notching. These are very expensive, sometimes ineffective, and often unsustainable. But, this non- invasive technique more effective to track them in rain forest (Jewell et al, 2000).

Spoor analysis identification technique on rhinoceros has a very promising future in wildlife conservation, and has shown itself to be adaptable to other endangered species, such as elephant and Tembadau in Tabin Wildlife Reserve (Boonratna, 1987).

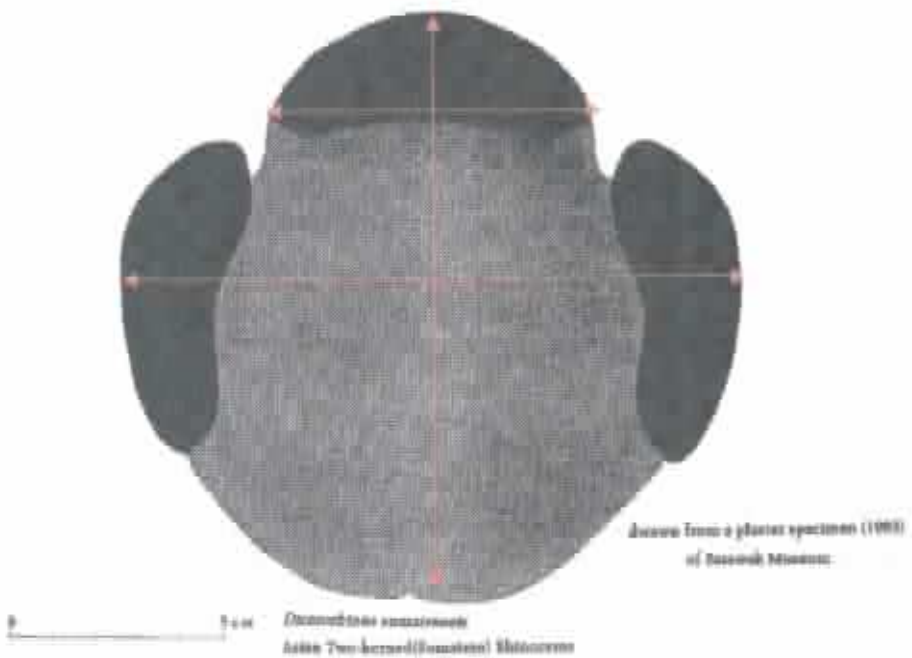
Further more, this method is also capable to provide the true comprehensive data about rhinoceros ranging behaviour. Spoor identification by tracking is an age-old technique, still practiced by many indigenous peoples (Jewell et al, 2000) for hunting and interpreting animal behaviour and individual identification. Most published work on rhinoceros spoor identification is on Asian rhinoceros populations from the late 1960s to early 1990s (Strickland, 1967; Borner, 1979; Flynn and Abdulah, 1983; Van Strien, 1986, Ahmed, 1991). In all this study attempts were made to census unknown populations using spoor identification. For measuring the foot print have to well known about anatomy of Sumatran rhinoceros foot.

2.9 Sumatran rhinoceros foot Anatomy

The Sumatran rhinoceros (Order Perissodactyla) has 3 toes on each foot. Anatomically these are digits two (medial), three (anterior), and four (lateral). The distal (third) phalanx of each digit is enclosed in a hoof (Van Strien, 1986) (Figure

2.7). The planter cushion helps support the distal metatarsals and digits where they make ground contact. Figure 2.8 shows the sole of the Sumatran rhino foot. Most of the rhinoceros weight is carried at the front of the body. Because of this, hind feet impressions are less subjected to distortion from pace of posture and tend to be more consistent in quality (Flynn and Abdullah, 1983). Hind feet impressions are also more easily obtained than the front, since hind feet usually step on the impressions made by the front feet. It can reveal clear outlines of the outside edge of each hoof, and also the outline of the hind part.

Figure 2.7: The Anatomy of Sumatran rhinoceros foot. (Obtained from Van Strien, 1986)



Source: Yasuma's Mammals of Sabah

Figure 2.8: The Diagram of footprint

2.10 Previous studies on rhinoceros population in TWR

During 1995 a general survey was conducted by Wildlife Department and reported the existence of estimated population between 9-20 rhinoceros in the area (Malim

and Ambu, 1995). In 1997, state wise rhinoceros survey was conducted to estimate population in TWR, it covered an area of 210 square km or 17.5% of the total area of TWR. This survey results produced shows that there were three known, five probable and nine possible rhinoceros was in the through out TWR (Boonratna, 1997). Foose and Van Strien (1997) estimated the population are in TWR between 20-35 individuals. During Tabin Wildlife Expedition, 1999 conducted by University Malaysia Sabah, Jomitin (1999) revealed that there were at least three rhinos residing in the core area and the surrounding forest. Bosi et al (2005) covered an area of 550 square km of the total area of TWR, and estimate 6 known, 16 probable and 32 possible rhinos in this area. The above mentioned researchers statement shows that TWR have a viable population of rhinoceros, more than 25 individuals

Criteria for categorizing Sumatran rhinoceros numbers: (Boonratna, 1997)

1. Known – Based on minimum number of identifiable tracks.
2. Probable – Based on number of track sets and recent presence of other types of evidence
3. Possible – Based on presence and location of others type of evidence.

2.11 Feeding Behaviour.

The Sumatran rhinoceros are selective feeders (Van Strien, 1974; Van Strien, 1986), especially very selective in plant parts and species. They mainly found in dense forests, usually near the streams. They are typical browsers. Their feeding times are usually early morning and evening (Van Strien, 1974) and mostly during the night, browsing on a wide variety of plant material including fruit, leaves, herbaceous growth, shrubs, and saplings.

The Sumatran rhinoceros obtain most of the food by breaking down small trees and pushing against them with fore head or chest until the tree bend over to enable the rhinoceros to walk on it. Young saplings appear to provide the largest

portion of their diet (Strickland, 1967). Sometimes the tree is fairly large, it put his fore feet on it and tries to browse young saplings (Van Strien, 1974). The favourite trick of the rhinoceros at that time of feeding is to get saplings using its front horn and twist it round and round until it's thoroughly decorticated (Figure 2.9). The Larger ones are broken by first bending them over and then stepping on it. In some cases the trees are uprooted in the bending process.

Figure 2.9 Rhinoceros food plant.

The rhinoceros feeding behaviour is influenced by forage quality, the availability of foods, habitat attributes and feeding adaptations. The list of food plants as far as is recorded, consists of a great number of species of many plant families. It is indicating that few species were recorded by more than one author. It is a good sign that it will be possible to find many more rhinoceros food plants, which is studied in this research.

1.1.2 Previous studies on Rhinoceros food plants.

Previous papers contained only list of plants that are recorded as the plant eaten by the rhinoceros. In Malaysia, Hubback (1939) recorded 44 plant texa as rhinoceros

food plants. Additional taxa were provided by Strickland (1967) in the west-costal lowland forests of Sungai Dusun Wildlife Reserve. In Endau Rompin region Flynn (1983) listed 49 plant families, 102 genera and 156 to 181 species represented as rhinoceros food plants. From his observation most of the plants browsed from *Prunus* sp (15.1%), *Ficus* sp (6.4%), and *Eugenia* sp (3%). In addition in Danum valley, Sabah; rhinoceros food plant studied by Ahmad (1991) recorded 31 plant species from thirteen families were observed to be eaten by *D. s. harrisoni*. Most of the plants browsed from Rubiaceae, Euphorbiaceae, Melastomataceae and Annonaceae. So far no published data on rhinoceros food plants are recorded from Tabin Wildlife Reserve.

2.13 Sumatran rhinoceros Health Status in Captivity

The health of the Sumatran rhinoceros in captivity appears strongly linked to dietary husbandry (Dierenfeld, 1995, 1996; Dierenfeld et al 1995, 1988). Stools consistency problems, gastric torsion and metabolic imbalances have been reported due to captive diets (Dierenfeld, 1995, Dierenfeld et al, 2005). Excess or deficiencies in several feed components including Protein, calcium, phosphorous, iron, Copper linked to disease in browsing rhinos.

Several disease syndromes in captive rhinoceros have been linked to an inadequate diet. Every major nutrient category appears to be involved with some aspect of disease (Dierenfeld et al, 1999; Marcus Clauss et al, 2005). A starting point for investigating nutrition of the browsing rhinoceros comes from looking at the chemical composition of native foods. They consume a large number of species of plants with diverse array of physical characteristics and nutrition. Captive diet may include possible imbalances in some species in dietary fats, soluble and insoluble carbohydrates, as well as protein, minerals and vitamins. This thesis provide out line of current browsing plants information, basic mineral and protein content of browses

browsed by Sumatran rhinoceros in Tabin Wildlife Reserve Core Area. These details will be a great contribution in future for feeding captive animal to improve their breeding ability.

2.14 Animal Nutrition

Protein, soluble carbohydrate, most minerals are basic common positive nutrition required by animals for growth, maintenance and reproduction (Flynn, 1983). An averaged weight 600-800 kg Sumatran rhinoceros eats 50-60 kg per day. The deficient of protein, and either macro or micro minerals have an obvious effect to the health and reproduction (Kilbourn, 2005).

2.14.1 Proteins

Proteins can be defined as any substance which is made of amino acids in peptide linkages. It makes up three–froths of the dry weight of most living cells. Proteins are also involved in the biochemical structure of hormones, enzymes, nutrient carriers anti bodies and functions essential to life. They carried major role in animal nutrition, growth and reproduction (Direnfeld, 2001). It is important in structural make up and the immune system to maintain their health.

2.14.2 Minerals

Various diseases of captive rhinoceros have indicated mineral imbalances as an underlying factor (Dierenfeld, 1995). Health syndromes receiving most attention regarding mineral metabolism include those associated with Fe storage diseases. In the oxidative processes the minerals are the essential co-factors (Paglia et al, 2001; Paglia and Dennis, 1999). The elemental nutrients are classified as macro (Na, K, Ca, P and Mg) and micro (Fe, Zn, Cu, Mn, and Mo) nutrients. Micro nutrients present in

lower concentration but are essential for animal health and reproduction. Animals get the nutrients from the plants for healthy growth.

i) Calcium and Phosphorus

Calcium and Phosphorus account for 70% of the animal's mineral content. About 90% of the Calcium 80% of the Phosphorus is present in the bones and teeth. These are the most important minerals for the bone maintenance. Phosphorus should never be higher than calcium (Dierenfeld, 1993, Kilboum, 2005). One part of phosphorus to eleven part of calcium is considered correct proposition. Deficiencies or imbalances may result in abnormal bone development, stiff gaits and fractures.

Calcium is needed for Bone formation and maintenance, contraction of muscles, regulation of heartbeat, for normal blood clotting and stabilization. While Phosphorus is necessary for bone formation and maintenance, blood buffer systems, activation of vitamins to form co-enzymes and takes part in carbohydrate metabolism, Part of ATP (National Research council, 1989).

ii) Magnesium

Magnesium is essential for skeletal development. Its helps enzymes involved energy transfer and transmission of muscle impulses.

iii) Sodium

Sodium mainly maintenances of acid base balances, body fluid balance, contractibility of smooth and cardiac muscles and cellular uptake of glucose. Native browses usually lack of sodium (Direnfeld et al, 2000, Lee et al, 1993,

Van Strien, 1986) but animals fulfil their requirements by getting from natural resources such as salt licks and mud volcanoes.

iv) Iron

Fe is essential for haemoglobin and myoglobin formation as a constituent of oxygen carriers and other enzymes. The iron overload may lead to poisonous in captive black rhinoceros (Paglia and Dennis, 1999)

v) Copper

The copper is acting as catalyst in the formation of haemoglobin. This is an oxygen carrying component in the blood. It is the major source in haemoglobin and its helps maturation of RBC, bone formation, tendon and ligament formation and repair and strength blood vessel (National Research council, 1989). Low copper cause not enough oxygen in the cells, anaemia associated with lack of oxygen and high copper levels cause toxic to the animal.

The actual requirement of Sumatran rhinoceros nutrition is unknown and due to similarities in the digestive tract morphology, the domestic horse probably represents the best nutritional model for all rhinoceros species (Dierenfeld, 1995., Van Strien, 1986, Lee et al, 1993).

Duplication of natural food stuff for rhinoceros in captivity can be difficult task, while it may not be possible to provide food sources normally available in an animal's natural habitant. This study's prospective goal is to provide the same plants browsed by rhinoceros in TWR to the rhinoceros in captivity.

CHAPTER 3

MATERIAL AND METHODS

3.1 The Study Site/ Research Area.

3.1.1 Tabin Wildlife Reserve (TWR)

Tabin Wildlife Reserve (TWR), is located at 5° 11' 41N 118° 30' 13E, which is about 50 km to the northeast of Lahad Datu, Sabah, Malaysia. It is located in the centre of the Dent peninsula, south of the lower reaches of the Segama River, covering an area of approximately 120,521 ha (Figure 3.1). It was gazetted as a Wildlife Reserve in March 1994 (Maryati et al, 1999). The Forestry Department of Sabah has the legal authority on TWR. The Tabin Wildlife Management Committee was established and chaired by the Director of Forestry Department. The Sabah Wildlife Department has been authorised to manage wildlife in the reserve.

The forest in TWR comprises of Virgin forest, Secondary forests, Riverine forest and Nipah palms swamp forest (Malim and Maryati, 1999). In Tabin Wildlife Reserve consists of several rivers. The main ones are Tabin River, Lipad River, Urik River, Maruap River and Lumpangon River. The Tabin River and the Lumpangon River (Jomitin, 1999) are located inside the Core Area. There are seven mud volcano areas in Tabin Wildlife Reserve (Dalimin and Ahmad, 1999). The main mud volcano Lipad is located about 2km from the western boundary and others are present with in the Core Area. Many wild animals frequented these sites. The water in the area is highly saline (Dalmin and Ahmad, 1999).

Dipterocarp forest covers the TWR and the surrounding areas were under unexploited, since most of the forest has been selectively logged for timber. 8,616 hectares has been allotted as Core Area in the reserve forest. It is never been allowed for logging. TWR is characterized as moderate to steep slopes, 100-300m above sea level, with highest peak at 570m (Mt. Hatton) (Maryati et al, 1999), and flat lowlands in the north east. Oil palm plantations share common boundary with the reserve except for the swampy north-eastern part. There are three villages on the northern part of the reserve, which are Kg Dagat, Kg Parit and Kg Tidung respectively.

Figure 3.1: Location of Tabin Wildlife Reserve

3.1.2 Flora and Fauna in TWR

TWR is rich in biological resources that represent many important lowland rain forest components of Sabah's biodiversity. It is comprised of logged and un-logged lowland Dipeterocarp forest. The Core Area consists of 10% reserve which remains un-logged. The vegetation at the Core Area is not precisely known.

The vegetation of TWR is mostly secondary forest following selective logging from 1976 to 1984. It lies in a region where the natural vegetation on dry land at low altitude is evergreen moist forest. It usually dominated by trees of the family

Dipterocarpaceae and species such as *Parashorea tomentella*, *Shorea leptoclados*, *Shorea symingtonii* and *Dipeteropus cauditerus* are common from this family (Payne, 1987).

TWR is tropical lowland rain forest; it means that the forest rainfall in the range of 1000 - 2000 mm per year (Sale, 1994) and no extended dry season or humid through out the year. The main features of tropical rain forest are that, the most plant life forms are woody, up to 80 m tall, and evergreen. The non-woody plants such as epiphytes, climbers and ground herbs can also be found.

There are eighty-five families of woody plants consists of 945 species (Sale, 1994) have been reported in TWR. The largest trees are dominated by the family Dipterocarpaceae. The most dominating species Euphorbiaceae with 97 species, followed by Annonaceae (72species), Rubiaceae (57 species), Lauraceae (53 species), Meliaceae (45 species), Dipterocarpaceae (49 species), Leguminoseae (34 species) and Moraceae. These are very important sources of food for wildlife (Sale, 1994).

There are many varieties of animal and bird populations are living in TWR. Those are elephants (100-200) (Payne, 1987), Sumatran rhinoceros (15-20) (Boonratana, 1987), tembadau (50) (Payne, 1987), deers, pigs, primates a variety of small mammals (73 species) (Bernard et al, 1999) and others.

3.1.3 Climate.

The mean daily temperature recorded in TWR is in the range 28°C- 32°C (Payne, 1987). In general, there is a rain fall gradient from northeast to south–west in the reserve. Where the northern part receives around 2,540mm, the central part 2,032 mm, and the southern portions 1,524mm rainfall per year (sale, 1994). It implies that core area receives relatively more rain per year. The wettest time of the year is from

late November to early January. While, there is relatively dry season from August to November.

3.1.4 Geology and soil structure.

The mineral resources of TWR, have not yet been fully explored. Only a preliminary report on chemical constituents of soil collected near and from the mud volcanoes were available. Dalimin and Ahmad (1999) were analysed in the above mentioned areas and also at the forest floor, the Tabin river bank. The minerals present in the soil highly influence the chemical (mineral) composition of plant materials and growth. The geographical distribution and seasonal variation also will influence the plant growth. It causes the variation of plant material (mineral) intake of the individual animals.

3.2 The Study Area Selection.

The study area has been chosen in the central part of the reserve (collectively known as the 'Core Area' (figure 3.2). It is 22km from western part and can only be accessed on foot. The total area comprises 8,816 ha, out of that only 48 km^2 of the land was chosen as study site. It is surrounded by logged or selectively logged forest. It has been left un-logged as primary forest for conservation of the flora and fauna (especially elephants and rhinoceros) (Sale, 1994).

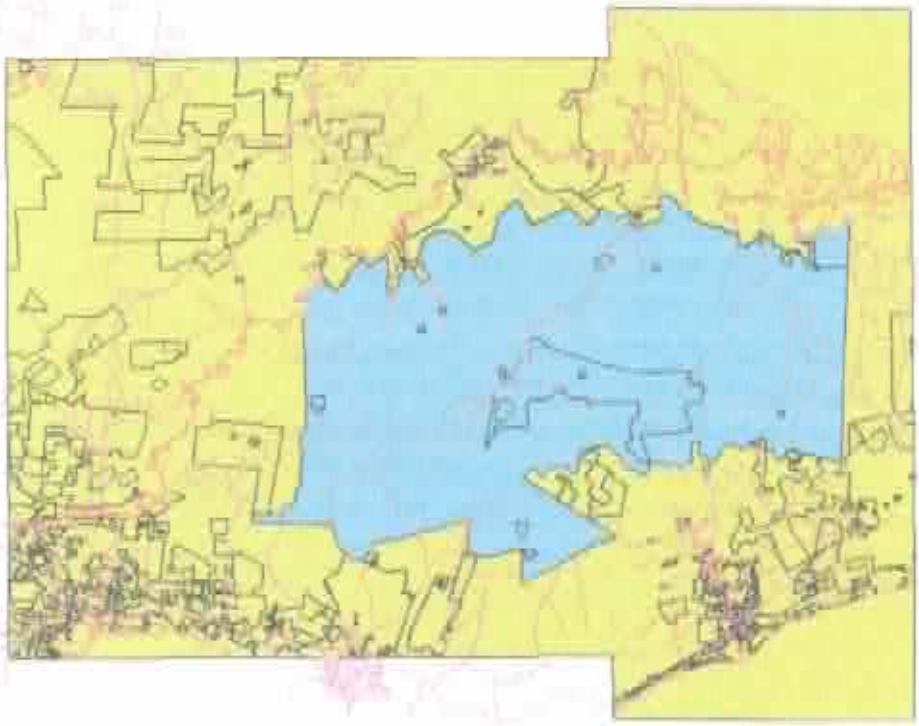


Figure: 3.2. The Map is indicating the Core Area.

3.2.1 Survey design to locate rhinoceros.

The study area of 48 KM^2 was divided into 12 equal 4 KM^2 squares (Figure 3.3) for searching rhinos. For the convenience, 2km interval transects were made for rhinoceros tracking. Every day researcher walked 4-6km in searching for rhinoceros prints. After 6-7 Km walk temporary camps were made for the night stop, until one week researcher were followed transects and end up with main camp at km 32. The rhinoceros tracks were searched along the trail with the assistance of skilled trackers provided by SOS Rhino (Borneo). Survey was carried out from July 2004 to Feb 2005. The rhinoceros track had been located and the trail was followed. The foot prints and feeding behaviour of the rhinoceros were recorded.

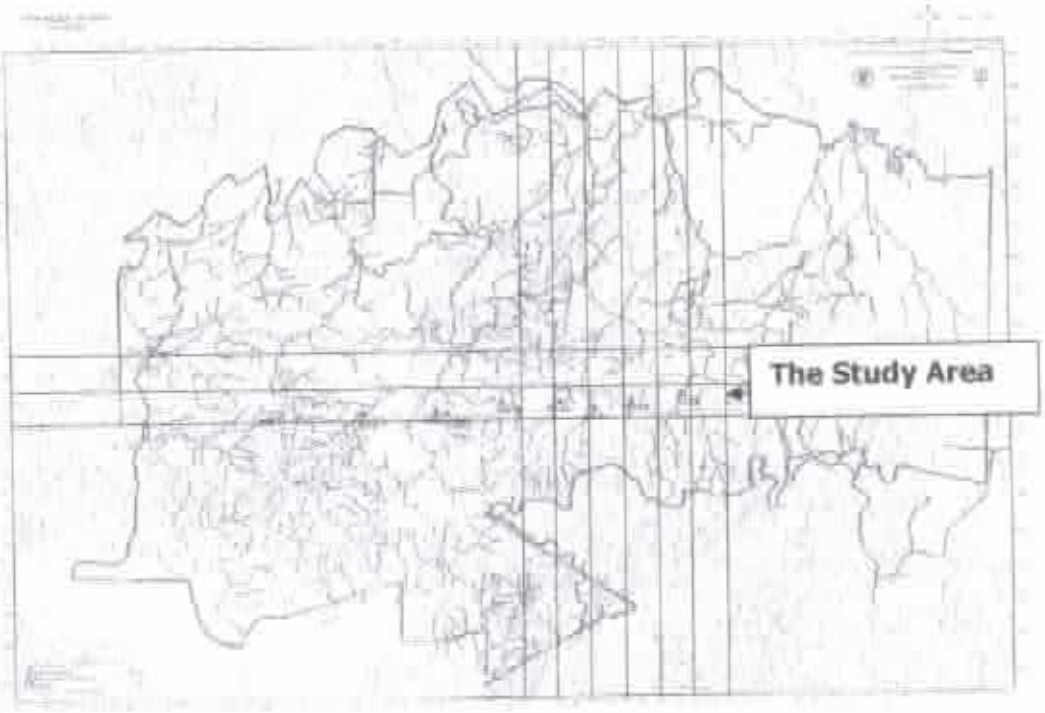


Figure 3.3: The Map indicating the survey design.

3.2 Tracking rhinoceros foot prints.

The Sumatran rhinoceros is illusive animal and with the low population density, tracking is a difficult and challenging task. Thus, hoof prints were the main identification of tracking individuals. Rub marks on tree trunks, faces, urine, hairs, signs of browsing and wallows are other evidences used to detect the presence of animals. When a fresh rhinoceros footprint is found, it was followed to the point where the tracks are not being able to be identified further more. The individual tracks were followed either by the study site (48 sq km) or even though they were wandering out side to the study area. The locations, sizes of tracks were used in documenting Sumatran rhinoceros distribution and estimating population in the study area. The locations of all fresh signs observed were plotted on topographic map and given GPS coordinates. Identified tracks were followed until clear prints of the animal's hind foot could be recorded.

The individual has toenails that make clear impressions in the soil. The maximum width between the lateral and medial toes of these tracks could measure accurately. In each track, the maximum width between the lateral and medial toenails (D1-D3) and the width of the middle toenail (D2) were measured to the nearest millimetre with steel measuring tape and vernier callipers. Only tracks made by the hind feet were recorded because the rhinoceros frequently placed their hind feet on top of the fore foot prints. Other than the track measurement, in each fresh rhinoceros print were also captured using digital photo images.

3.3.1 Cyber Tracker and GPS usage in Rhinoceros Tracking.

The cyber tracker field computer system will enhance the value of trackers and develop the art of tracking into a new science with many practical applications in nature conservation and wildlife. The field computer unit consists of a palm OS compatible handheld computer (PDA) connected to a GPS (Global positioning system). Cyber tracker software for the PDA is designed to take data in the field quickly in a pre defined, systematic way. Most of the data entry is done by clicking on icons or text following a fixed sequence of screens. GPS coordinates can be recorded for each observation. The data base and screen sequence on the PDA can be customized for particular projects.

3.4 Collection of Rhinoceros Food plants in the field

The leave samples were collected from each plant notified as eaten by rhinoceros at a feeding site for later identification and nutritional analysis.

3.4.1 Preservation in the field

Specimens were collected from flowering or non flowering plant. These samples are then trimmed to the size of the mounting newspaper. These are arranged and pressed on newsprints. Ensuring that all parts of the plant are shown clearly, e.g. both front and back of leaves should be shown.

The pressed specimens are then stacked together and tied with a raffia string, placed into a plastic bag with the two ends free. Methylated spirit (70%) (Bridson and Forman, 1992) is then poured into the plastic tube with a little bit of water by closing one end of the plastic. The two ends of the plastic tube are then moved upwards to downwards or sideways to ensure that the chemicals are mixed well. Later the two ends are folded inwards (to the centre) and tied with raffia string. Specimens can be preserved in this manner for months (Bridson and Forman, 1992).

3.5 Collection of animal data at field

A few parameters and features were recorded and observed during the jungle trip. The observed particulars are as elaborated below.

3.5.1 Rhino foot print measurements

The length of the middle toe (D2) and the width between the medial and lateral toes (D1-3) are measured by using Vernier calliper and measuring tape. The most of the clear hoof prints photographed are shown (Figure 3.4 and 3.5).

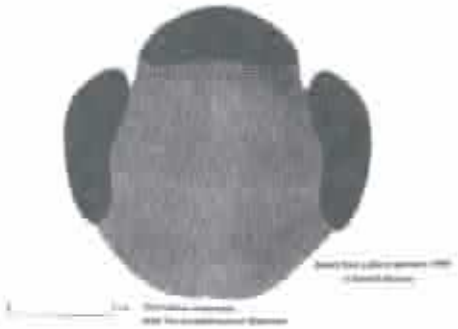


Figure: 3.4 Diagram of Sumatran rhino foot print (From Yasuma's Mammals of Sabah)

Figure: 3.5 Digital Image of Sumatran rhinoceros foot print

Sumatran rhinoceros have considerable flexible in the movement of their toes. While ascending steep terrain, they tend to pull their toe nail inward for better grip on the hill side. Like wise, they spread their toes in a barking motion while descending. Tracks made in soft soil tend to be expanded, usually 2- 5 mm (Flynn, 1983) a large sample of track measurements provides a better estimate of location in a data set. An attempt was made to follow a set of tracks until 25 clear prints made by the animal walking on flat, firm ground could be measured. The total number of tracks that were measured at each observation varied depending on weather conditions, topography and soil condition were recorded at each track observation. Each rhinoceros track analyzed by using SPSS (Statistical Package for Social Science) statistical software to differentiate the foot print sizes.

3.5.2 Feeding behaviour

This was studied by recording the evidences of their feeding activities left at feeding sites. Once a rhinoceros activity is noticed, the following observation were recorded: hoof prints, plants consumed by rhino, plant form (sapling, vine etc), parts eaten and how it is obtained, its browsing behavioural, number of bites taken by them and degree of damage to plant by feeding.

3.6 Laboratory Analysis.

The well preserved samples from the field were analyzed in the laboratory to determine the species of plant, the minerals and protein.

3.6.1 Pressing and Drying

The samples were brought to UMS herbarium in every two weeks. The specimens that were preserved in metylated spirit, then removed from the plastic tube and arranged in fresh new newsprints. These specimens were tied together with pieces of corrugated zinc in between few piles of specimens and plywood is placed at the two ends to compact. They were tied with raffia strings and placed in drying cabinet at 45-55° C for a period of 4-5 days (Bridson and Forman, 1992).

3.6.2 Identification of plants

The plants were identified at the Herbarium in School of Forestry at UMS and the Department of Forest Research Centre (FRC), a section of the Forestry department of Sabah. Digital photo images of the plants were also used for identification.

3.6.3 Mineral analysis

The mineral content of rhinoceros's food plants were analyzed for, Ca, Na, K, Mg, Cu, and Fe using flame Atomic Absorption Spectrometer AAS ((Hitachi model Z-5000 polarised zeeman AAS) (AOAC, 2000). The detailed method is explained in the following chapter.

i) Total Metal Content

Total metal content was determined by dry ash method (AOAC, 2000). 0.2 grams of the stock plant samples (<2.0mm fractions) were digested in 5 ml

HCl (70%) solution. The mixture kept for cooled down and approximately 10 ml of distilled water was added. It was filtered to a 50 ml volumetric flask and volume made up to the mark. The solution was kept in the plastic bottle prior to elemental analysis using Atomic Absorption Spectrometer (AAS). All digestions were performed in four duplicate.

ii) Elemental analysis using Atomic Absorption Spectrometer

The solutions which prepared using dry ash method in the above section were analyzed for Ca, Na , K, Mg, Cu, and Fe using flame AAS. The standard conditions for each mineral was shown in Table 3.1

Table 3.1: Standard atomic absorption condition for elemental analysis using AAS

Element	Wavelength (nm)	Gas
Ca	422.7	Air-Acetylene
Na	589.0	Air-Acetylene
K	766.5	Air-Acetylene
Mg	285.2	Air-Acetylene
Fe	248.3	Air-Acetylene
Cu	324.8	Air-Acetylene

During the analysis of each mineral, a calibration curve was prepared (Appendix 3). For each calibration curve, a set of stranded solution of varying concentrations were prepared. The stock solution is available at a concentration level

of 1000 ppm (mg/l). The formula below shows the determination of quantities required for the preparation of standard solutions from the stock solutions.

$$M1V1=M2V2 \qquad \text{---------- (1)}$$

Where

V1= Volume of stock solution required

M1 = concentration of stock solution

M2= concentration of dilute standard

V2= Volume of dilute standard

The absorbance value of each standard solution was measured and plotted against the concentration to obtain the calibration curve (Appendix 3). The absorption reading derived for each sample was referred to this calibration curve to compute the concentration of metal in each sample in mg/l.

The concentration of the elements in μg/g determined by the following equation:

$$\textbf{Mineral concentration } (\mu g/g) = (C)(V)(d.f) / (W) \text{-------- (2)}$$

Where

C = the concentration of the elements in the sample solution in mg/L

V= the volume of the undiluted sample solution in mL

W = the sample weight in grams

d.f = (volume of the diluted sample solution in ml) / (Volume of liquid taken for dilution in mL)

3.6.4 Protein analysis.

All the food plants which are browsed by rhinoceros were analyzed for determining protein content. Each samples performed 3 duplicates. Crude protein (CP) levels were determined as total nitrogen x 6.25 using macro-Kjeldal method. Two duplicates analyzed manually and the other one was determined by using N/Protein analyzer (Model: Flash EA 1112 series).

The samples were properly homogenised by using blade or ball mills before the analysis. The 1 mm mesh sieves were used for N/Protein determination.

3.6.4.1 Sample Weighing Technique

The tools that were used are a balance, tin disks, spring tweezers, sealing device and cylindrical tool, brush and spatula (Figure 3.6)

Figure 3.6: Used material for weighing sample.

As shown in Figure 3.7 (a), using the tweezers, the tin disk is placed on the cavity of the sealing. Then using the cylindrical tool, the tin disk is pressed in and enters the cavity of the sealing device, as shown in Figure 3.7 (b). Then the tin disk in the sealing device is taken out using a spring tweezers as in figure 3.7 (c). Finally it is

placed in prepared container in a clean area as shown in the picture inset of figure 3.7(c).

a) Preparation of the tin container

b) Tin container into the sealing device

c) Tin disk in the sealing device is taken out using a spring tweezers

d) Pressing the sample into the tin container

Figure 3.7: Sample preparation

Using spatula, samples were introduced into the tin container until sufficiently filled and delicately pressed using the cylindrical tool, as shown in figure 3.7 (d). The container was closed using the lever located on the top of the surface of the sealing

device. Using a spring tweezers, the container is removed, weighed and the value was noted. Nitrogen is eluted in the chromatographic column (CC) and conveyed to the thermal conductivity detector (TCD) that generates an electrical signal, which, properly processed by the Eager 300 software, provides the nitrogen-protein percentage.

3.7 Data analysis

The rhinoceros foot prints data were analysed by using the statistical analysis software SPSS 12.1. Single ANOVA test were performed to analyse the mean differences between individual groups. The remainder of the track series recorded during study period was treated as independent observations. If the null hypo-thesis was rejected implies that the animals were not in the same group. If the confidence intervals for the difference between the medians of a pair of observations did not include zero, then it concluded that the track distributions had been made by different individuals. Nine track series of track measurements were investigated by computing descriptive statistics (mean, median, range and skewness) and frequency histograms. A 95% confidence interval for the median was constructed for each track series (Flynn and Abdullah, 1983). The track series data colleted during the study period were analyzed to determine the minimum number of animals living in the study area.

The described statistical analysis method gives the result of a minimum number of rhinoceros in the study area in that study period. The young rhinoceros in the population was determined using track size criteria (Flynn and Abdullah, 1983). All animals with a median track width less than 17.0 cm were considered as depended young. Other animals were assumed to be either sub-adults or adults.

CHAPTER 4

RESULTS

4.1 Rhinoceros foot prints

The overall data obtained from nine different rhinoceros tracks presented in appendix B. Each rhinoceros tracks found in different location considered as different tracks.

4.1.1 The date and the freshness of rhinoceros tracks

Table 4.1: The time period and freshness of rhinoceros prints

The Track No	Date of data obtained	Freshness of prints
Track 1	16/08/04	One day old
Track 2	21/08/04	3-5 day old
Track 3	22/08/04	1-2 day old
Track 4	23/08/04	One day old
Track 5	07/09/04	1-2 weeks old
Track 6	18/10/04	1-2 days old
Track 7	20/10/04	One day old
Track 8	17/12/04	One day old
Track 9	20/12/04	2-3 days old

The freshness of rhinoceros tracks are determined by the following principles,

1. Aid by a few experienced rhinoceros trackers from SOS Rhino.
2. Determined by the freshness of the plants browsed by rhinoceros.
3. The climate condition in that area can be used to estimate the freshness of rhinoceros prints.

Only the tracks found to be less than two weeks were used to track the individual and collected the browsed food plants. The tracks which are observed to be more than two weeks old ignored as it would be difficult to track and the lower possibilities of coming into contact with tracked rhinoceros.

4.1.2 Location of rhinoceros tracks

Table 4.2 Location of tracks and their GPS readings

Tracks	Longitude	Latitude
Track 1	N05'17.416	E118'44.418
Track 2	N05'12.619	E118'45.380
Track 3	N05'12.557	E118'47.013
Track 4	N05'14.066	E118'46.481
Track 5	N05'14.375	E118'46.478
Track 6	N05'12.752	E118'42.656
Track 7	N05'13.190	E118'42.860
Track 8	N05'12.591	E11845.106
Track 9	N05'12.952	E118'43.323

Track 2, Track 4, Track 8 found at close to the biggest wallow and the foot prints measures indicated that very high possibilities it's from the same animal. The maps below show the distribution pattern of the tracked rhinoceros (Figure 4.1).

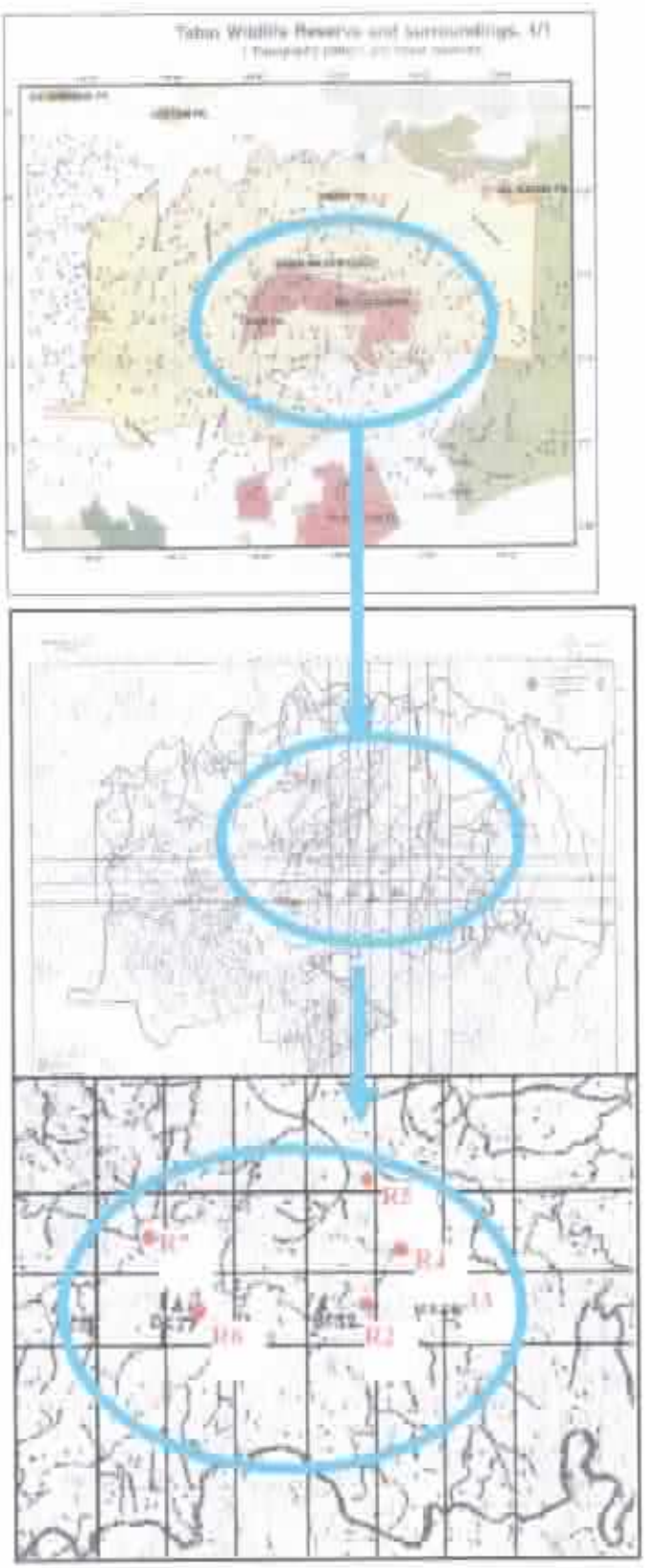
Table 4.3 Summery of the food prints after analyzed from ANOVA

		Mean (cm)	Minimum (cm)	Maximum (cm)
LWW	Rhinotrack1	20.54	19.90	21.70
	Rhinotrack2	19.20	18.80	19.50
	Rhinotrack3	21.17	19.20	22.50
	Rhinotrack4	19.38	19.00	20.30
	Rhinotrack5	20.53	20.30	20.80
	Rhinotrack6	21.01	20.20	22.80
	Rhinotrack7	19.42	19.00	21.00
	Rhinotrack8	19.33	18.70	20.70
	Rhinotrack9	20.27	19.10	21.90

LWW- Widest width from left hind foot.

Table 4.3 is illustrating the summary of the rhinoceros foot prints that is the each track mean value and minimum and maximum readings.

Figure 4.1: The Distribution Pattern of the Tracked Rhinoceros



believed to be used by the same rhinoceros were found here. Six months before, one of the SOS rhino field staff sited a male individual in this same wallow. The sample of the dung found close to the wallow is collected. Ten types of food plants were gathered from this trail for future identification and nutritional analysis.

The first footprint of rhinoceros track two was found at open canopy area and researcher followed the path for around 50-75 meters were followed. The rhinoceros prints could not followed further more because of dry floor, no visible or clear footprint left behind to be tracked. The tracked rhinoceros prints shows browsed plant marks every 30-50m distance. Each of the plant samples at every distance were collected for analysis. Then the rhinoceros track followed the opposite direction around 600-700m and a prominent wallow was identified and fresh activities were also observed. The location of the wallow was in flat area with the dimension 2.4meters x 2.3meters and a half meter in depth.

iii) Rhinoceros track 3

This rhinoceros print was found along the river bank at km 36 from the camp area. The track signs showed that presence of a Sumatran rhinoceros was there on pervious night or one day before. Because the foot prints along the river was very clear with out disturbance of the water flow. The individual seems to move across the rivulet and entered to the thick forest. Rhinoceros feeding behaviour was observed and plant samples were collected for the future identification and chemical analysis. The clear foot prints were also measured for identifying individual animals. This rhino track was trailed for approximately 500-600 m and after that no evidences were found to follow

the track. No signs of wallows found around the area mainly due to the thick forest and dry floor.

iv) Rhinoceros track 4

This rhinoceros prints were also found along a riverbank. Footprints were found along the rivulet approximately around 100-150m and then it moved to a slight hilly area. The tracked rhinoceros seems to be browsing the plants along its way. The distance between two browsed plants was in the region of 20-30 m distance. The track could not be followed further because of the dense forest and close canopy. The situation got worse due to heavy rain in the evening which made the track slippery and the evidence of the tracks and traces were washed off.

v) Rhinoceros track 5

This print in rhinoceros track five which was discovered was roughly one to two weeks old. But feeding activities were observed and eleven samples of plant including from bamboo shoots were collected. The chains of wallows, found in this region are towards the size range from medium to large. In large wallow the previous rhinoceros food print was identified. All clear prints was measured by using a calibre and measuring tape.

vi) Rhinoceros track 6

The weather was rainy, due to the wet weather some very clear prints were clearly imprinted in the damp forest floor. So the clear prints were traced

behind as much as possible. This indicated that wet ground is a good really assistance in following and creating more clear footprints for tracking in longer distance. Browsing signs and behaviour were also observed along the rhinoceros track six. The tracked rhinoceros has browsed the plants with out causing severe damage to the plants. The plant samples were collected for analysis. The measurement of foot prints here was more accurate and enabled the researcher to collect more matching pairs due to clear imprints in the wet soft ground. This track six is located in dense forest area and closed canopy with flat environment.

vii) Rhinoceros track 7

This rhinoceros track was trailed for more or less 600 m. It is along the river and then it leads towards a hill area. The clear foot prints were measured for the individual identification. Along the trail feeding signs were observed and plant samples were collected for future identification and analysis. The chains of wallows were also identified here. But none of them indicated any resent rhinoceros activity.

viii) Rhinoceros track 8

This rhinoceros track eight prints was discovered on the second day of the field excursion. The rhinoceros tracks were followed by following their footprints for around 1500 m. Signs of a rhinoceros activity were noticed in a major wallow that is assumed to be used by same rhinoceros tracked earlier. This trail was discovered after a rainy day. Due to that, all the prints were clear and could easily trace many prints along the way. Feeding signs were

observed, but most of the plant species that were already identified before. So the feeding activities were just recorded and taken note in a log book without obtaining life specimens from this tracks for the future reference.

ix) Rhinoceros track 9

It was followed approximately for 900 m. Feeding activity was observed along the trail. But as mentioned before, most of the plants were already identified before. Only the feeding frequency was recorded in log book for the future reference.

4.2 Plants finding and the frequency of consumption by rhinoceros.

Seven months of intense effort, hard work and precious time were put in data collection, searching and tracking for rhinoceros footprints. Along the discovered tracks, rhinoceros behavioural and food consumption pattern were managed to be studied. The four main browsed habits of rhinoceros were identified during the plant collection in the field. Those behaviours include i) Simple browsing, ii) Plants bent down by using its forehead and chest, iii) Plants being broken using its horns and iv) Plants being uprooted by the individuals.

From the identification process of the collected plants, results shows that the total of 65 species from 33 plant family being consumed by Sumatran rhinoceros.

4.2.1 The plants findings from TWR

Total of 147 specimens were recorded from the rhinoceros tracking trip. The most common species consumed by the animal are from the family of Euphorbiaceae with ten species, followed by the Annonaceae with eight species, four species each from

the family of Dipterocarpaceae, Meliaceae and Rubiaceae. Those are shown in Table 4.3. Apart from the above mentioned Leguminosae, Lauraceae, and Burcsaracea all with three sub species identified.

Table 4.3: List of 10 main family names and the number of species in each family from the specimens obtained from tracks.

No	Family	Total number of species	Species
1	Euphorbiaceae	10	*Cleistanthus* sp, *Mallotus oblongitolia, Mollontus miqueliaanus, Mallotus wrayii, Omphalea sargenii, Drypetes* sp, *Croton oblongus, Glochidion* sp. *Spathistemon javanice, Mollotus* sp.
2	Annonaceae	7	*Dracontomelon* sp, *polyalthea* sp. *Goniathalamus woodii, Segerae* sp, *Enicosanhum paradoxum, Friesodielsia* sp, *Lorphea myriantha, Polyalthia* sp.
3	Dipterocarpaceae	4	*Hopea nutans, Parashorea malaanona, Shorea gibbosa, shorea* sp.
4	Meliaceae	4	*Walsura Pinnata, Aglaia* sp, *Chisocheton sarawakanus, Dysoxylum* sp.
5	Rubiaceae	4	*Uncaria* sp, *Lasianthus stirpularis, Myrmeconauclea stipularis, Ixora* sp.
6	Burcsaraceae	3	*Dacryodes* sp, *Canarium odonthophyllum, Darcryodes rugosa.*
7	Lauraceae	3	*Cryodophnopsis onkensis, Cinnamomum* sp, *cryptocarya* sp.
8	Leguminoceae	3	*Cynometro* sp, *Spatholobus* sp, *Fagraea baukar.*
9	Connaraceae	2	*Agelae borneensis, Connarus grandis*
10	Flacourtiaceae	2	*Ryporusa auminata, Caseria* sp.

Along rhinoceros track one, total of 23 plant specimens were collected, from that eight of the specimens belongs to the Annonaceae plant family and three from Dipterocarpaceae. Track two, the numbers of samples collected were 23, most of the samples are from Annonaceae, Burcsaraceae, and Euphorbiaceae and Meliaceae plant family. The numbers of samples obtained from track three and four are 21. The samples contained high numbers of plants from Annonaceae and Burcsaraceae. In track five only ten samples were obtained and the plant varies from various mixed family and species. In track six to nine numbers of samples obtained were 14, 10, 9 and 16 respectively, not dominated neither by certain family nor species.

It shows that the most dominating plants from the samples collected, are consists of 24 % are from Annonaceae about 32 bites from the whole 9 rhinoceros tracks, the most common species in this family are *Goniathalamus woodii*, followed by Euphorbiaceae 19%, 26 bites, Dipterocarpaceae 7% or 9 bites, Leguminoceae7% or 9 bites and Burcsaraceae 4% which is 6 bites. This 5 plant family can be said as the mainly consumed plants as the percentage of these plants by 33 other family filled up with 39 %.

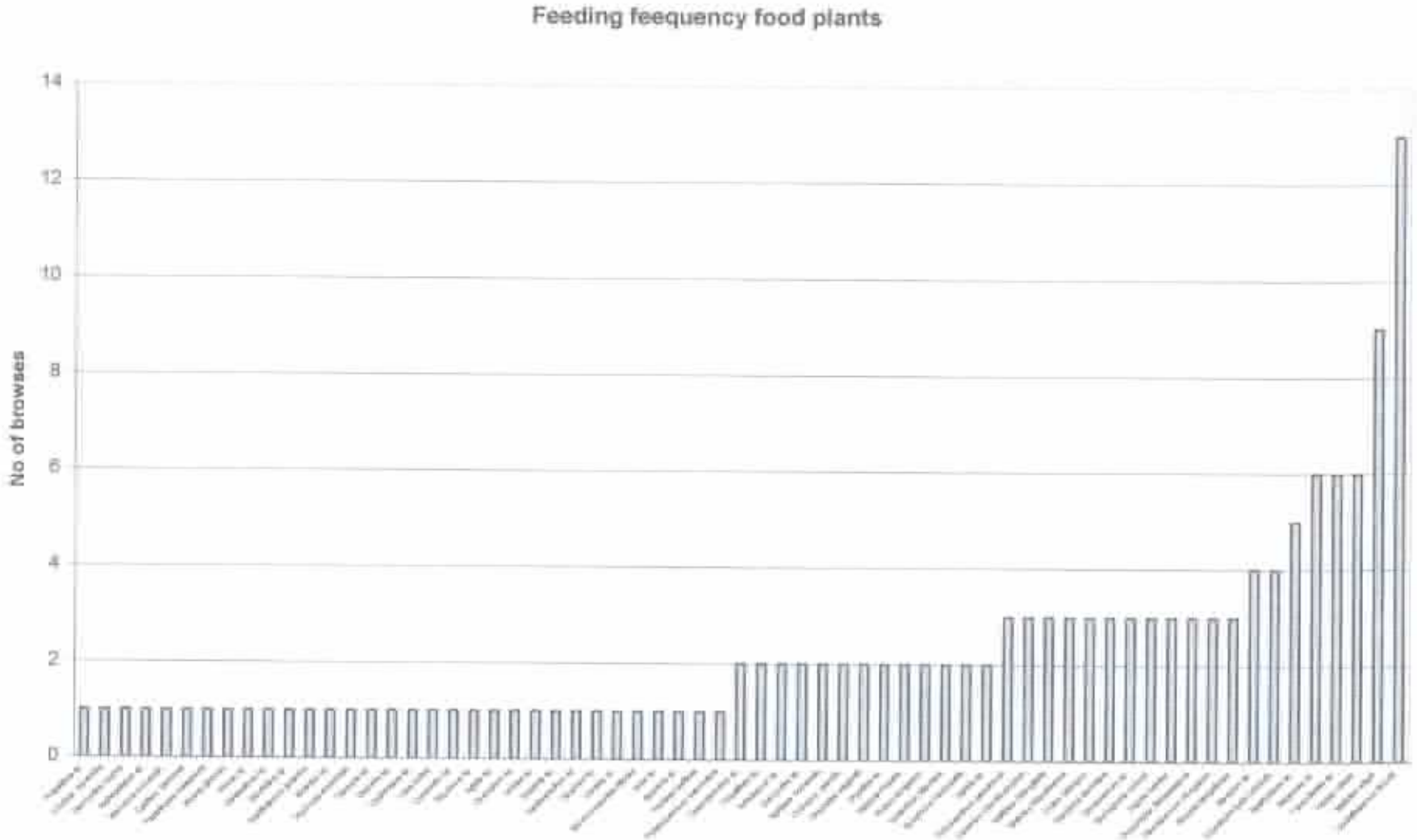


Figure 4.2: Feeding frequencies of browsed plants

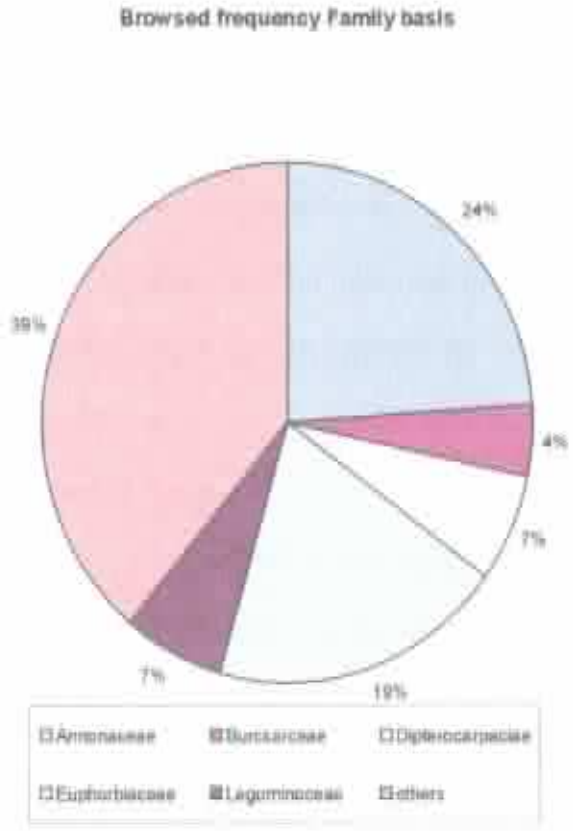


Figure 4.3: The Feeding frequency family bases

The mineral and protein content data shows the importance of each family plants which is essential for good nutritional needs for the Sumatran rhinoceros. The mineral content and protein analysis results will be further elaborated in detail in the next part of this chapter.

This research outcome was also compared with studies conducted by Flynn (1983) from Endau Rompin region, Van Strien (1974) from Sumatra and Ahmad (1991) from Danum Valley. Out of the 33 plant family, 15 family and 24 out of 65 recorded species in this research overlaps with the findings conducted by the three researchers on Sumatran Rhinoceros. Table 4.4 shows that, the plant species it was obtained in this research. The plant names which are marked with colour indicates that overlap with previous studies. The previous study details were given in appendix C.

4.3 Defecation Pattern of Sumatran rhinoceros

During the field survey, the location of rhinoceros defecation places identified. Three out of four different locations, were defecated inside the water resources and one in the land. The dung piles help to determine the freshness of rhinoceros foot print. In each places approximately 500 g faecal sample collected for the future references.

4.3.1 General appearances of dung.

Dung which deposited in the ground and the water usually scattered, could not find the round Bowles. The dung contains major of small wooden sticks, these remains of the twigs and small branches of browses which have been eaten by rhinoceros. The Colour of the fresh dung generally appears green to brown.

4.4 Location and Distribution of wallows

Out of nine rhinoceros tracks, 5 places found prominent wallows and 4 places found fresh wallow activity. Active wallows were filled with watery clay. These are usually oval to elongated oval shape with dimension of two meters wide and 2.5 m long averagely. Most of the wallows located in flat areas. The soil structure of the wallow is very different from normal soil. Suitable wallow were abundant only in flat areas.

Table 4.4: Plants consumed by Sumatran Rhinoceros found in this research, conducted in Tabin Wildlife Reserve.

No.	Family	Species
1.	Alangiaceae	*Alangium* sp
2.	Anacardiaceae	*Dracontomelon* sp
3.	Annonaceae	*Polyalthea* sp
	Annonaceae	*Friesodielsia latifolia*
	Annonaceae	*Goniothalamus Woodii*
	Annonaceae	*Segeraea* sp
	Annonaceae	*Enicosanthum paradoxum*
		Friesodielsia sp
	Annonaceae	*Lorphea myriantha*
	Annonaceae	*Polyalthia* sp
	Annonaceae	
4.	Araceae	*Scindapsus* sp
5.	Burcsaraceae	*Dacryodes* sp
	Burcsaraceae	*Canarium Odonthophyllum*
		Darcryodes rugosa
	Burcsarceae	
6.	Celestraceae	*Iophopetalum* sp
7.	Connaraceae	*Agelaea bornensis*
	Connaraceae	*Connarus grandis*
8.	Convolvulaceae	*Mervemia bornensis.*
9.	Cyatheaceae	*Cyathea latebrosa*
10.	Dipterocarpaceae	*Hopea nutaris*
	Dipterocarpaceae	*Parashorea malaanona*
	Dipterocarpaceae	*Shorea gibbosa*
	Dipterocarpaceae	*shorea* sp
11.	Euphorbiaceae	*Cleistanthus* sp
	Euphorbiaceae	*Mallotus Miquelianus*
	Euphorbiaceae	*Mallotus wrayii*
	Euphorbiaceae	*Omphalea sargentii*
	Euphorbiaceae	*Drypetes* sp
	Euphorbiaceae	*Croton oblongus*
	Euphorbiaceae	*Glochidion* sp
	Euphorbiaceae	*Spathistemon javanica*
	Euphorbiaceae	*Mallotus* sp
12.	Flacourtiaceae	*Ryporusa acuminata.*
	Flacourtiaceae	*Casearia* sp
13.	Gramineae	*Dinochloa darvelana.*
14.	Guttiferae	*Garcinia* sp
15.	Lauraceae	*Cryodophnopsis onkensis*
	Lauraceae	*Cinnamomum* sp
	Lauraceae	*Cryodophnopsis* sp
	Lauraceae	*Cryptocarya* sp
16.	Ecythidaceae	*Barringtonia curranii*
17.	Leeaceae	*Leea indica*
18.	Leguminoceae	*Cynometra* sp
	Leguminoceae	*Spatholobus* sp
	Leguminosae	*Filgraea belukar*

19.	Loganiaceae	*Strychnos* sp
20.	Meliaceae	*Walsura Pinnata*
	Meliaceae	*Aglaia* sp
	Meliaceae	*Chisocheton Sarawakanus*
	Meliaceae	*Dysoxylum* sp
21.	Myrsinaceae	*Ardisia* sp
22.	Myrtaceae	*Eugenia* sp
23.	Polygalaceae	*Xanthophyllum* sp
24.	Rhamnaceae	*Zizyphus* sp
25.	Rosaceae	*Rubus elongatum*
26.	Rubiaceae	*Uncaria* sp
	Rubiaceae	*Lasianthus stipularis.*
	Rubiaceae	*Myrmeconauclea stigosa*
	Rubiaceae	*Ixora* sp
27.	Saurauiaceae	*Saurauia* sp
28.	Sterculiaceae	*Pterospermum elongatum*
29.	Symplocaceae	*Symplocos fasciculata*
30.	Tiliaceae	*Pentace laxiflora*
31.	Urticaceae	*Poikilospermum suaveolens*
32.	Violaceae	*Rinorea bengalensis*
33.	Zingiberaceae	*Zingiberaceae alpinia*

Note;

* Names marked in red shows the plants that match with the findings conducted by Flynn, 1983.

* Names marked in green shows the plants that match with the findings conducted by Ahmad, 1991.

* Names marked in green shows the plants that match with the findings conducted by Van Strien, 1974.

4.5 Nutrition Analysis

The following part describes and elaborates in detail the Protein and mineral analysis that have been conducted. The mineral analysis includes Calcium (ca), Potassium (K), Sodium (Na), Iron (Fe), Magnesium (Mg), and Copper (Cu).

4.5.1 Mineral Analysis

Six types of minerals were analyzed from the collected plants samples. These samples were analyzed for Calcium (Ca), Potassium (K), Sodium (Na), Iron (Fe), Magnesium (Mg), and Copper (Cu). Euphorbiaceae plants species were widely found in the collected samples. The following family was dominated in rhinoceros food plants Annonaceae, Dipterocarpiaceae, Lauraceae, Meliaceae, and Rubiaceae. The other families contain involved in trifling proposition. The comparison among the Species in the dominant plants families was conducted in advanced. It was followed by comparison of mineral values among the other plant families. This would make it easier to interpret the obtained data values and to calculate the amount consume based on the numbers of bites taken in each tracks.

i) Calcium (Ca) Analysis

In comparing the Ca content in overall plants, the highest Ca contain was 8.97 % based on Dry method basis (DM) is obtained from *Polkilospermum suaveolans* and the least value contain reading obtained was 0.95 % DM from *Cyathea latebrosa*. The average Ca availability from all browses browsed by Sumatran rhinoceros is 5.55 % DM with 2.39 % DM as standard deviation. Comparison analysis of Ca content was conducted starting from the most dominating plants species followed by other plants species. Euphorbiaceae is the most dominating plant species as mentioned above, the Ca content present in this species ranges from 2.85 % DM to 8.81 % DM. The least Ca content was recovered in *Glochidion* sp which is also the least favoured or consumed species from this family. It is only a bite from this species was eaten by the rhinoceros. The other 8 species from this family Ca content was

higher than 6.35 % DM. The highest content was in found in the *Mallotus Oblongifolia*. Total of 42.8 % of this species was consumed by rhinoceros in Euphorbiaceae plant species. The graphical view of Ca content in all plants is shown in figure 4.4.

The Annonaceae plants family was recorded as the most bites taken from the other plants. The *Goniathmus Woodii was the* highest Ca content species consumed by the rhinoceros, with 7.84 % DM content of Ca (Figure 4.4, Figure 4.2). The range of Ca content in this plants species from 1.70 % DM to 7.84 % DM.Plants from the Dipterocarpaceae family contained fairly high amount of Ca content. The lowest Ca content in this family detected from the *Shorea sp* which contains 3.52 % DM of Ca, followed by the *Hopea nutans sp* with 3.83 % DM of Ca detected. The highest content of Ca in this family belongs to the *Shorea gibbosa sp* with 8.48 % DM detected.

While comparing the Ca content on three species of Lauraceae, it showed that the Ca content was fairly high in all the species. The lowest Ca reading were obtain in *Cinnamomun sp* about 2.88 % DM, 4.58 % DM in *Cryptocarya sp* and highest in *Cryyodophnopsis onkensis* approximately 5.42 % DM.The Meliaceae plant was obtained in 4 different species which are *Dysoxylum sp, Aglaia sp, Walsura Pinnata* and *Chisocheton Sarawakanus* contains high amount of Ca. The analysis result showed that 4.8 % DM, 5.47 % DM, 6.92 % DM and 7.89 % DM of Ca in each species respectively. Different pattern of Ca were detected in the Rubiaceae plant species. Where some of the species contains low Ca like the *Uncaria* with 1.72 % DM very little compared with *Ixora sp* and *Mrymcomaula* sp with 7.91 % DM and 8.51 % DM of Ca.

Lowest amount of Ca detected overall in the analysis was from the Cyatheaceae family 0.95 % DM, and the highest reading through out the analysis was obtained in Symplocaceae plant sample with ca content of 8.97 % DM. Other families fairly obtained high Ca reading from the analysis was Urticacea 8.96 % DM, Flacourtiaceae 8.82 % DM, Violaceae 8.65 % DM, Araceae 8.4 % DM and Connaraceae 8.19 % DM.

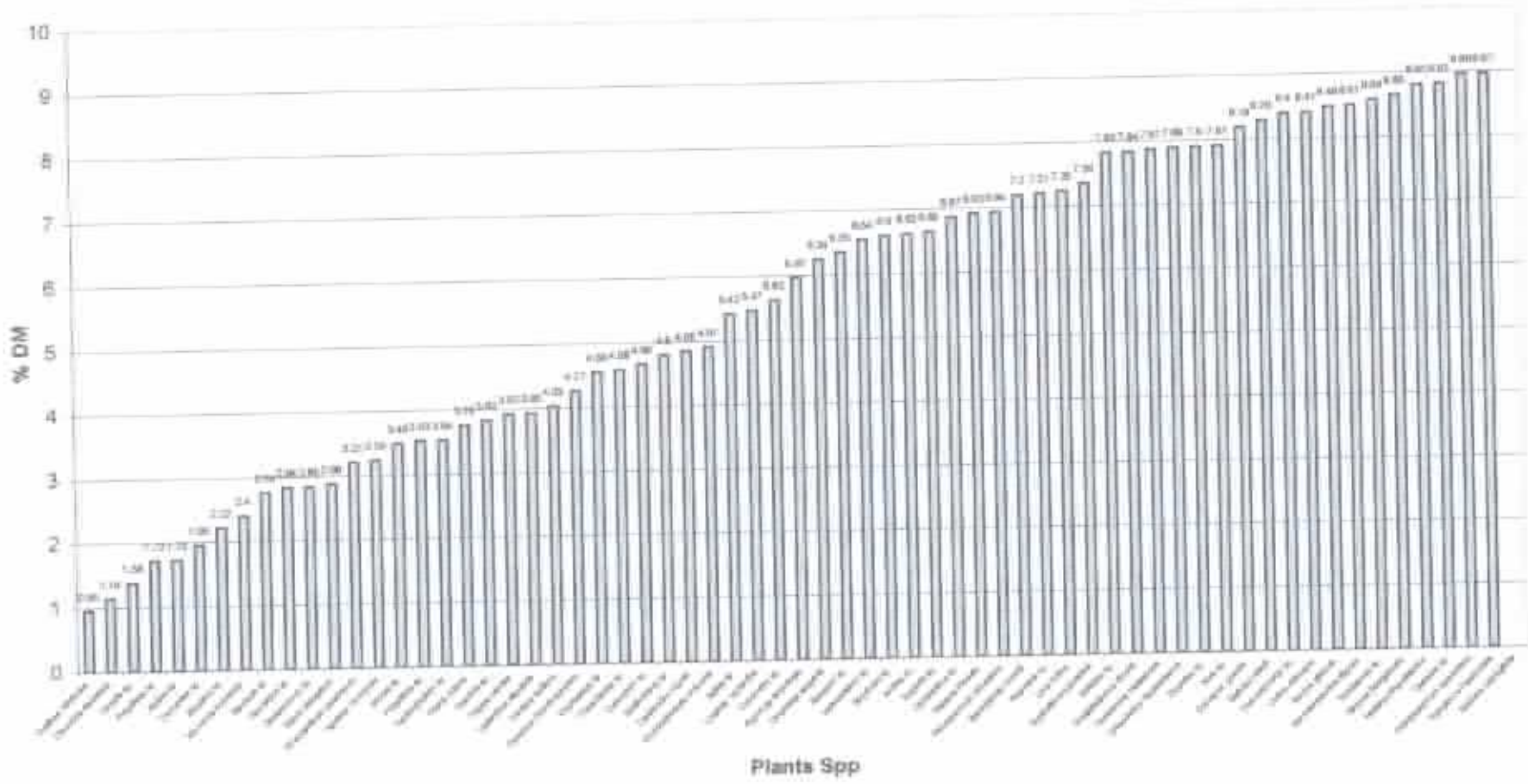


Figure 4.4 The Ca content in rhinoceros browsed plants in % DM

ii) Potassium (K) analysis

The highest value was obtained 4.06 % DM from *Pentace laxiflora* and the least K contains obtained 0.07 % DM from *Glochidion* sp. The both plants are browsed by rhinoceros only once. The average availability of Potassium from browsed plants was 2.22 % DM with the standard deviation 1.11 % DM.The K content in Euphorbiaceae plant species contains almost the same amount. All species are not less than the range of 2- 2.52 % DM. The average K content in Euphorbiaceae plants species is 2.2 % DM. The same pattern of K content was also present in the Annonaceae plant species. The amount of K in each species was almost in the same range. The highest was 0.72 mg/g which is obtained in *Polythea* sp.

The K content in Dipterocarpaceae plants were twice the amount from Annonaceae plants but half the amount with Euphorbiaceae. The minimum content of K in Dipterocarpaceae plant was in *Shore gibbosa* with the content of 1.53 % DM and the highest of K was found in *Shorea* 1.77 % DM (Figure 4.5). The K value in Lauraceae plants species were dispersed evenly and this content value was much higher compared to Euphorbiaceae, Annonaceae, and Dipterocarpaceae plant species. The K content in Lauraceae plants were 2.78 % DM in *Cinnamomum sp* and 2.8 % DM in both *Cryodonopsis sp* and *Cryodonipsis onkensis* (Figure 4.5)

The K content in Meliaceae plans fairly high in the range of 3 % DM and above. The average K content in Meliaceae plants are 3.13 DM. Same K content patterns are obtained in the Rubiaceae plant species. The K content only differs 0.2 % DM in each sampled species. The average content of K in

Rubiaceae plants are 3.65 % DM. The other plant's K content, the lowest value was less than 1 % DM detected in Leguminoceae, Anacardiaceae, Arceae and Burcsaraceae. The highest quantity of K detected was in the range above 3 % DM. The amount of K other than the above discussed plants, could be found in Saurauiaceae 3.70 % DM, Rasaceae 3.57 % DM, Alagiaceae 3.51 % DM, Rhamnaceae 3.49 % DM, Martaceae 3.17 % DM, Myrsinaceae and polygalaceae 3.13 % DM each.

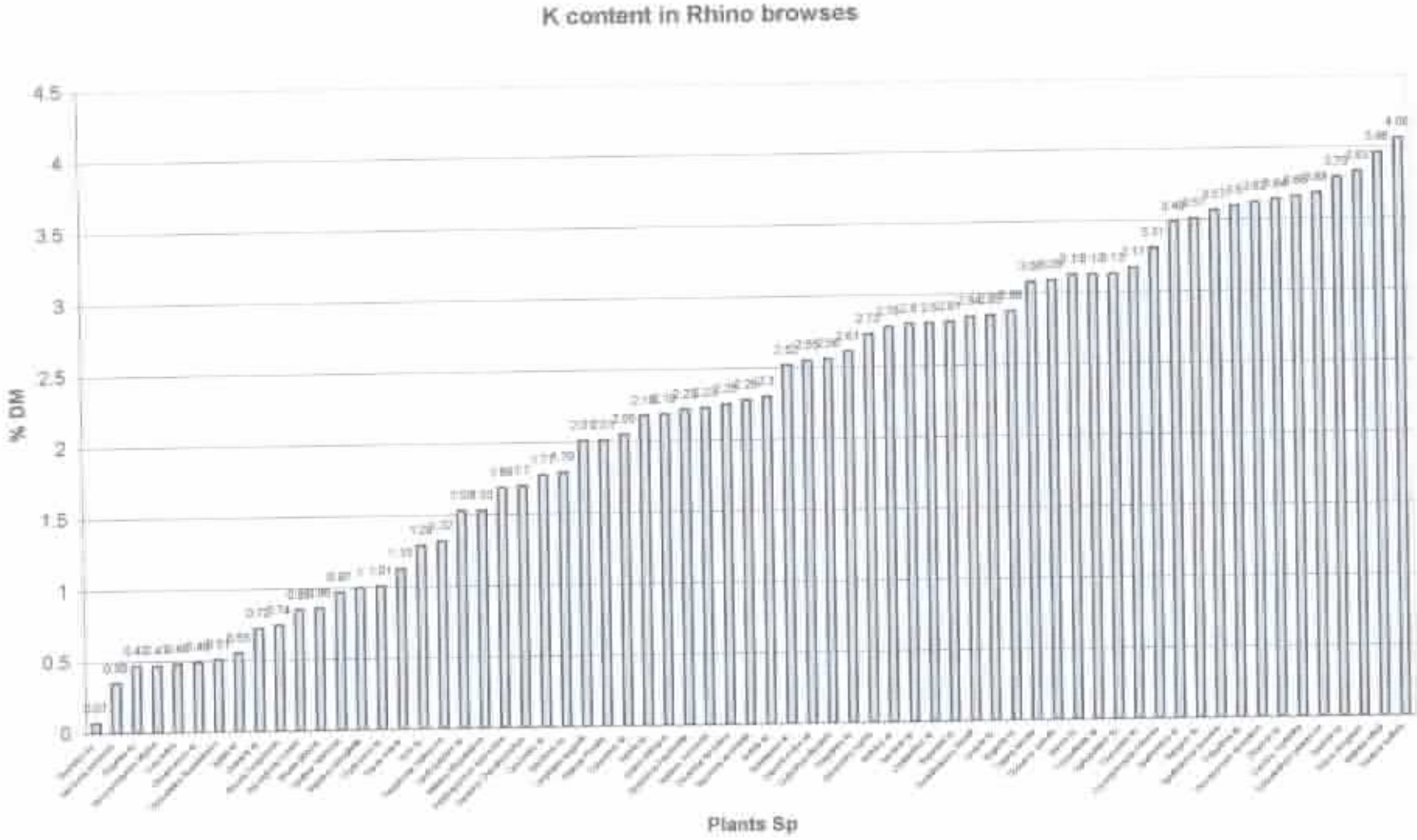


Figure 4.5: The K content in Rhinoceros browsed plants in % DM

iii) Sodium (Na) Analysis

In the Na analysis, the highest value obtained was 0.409 % DM and the lowest value detected 0.05 % DM. The average content of sodium from browsed plants is 0.10 % DM with 0.04 % DM standard deviation. Plants from the Euphorbiaceae have Na content from the range 0.072 % DM to the highest in group *Glochidious* sp 0.122 % DM (Figure 4.6). Plants from the group Annonaceae and Dipterocarpaceae have the content of Na not more than 0.112. Lauraceae plants species contains fairly high content of Na, found in *Cinnamomom sp* 0.116 % DM (Figure 4.6). Same trend obtained in Meliaceae plants ranging from 0.081 % DM to 0.123 % DM.

The content of Sodium present in Rubiaceae plants species were less then 0.1 % DM. The plants from Burgaceae plants were also in the same range as Rubiaceae plants, where *Darcrydes rugosa, canarium odonthophyllum* and *Darcryodes sp* with Na content of 0.087 % DM, 0.094 % DM and 0.085 % DM respectively. Leguminoceae plants also have Na content of below 0.1 % DM. The Na content in sub species of Leguminoceae plants was *Fagrea Balukar* 0.093 % DM, *Spatholobus* sp 0.086 % DM and *Cynometro* 0.05 % DM.Plants from other family, the Na content value varies in wide range. Some plant family content higher amount of Na compared to dominating plants. There are 10 types of plant species where the Na content was higher than 0.1 % DM. Those plant families were Alangiaceae, Anacardiaceae, Araceae, Cyatheaceae, Ecythidaceae, Flacaurtiaceae, Guttiferaeae, Myrsinaceae, Rocaceae and Urticaceae. The rest 13 plant species content were close to 0.1 % DM of Na.

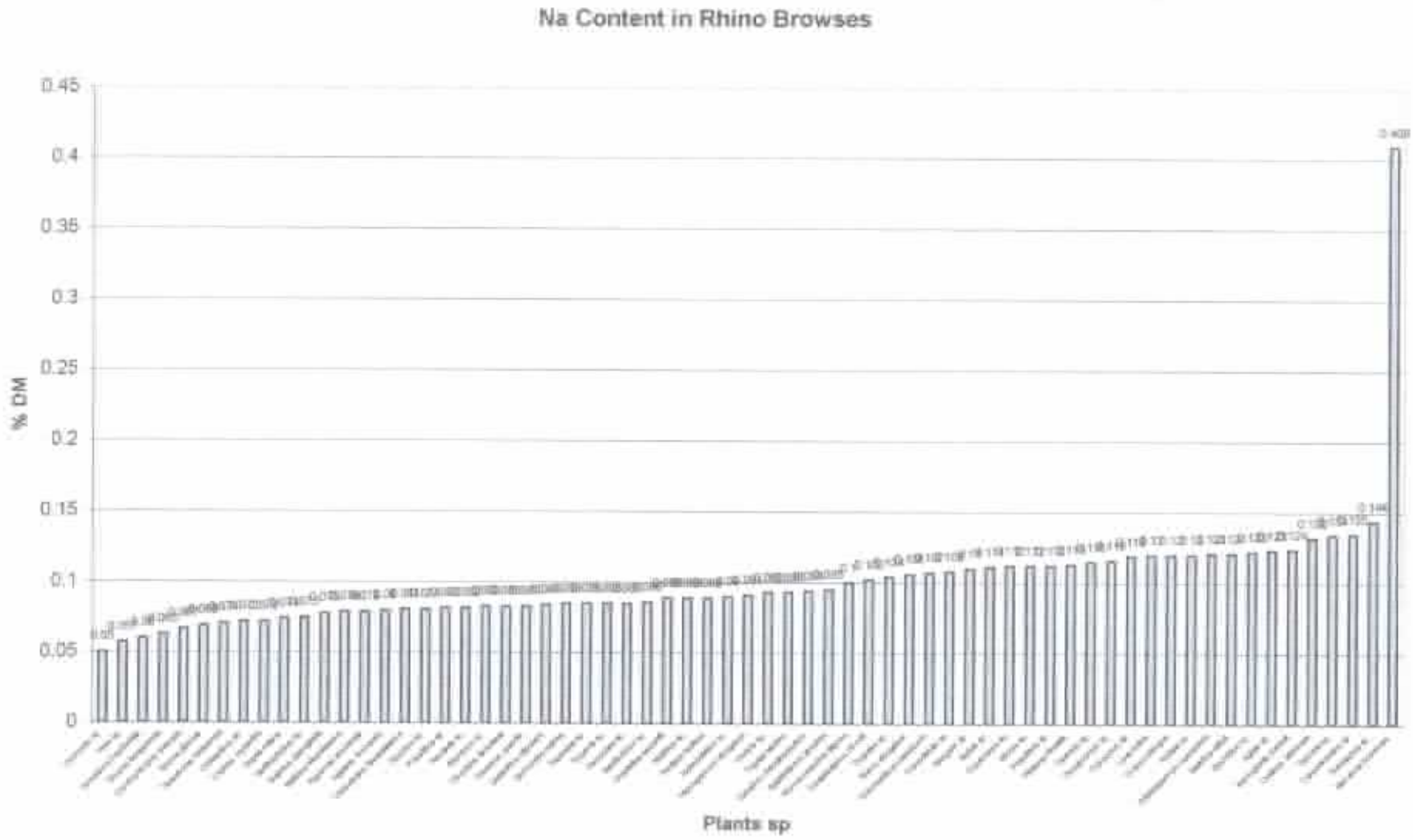


Figure 4.6: The Na content in Rhinoceros browsed plants in % DM

iv) Magnesium (Mg) Analysis

Highest Mg content was present in plants samples detected 0.4 % DM. The Mg analysis in Euphorbiaceae plants showed, *Mollutus miqueliaanus* and *Mollutus* sp contains 0.4 % DM and *Glochidion* sp, *Mollutus oblongitoha, spathistemon javanica* and *Cleistanthus* sp contain Mg more than 0.3 % DM (Figure 4.7). All the Annonaceae plant species, Dipterocarpaceae and Lauraceae contains Mg more than 0.3 % DM.The Mg content in Meliaceae plant species was moderate. It ranges from 0.23 % DM to 0.34 % DM. The highest obtained in this family was from the *Walsura Pinnata* sp (Figure 4.7).

Almost the same content trend was obtained in the Mg content in Rubiaceae plants family. The content ranged from lowest reading at 0.14 % DM and highest from *Uncaria* sp 0.37 % DM. Burcsaraceae plants contains averagely high content of Mg, all above 0.3 % DM *Canarium odonthophyllum* 0.33 % DM, *Darcryodes rugosa* 0.36 % DM and *Dacryodes sp* 0.41 % DM. The three species from the Leguminoceae plants having Mg average of 0.34 % DM. The analysis was also conducted in other plants species showed that more then half of the other plant groups contains more than 0.3 % DM. Some species Mg were undetected like the Ecythidaceae plants were detected with 0 %DM. The detailed values obtained in each plant family collected are shown in figure 4.7.

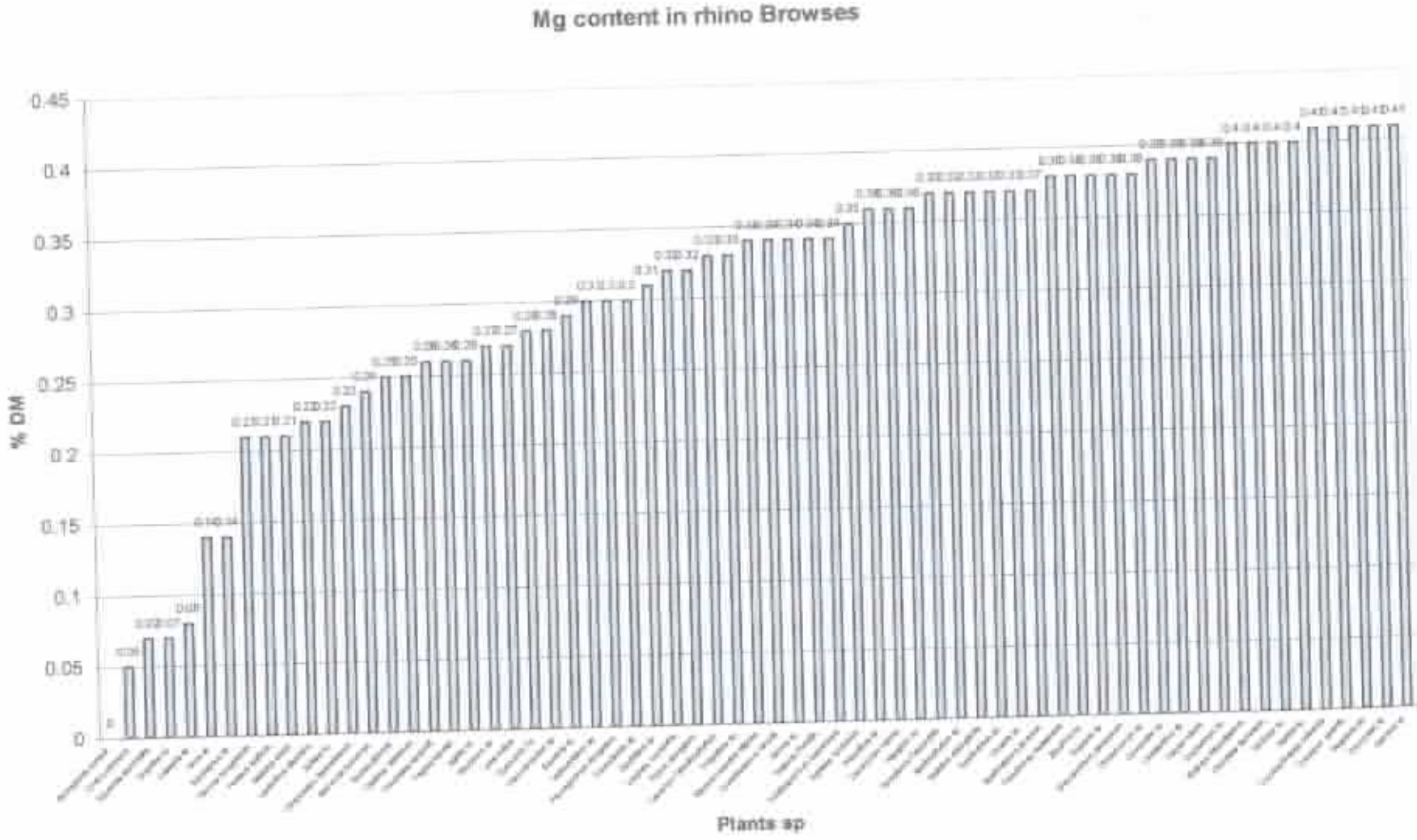


Figure 4.7: The Mg content of rhinoceros browsed plants in % DM

v) Ferrous Analysis

The highest value of Fe obtained is 1170 mg/Kg which are found in Annonaceae plants and Araceae plants. Most of the plants that were analyzed contain Fe less then 100 mg/Kg. Euphorbiaceae plants Fe content was very low even though it was favoured by individual. The highest amount of Fe detected was *Mallotus* sp 320 mg/Kg as shown in Figure 4.8.The Fe content in Annonaceae plants was higher compared with the dominating Euphorbiaceae. The lowest Fe content in Annonaceae from the *Goniathalamus Woodii* species 130 mg/Kg compared to the highest value of Fe in *Fnesoldiesia* sp 1170 mg/Kg. Plants from other family like the Dipterocarpaceae species as well as Lauraceae and Meliaceae tends to have very low content of Fe.

The plants from Burcsaraceae plants showed a different trend in Fe content. Two out of the four sub species contains fairly high content of Fe and the rest two sub species contains very low. The Fe content with the other plants species shows most the plants were fairly very low

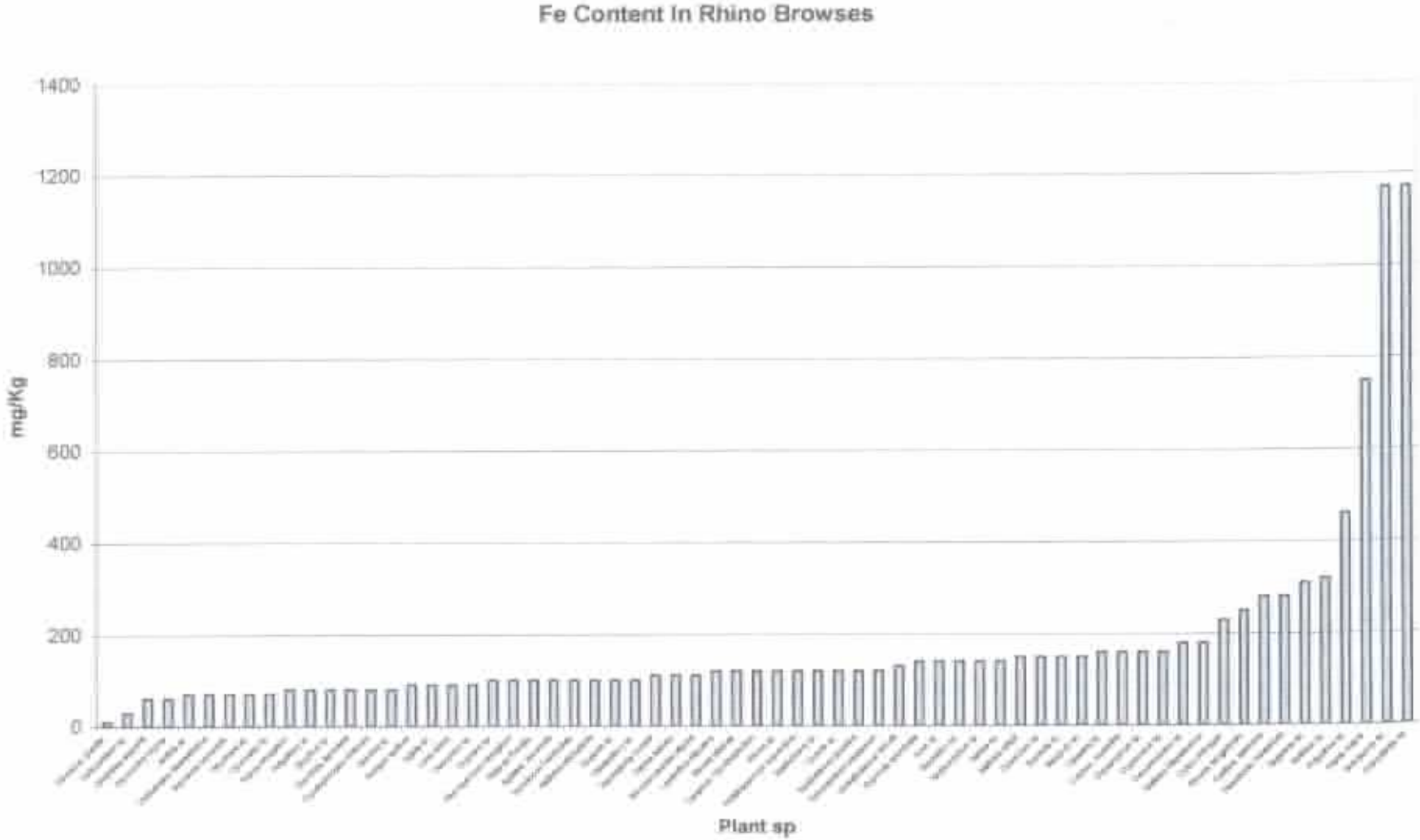


Figure 4.8: The Fe content in Rhinoceros browsed plants in mg/Kg

vi) Copper (Cu) Analysis

The highest amount of Cu content found was 120 mg/Kg. The Cu in Euphorbiaceae with the value in the region of 30 mg/Kg and 50 mg/Kg is its sub species (Figure 4.9). The same pattern exists in Annonaceae plants, ranges from 30mg/Kg to 50 mg/Kg. The highest Cu content in Annonaceae plant was 60 mg/Kg in *Enicosanthum Paradaxum*. Other main plant families like Dipterocarpaceae, Lauraceae, Meliaceae and Rubiaceae except *Myrmeconauclea stigosa* (60 mg/Kg) are in the same range as Euphorbiaceae and Annonaceae plants.

The other plants family Cu analysis showed that the highest value of all the other family belongs to the Flacaurtiaceae plant with 120 mg/Kg. Followed by Araceae 70 mg/Kg of Cu and 5 species with the content above 50 mg/Kg which are Alangiaceae, Anacardiaceae, Cyatheaceae, Guttiferaeae and Leeaceae.

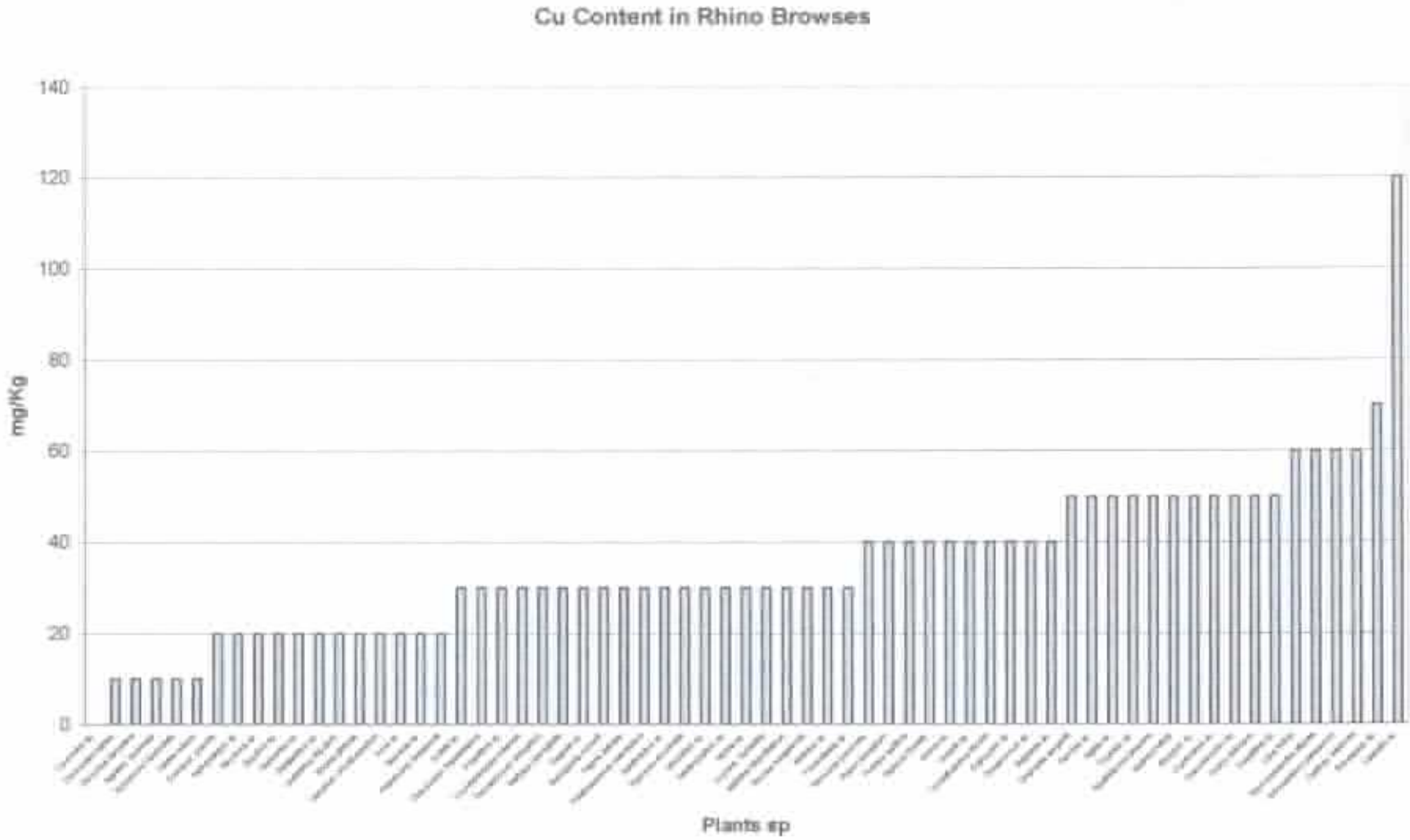


Figure 4.9: The Cu content in Rhinoceros browsed plants in mg/Kg

4.5.2 Protein analysis.

The average protein availability from rhinoceros browsed plans is 8.39% DM. The highest amount of protein is 14.35% DM obtained from *Rubus elongatum*. The least value was 2.94% DM obtained from *Dracontomelon* sp. The feeding frequency of browsing this specific plant which was *Rubus elongatum* has been observed two times.

Similar with the mineral analysis, the comparison of protein content also done in same order, beginning with the most dominating plants species followed by the comparison of protein content in other plants species. The protein content in Euphorbiaceae plant species ranges from 6.18 % DM to 10.15 % DM. Genus *Mallotus* plants were providing same amount of protein. It was 6.18 % DM and *Mallotus wfayii* was most favoured plant and frequently browsed by rhinoceros.The Annonaceae plants family was recorded as the most bites taken which contains the highest protein contains *Goniathalamus Woodii sp* with 7.08 % DM content of protein (Figure 4.10). The range of protein content in this plants species ranges from 6.62 % DM to 11.95 % DM.

Plants from the Dipterocarpaceae family contained average amount of protein. The lowest protein content in this family detected was from the *Hopea nutans,* it contains 5.3 % DM of protein, followed by the *Shorea gibbosa sp* with 5.71 % DM of protein detected. The highest content of protein in this family belongs to the *Parashorea malaanano sp* with 8.51 % DM detected (Figure 4.10). The protein content on three species of Lauraceae shows that the protein content was fairly high in all the species. The lowest Ca reading were obtain in *Cryptocarya sp* about 9.47 %

DM, 9.56 % DM in *Cinnamomum sp* and highest in *Cryodophnopsis enkensis* approximately 10.56 %DM (Figure 4.10).The Meliaceae plant was obtained in 4 different species which are *Dysoxylum sp, Aglaia* sp, *Walsura Pinnata* and *Chisocheton Sarawakanus*. The analysis result showed that 9.49 % DM, 10.29 % DM, 8.81 % DM and 11.73 % DM of protein in each species respectively.

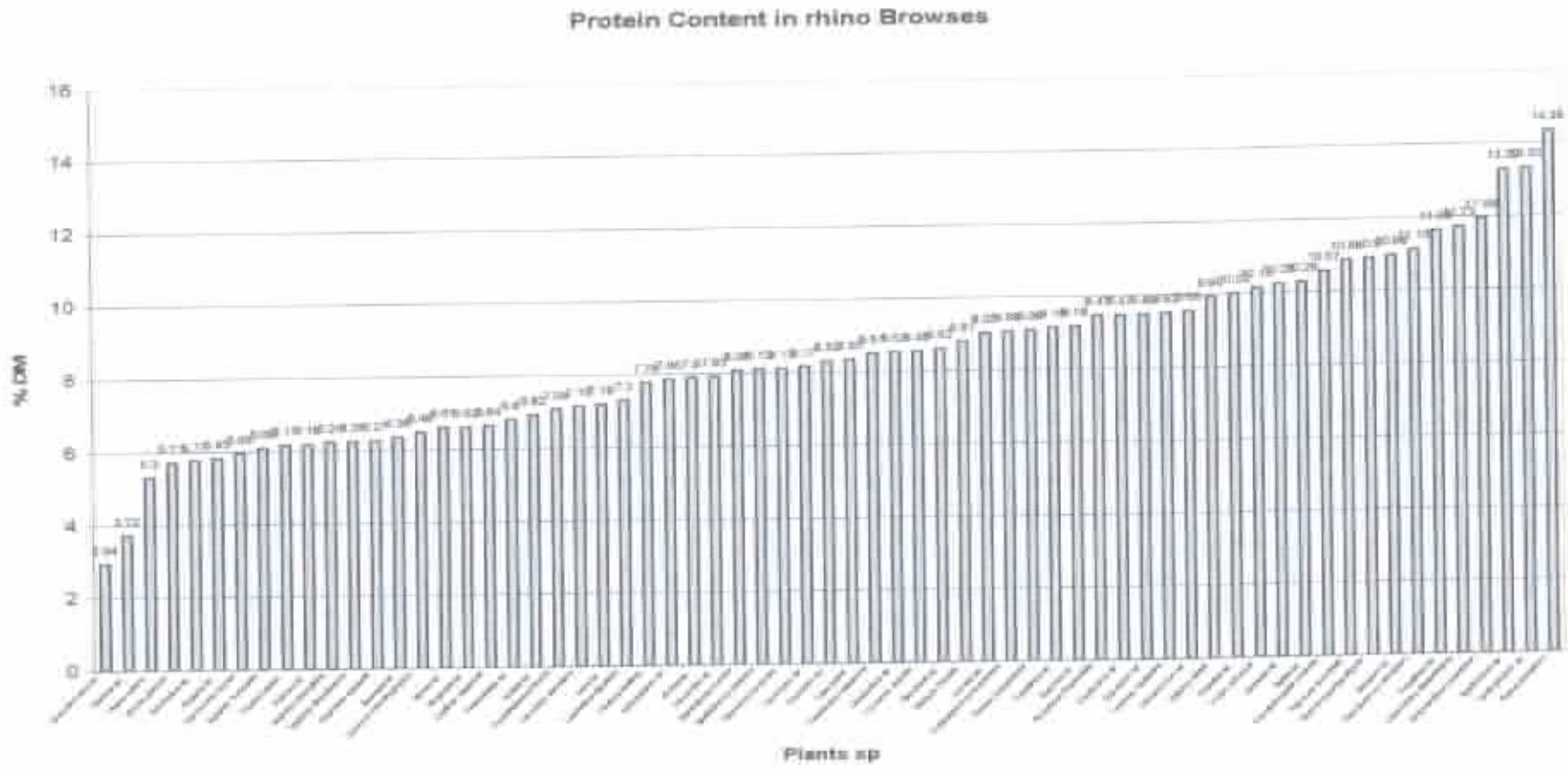


Figure 4.10: The Protein content in Rhinoceros browsed plants in % DM

CHAPTER 5

DISCUSSION

5.1 Population Density and Foot print analysis.

The study indicated that the locations and sizes of rhinoceros tracks were useful in identifying individual variation of Sumatran rhinoceros distribution and estimating the individual existing from the trailed tracks in the Core Area. For these purpose, the rhinoceros toenails that make clear impressions on the soil and maximum width between lateral toes and middle toe of these tracks should be measured accurately. This measurement is used to calculate the mean value, which is very useful in differentiating and determining the population density of the Sumatran rhinoceros in the research area. Only hind feet tracks are considered for measurement because these animals place their hind foot on top of the fore foot print. Measurements of several foot prints were used to differentiate the individuals because mean value can indicate and differentiate even the small difference among the data included in calculation.

Table 5.1 shows the mean value calculated using the left hind feet measurement taken in field according to the tracks. It shows the number (represented as N) of reading taken in each track and separates the mean readings obtained to the similar groups. The similar mean value indicating the readings contain high possibilities to originate from the same individual. The values were derived using the aid of SPSS software by mean analysis.

Table 5.1: Median Value obtain for the Left hind foot width

LWW

Tukey HSD[a,b]

RTRACK	N	Subset for alpha = .05		
		1	2	3
rhinotrack2	25	19.1960		
Rhinotrack8	34	19.3294		
Rhinotrack4	25	19.3840		
Rhinotrack7	25	19.4240		
Rhinotrack9	35		20.2743	
Rhinotrack5	16		20.5250	
Rhinotrack1	25		20.5440	
Rhinotrack6	25			21.0080
Rhinotrack3	25			21.1680
Sig.		.738	.527	.955

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 24.966.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guarantee

N= Number of foot print sets.

This table is clearly indicating out of nine rhinoceros track left hind foot print measurements Track two, seven, and eight were made by same rhinoceros based on the One way ANOVA test. Which also shows that no significant difference between groups exist and could be concluded as prints from the same rhinoceros. In the same interpretation, track nine, five and track one were also showing that no significant different exists among the group, suggesting the existence of another rhinoceros. Track six and track three shows that the closer mean value between the produced data.

In Figure 5.1 the chart of error plot used to summarizing the distribution of a single numeric variable. In this case the LWW with the category of another variable was in the tracks. Similarity of the median value and the track with similar value obtained using the 95% confidence interval for the median left hind width in SPSS. This output can be used to conclude and interlink the tracks are made by the same

rhinoceros, based on SPSS analysis and combined with field observation. Filed observation here includes the geographical location and the distance between the tracks. The chart clearly shows the cluster of three different rhinoceros existing in the study area based on the median value obtained. The first rhinoceros is identified by the mean value from track one, track five and track nine. The second rhinoceros is found to be present based on the median value which shows no significance difference value (Significance (p) value less than 0.05) as shown in table 5.1. It was derived from track two, track four, track seven and eight. It concludes, not only backed up by the same range exists in the median value but also based on the geographical location of the tracks. The presence of third rhinoceros was assumed based on the same significant value of median and SPSS analysis indicating the similarity between track three and track six.

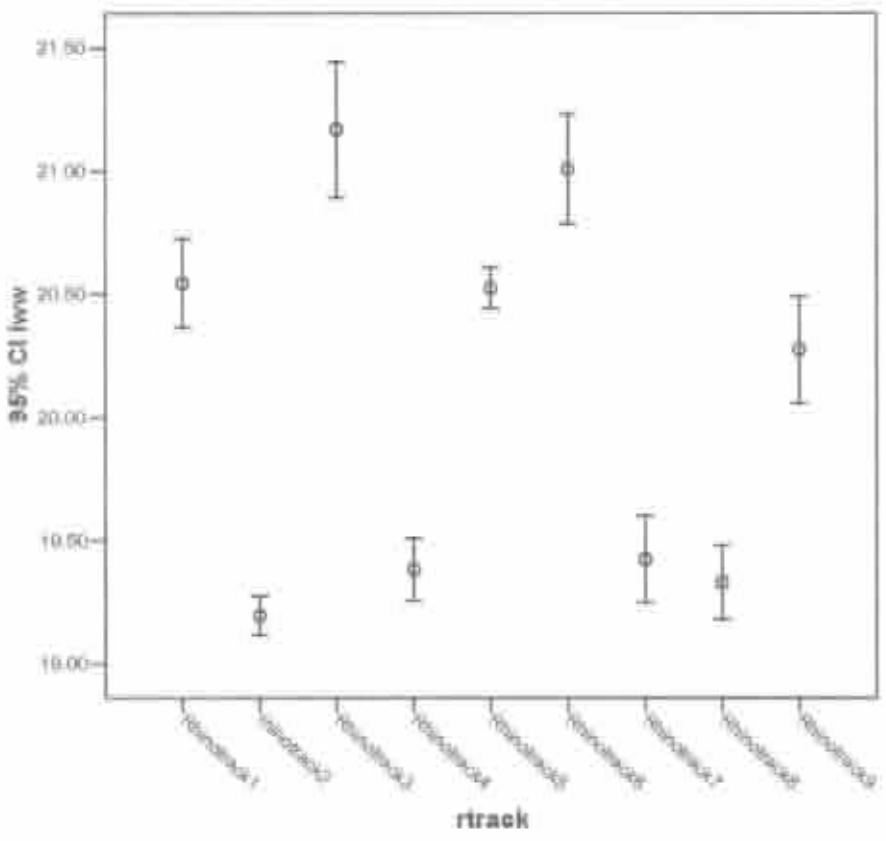


Figure 5.1: The 95% confidence interval for the Left Hind foot median track width

Sumatran rhinoceros foot print study on captive animals (Boshi, 2005) mentioned that even minimum and maximum value of the width does not affect on the mean value of the measurements. Here there were three definite mean difference of left hind foot widest width identified three closer mean values to form three different groups of animals. It was presented in the previous Figure 5.1 those values were 19.3 cm, 20.4 cm, and 21.1 cm. During the field observation, there were no signs of rhinoceros and calf pair observed during the survey. No tracks of young animals were encountered trough out the jungle expedition, which could seriously imply that the animals were not showing any breeding activity. The sex ratio could not be determined as if it was not possible to determine sex animals based on track evidence. Out of this, three rhinoceros presence are confirmed in this study area with no breeding evidences shown. This means all the three animals' gender was unable to be determined. So study on sex determination also very important and suggested to determine the rhino management in future in this area.

Survey results managed to identify that, based on track evidences there were at least three rhinos present in the study area of 48 Km^2. In total 1200 Km^2 area it is predicted the estimation of minimum 25 rhinoceros may exist, if pattern of the forest area as well as similar distribution of the discovered tracks subsist.

5.2 Ecology and behaviour of rhinoceros

Out of nine rhinoceros track observation it is indicating that Sumatran rhinoceros could occupy a certain range of habitants. They mostly prefer flat high lands (altitude between 60-180 m) to browse for their foods. During the survey in the jungle, traces of rhinoceros widely found to be wandering along the rivers and highland flat areas (Van Strien, 1986, Van Strien, 1974). It prefers to wander around cool places.

5.2.1 Wallows.

Wallows were generally encountered in most trailed tracks, although the frequency of discovering one varies between areas. Areas which lead to rhinoceros tracks one, two, five, seven, and nine were the locations presets near the big wallows. Those were active rhinocero's wallow recently being used by them. Measurement of mud wallows averaged from 2.2 m in width, 2.8 m in length and heights of the walls of wallows 0.8 m. The shapes of the wallows almost elongated oval. These indicating wallows are good indicator of rhinoceros presence in the particular area and this is very important for its survival.

5.3 Feeding Behaviour

Analysis of rhinoceros browsed plants showed that the most browsed plants species are from Euphorbiaceae with 10 species, Annonaceae with 7 species, Dipterocarpaceae , Meliaceae, Rubiaceae with 4 species each, and Lauraceae 3 species. Considering the species availability in family level in TWR were as subsequent Euphorbiaceae with 97 species, Annonaceae 72 species, Rubiaceae with 57 species, Lauraceae with 53 species, Meliaceae 45 species, Dipterocarpaceae 49 species, and Leguminoseae with 34 species known to exist (Sale, 1994). This result was clearly indicated rhinoceros browsing the plants according to the availability of the species and not to its preference or liking.

If compared the rhinoceros plants discovered from TWR from other researchers result 15 plants are matching with the genus or species level of the plants identified as rhinoceros food plants from Endau Rompin region (Flynn, 1983) and nine plants are matching with the plants identified from Danum Valley (Ahmad, 1991).

4 Nutritional Analysis

The overall data as presented in Table 5.2 illustrates the summary of the all minerals are obtained from sampled plants which was browsed by rhinoceros in TWR. The average Ca 5.55 %DM (0.95 -8.97 % DM) was showed relatively high value compared with the horse Ca requirements. The Ca contents of the captive diet provided in Sepilok Rhinoceros Breeding Centre (SRBC) average was 1.5 %DM. It was far below compared with consumed amount in the forest (Direnfeld , 2000., Kilbourn et al, 2005).

Copper levels, ranging from 10-120 mg/Kg appeared high in 50 % browse species tested with the 34.92 mg/Kg. This value was three times higher than the normal requirement to horse.

Table 5.2 Summery of the Nutrition Value

Chemical composition of combined browse fed to	Tabin Wildlife reserve Core Area.	SRBC rhino*	Horse requirements**
Nutrient	Mean	Mean	Mean
Crude Protein, %	8.39	14.7	8 to 13
Ca, %	5.55	1.5	0.3 to 0.4
K, %	2.26	1.88	0.3 to 0.5
Mg, %	0.30	0.3	0.1
Na, %	0.10	0.02	0.15
Cu, mg/kg	34.92	8.4	10
Fe, mg/kg	172.46	230	50

** National Research Council 1989
* Data's obtained from Kilbourn et al, 2005

SRBC – Sepilok Rhino Breeding Center.

Average availability of Na content was appeared marginal to their normal requirement but one of the plant, which browsed by rhinoceros in TWR provides sufficient amount of sodium. It appeared relatively closer to their normal requirement and *Mervemia bomensis* provides more than sufficient amount of the

Na content that was 0.409 % DM. The amount of Na content in Tabin wildlife reserve plants shows five times higher value than the content of Na from food provided to captive animals (Kilbourn et al, 2001). The sodium content identified from Danum Valley food plants six times lower than the normal horse requirements (Lee et al, 1993). In the Gunung Leuser Park food plants showed that Na content of food plants was about one tenth of the requirement estimated for the horse (Van Strien, 1986). In Danum Valley three different species of plants were rich in Na, those are *Diospyros* sp (0.45% DM), *Mallotus* sp (0.10% DM), Fruit of the *Baccaurea* sp (0.16% DM) (Lee et al, 1983). This show that, this clearly states, Tabin wildlife browsed plants in an average provide more adequate amount of Na for rhinoceros with out seeking salt licks for their sodium requirement.

The Fe availability average from the plant species was 172. 46 mg/Kg, two analyzed plant species were provides higher amount of Fe which are *Friesodielsia* sp *and Scindapsus* sp. Iron overload identified as toxic to the captive Black rhinoceros (Paglia et al, 2003). Effect of iron over load in Sumatran rhinoceros is still unknown.

The *Rubus elongatum* plant species showed the highest amount of protein value obtained which was 14.35 %DM, but other mineral contents are less proving from this particular species. This species only recorded to be browsed twice during the survey period. One of the most frequently consumed plants in Tabin wildlife reserve, would be the *Goniathalamus Woodii* , which has also been recorded as rhinoceros browsed plants by other researchers (Ahamed, 1991.,Lee et al, 1993.). This plant species contains rather low amount of minerals and protein compared to other plants.

Other than Na all other minerals present is more than adequate level and appeared above recommended levels for horses. TWR Core Area plants contains high concentration of mineral concentration, it signifies that high nutritive value plants are available for the Sumatran rhinoceros survival.

CHAPTER 6

CONCLUSION

Mean difference of the rhinoceros foot print revealed that definite three different sizes of hind foot print individuals are living in the study area. This research reveals Tabin wildlife reserve is very important to maintain the viable population. Mainly the core area indicated several individuals living there.

Out of 65 different species food plants identified as browsed by rhinoceros in Tabin wildlife reserve. In that 25 plants are matching with the other researchers and remain plants identified as new record. There is no preference in browsing food plants and they are browsing according to the species availability in the area. Four type of feeding habit observed and wallows are indicating the rhinoceros presence and its showing that is very important for the survival of rhinoceros.

List of browses and mineral analysis of Sumatran rhinoceros food plants from Tabin wildlife Core area has provided on site information to help to improve the husbandry of the individuals. Most of the minerals are freely available from the plants for their survival. But availability of the protein is limited for their reproduction. Ca, Na, K, Fe, Cu, and Mg were higher than levels in previous captive rhino studies conducted by Direnfeld et al (2000) and these recommended for horse (NRC, 1989).In conclusion these are the recommendation should take to prevent the extinction of the species from this earth

1. Proper security around TWR especially in core area.
2. Have to study to find individual variation to decide to confirm they are breeding naturally.
3. More Concentrate on nutritional studies to determine their protein intake.