SUMATRAN ELEPHANT'S DIETARY ECOLOGY, MOVEMENT AND HABITAT USE: USING ECOLOGICAL APPROACH TO SAVE ENDANGERED ASIAN ELEPHANT AND THEIR HABITAT IN INDONESIA

Final REPORT

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A REPORT TO
THE INTERNATIONAL ELEPHANT FOUNDATION

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A. EXECUTIVE SUMMARY

Sumatran elephant population continue to decline in an alarming situation. In the last 30 years elephant population in Sumatra has declining about 40%. Habitat loss due to the rapid land conversion into plantations that leads to human elephant conflict is belived to be responsible for most loss of elephant population. Reducing habitat loss and identifying priority areas is a key strategy for elephant conservation in Sumatra. Thus information on elephant ecology, especially their dietary ecology, habitat use, movement and home range behaviors is clearly important to support such strategi. This report produce results of two years study of elephant dietary ecology, habitat use, movement behaviors, and human-elephant conflict in Seblat Elephant Conservation Center Area, Bengkulu Province. The important results we found in this study are;

- Observation of the activity budgets of Sumatran elephants indicate that they spend between 71% - 88 % of their time in feeding. Compared to other studies, activity budget of Sumatran elephant is greatly overlapped with African elephant and other sub species of Asian elephant in India and Sri Lanka.
- Sumatran elephant predominantly browse diet during wet month. Protein content in browse diet is higher than grass diet in Sumatra.
- Sumatran elephant feeding rate on grass was relatively similar compared to Indian elephant but different to African elephant. This result is probably due to similarity on anatomical and physiological character between Indian and Sumatran elephant. In this regard, there is a possibility that anatomical and physiological character is more important than environmental character on determining elephant feeding rate.
- Sumatran elephant at least consume **189 species** that belongs to 56 families of plants in their habitat. Major elephant diets belong to family of *Moraceae* (the mulberry family-18 species), *Fabaceae* (the legume family-18 species) and *Arecaeae* (the rotan family-18 species) and *Poaceae* (the grass family-16 species).
- Elephant diet from family *Annonaceae* has the highest protein and phosphor content compared to the other family, while *Palmae* family has the highest content of calcium. Gross Energy examination shows that plant from family of *Palmae* has the highest content of energy compare to other families.
- Size of elephant home range is depends on method used to calculate the home range. Using 100% MCP method we estimate elephant home range in SECC area is 9744.27 ha (97.44 km^2). The Jennrich-Turner method (95%) estimated the elephant home range is 13,927.5 ha (139.28 km^2). The Kernel home range estimates provide elephant home range is 9496.85 ha (94.97 km^2).
- During this study we found there was no relationship between rainfall neither with home range nor with elephant movement in Sumatra. This result shown that elephant home range and movement are not related to the dry and wet season.
- Total of 17 incidents during period of February 2008 to March 2009 was recorded in adjacent palm oil plantation company (PT Agricinal). Human elephant conflicts are rarely occurred in the villages adjacent to Seblat ECC.
- Based on our telemetry data we found no evidence that elephant using the corridor area. Given the vegetation structure and topographical condition of the corridor is relatively similar to SECC, we argue that human activities in the corridor area preventing elephant to use the corridor area.

B. INTRODUCTION

Asian elephant (*Elephas maximus*) populations continue to decline due to habitat loss, poaching and conflict with humans (Santiapillai & Jackson 1990; Sukumar 1992; Blake & Hedges 2004). In Sumatra, elephant populations are fragmented into small isolated population and cause conflict with humans (Santiapillai & Jackson 1990). Rapid land conversion into plantations cause extensive loss of elephant habitat. Futhermore, land conversion into plantation (i.e palm oil, rubber) is now a main priority of the development programs of most local governments in Sumatra. Developing a conservation strategy then becomes more complicated because limited ecological information exists about Asian Elephants in Sumatra. Clearly, to identify priority areas for elephant conservation we need more information on currrent population distribution and more importantly scientific information on elephant ecology. Ironically, until now, studies on dietary ecology of Sumatran elephant have never been conducted. Furthermore, there are no studies, which have attempted to link dietary ecology to the habitat quality across remaining elephant habitat and human elephant conflict. Understanding elephant dietary ecology will help us determine suitable areas for elephants, mitigating human elephant conflict and restoring elephant habitat.

In Sumatra, elephant range is mainly found as a cluster of fragmented elephant habitat with large and small elephant populations (Leimgruber *et al.* 2003). Conservation efforts for most elephant habitat in Sumatra therefore has focused on increasing the effectiveness of existing protected areas; identifying corridors linking protected elephant range, and better land use planning (Santiapillai & Jackson 1990; Leimgruber *et al.* 2003). To date, none of these recommendations have been adequately implemented, because of the lack of information on elephant habitat use, seasonal movement and home range area. Connecting isolated elephant populations by developing corridors to the larger elephant populations had been suggested to increase the long-term survival of the species. For example, in Bengkulu province, the corridor connecting Seblat Elephant Conservation Center (Seblat ECC) to Kerinci Seblat National Park (KSNP) had been proposed by Bengkulu Natural Resource and Conservation Agency (BKSDA Bengkulu) to the Directorate General Forest Protection and Nature Conservation, in the Indonesian Ministry of Forestry (PHKA). This proposal is very important, and scientific information to support this proposal is clearly needed. In this study we will investigate how intensively elephants use the corridor connecting Seblat ECC and KSNP as habitat, and how this corridor facilitates wild elephant movement as a part of landscape permeability concept. We believe if we can scientifically determine the importance of the proposed corridor for elephants, we have a better chance to establish the corridor as a protected area, and save one of the last remaining elephant population from extinction in Sumatra.

C. PROJECT GOALS AND OBJECTIVES

The goals of this project are to determine elephant dietary ecology and to assess elephant movement, home range and habitat use in Seblat ECC and surrounding area. The specific objectives of this project are;

1. To determine elephant dietary ecology in the tropical lowland forest in Sumatra
2. To assess elephant movement, home range, and habitat use, in Seblat ECC and corridor area connecting Seblat ECC to KSNP.
3. To determine if crop raiding frequency can be predicted from the phenological cycle in food quality in and adjacent to Seblat ECC.
4. To build a predictive model of crop raiding by elephants.

1. ELEPHANT DIETARY ECOLOGY

Effective conservation and management requires knowledge of species dietary ecology, habitat utilization and movement patterns. Unfortunately, foraging behavior of forest-dwelling wild elephant populations like Sumatran elephant are extremely difficult to observe due to the low visibility in forested area. Therefore wildlife ecologists use *lead animal technique* to understand dietary ecology of forest elephant. Lead animal technique has several advantages such as provide very precise information about food types and also selection can be investigated by sampling available foods.

During period of study period of March 2007- December 2008, we use 12 adult females, 1 adult male and 1 sub adult male elephants (Table 1) from Seblat Elephant Conservation Center (Seblat ECC) to investigate elephant natural diet, food habits and diurnal activity budget. Elephant were released free ranging in Seblat ECC area and followed by one observer and one mahout starting around 6 am in the morning until 5 pm in the afternoon. Elephant activity such as: feeding, moving, resting, and drinking were recorded every 5-minute interval using focal follow observation. All species eaten were sampled and collected for identification. Main elephant diet is also sampled for protein contents analysis.

Table 1. ECC elephants used for dietary ecology study period March 2007 – December 2008

Name	Sex	Shoulder height (cm)	Approximate weight (kg)	Approximate Age (years)
Fatma	AF	206	2150	21
Darmi	AF	220	2267	24
Tria	AF	224	2344	32
Natalia	AF	220	2190	36
Yanti	AF	205	1735	24
Sari	AF	223	2214	31
Mori	AF	216	2401	39
Aswita	AF	222	2281	21
Nelson	AM	240	2612	30
Ucok	SAM	220	1960	14
Gia	AF	220	1980	23
Desi	AF	215	2190	24
Paula	AF	205	1726	19
Eva	AF	215	2119	19

1.1. ACTIVITY BUDGET

Total **4495.67** hours of observation on daily activity were recorded during the study period of March 2007-Dec 2008. Twelve adult female elephants, one adult male and one sub-adult male were observed during the study period. Four main activities (moving, feeding, resting and drinking) were recorded daily and average time budget and standard deviation is calculated for each individual elephants. The result of this study indicates that Sumatran elephant may spend up to about 88 % of their time in feeding (Figure 1; Table 2). For comparisons, other studies in Africa show time-activity budgets of elephants on feeding vary from 40% to 75% (Guy 1976; Lindsay 1994). Studies in Sri Lanka reported that male elephant might spend up to 94% of their time-activity budget on feeding (Mckay 1973; Vancuylenberg 1977).

Table 2. Average time budget and standard deviation of 14 elephants used in the study in Seblat Elephant Conservation Center (SECC) Sumatra.

Elephants/Sex	Moving (SD)	Feeding (SD)	Resting (SD)	Drinking (SD)	Hours (Obs)
Fatma/AF	7.91 (4.30)	88.10 (4.14)	1.53 (2.13)	2.46 (1.94)	326.33
Darmi/AF	10.57 (5.22)	82.99 (6.99)	4.56 (5.52)	1.89 (1.80)	314.42
Tria/AF	6.25 (3.68)	86.21 (6.00)	5.98 (4.04)	1.56 (0.95)	243.50
Natalia/AF	13.00 (7.17)	77.43 (7.33)	8.47 (3.78)	1.10 (1.25)	143.83
Yanti/AF	13.61 (9.02)	79.41 (8.48)	5.75 (2.60)	1.23 (1.30)	364.00
Mori/AF	7.63 (4.09)	84.01 (4.57)	7.00 (1.26)	1.36 (1.26)	346.75
Aswita/AF	9.35 (6.07)	82.03 (6.47)	6.68 (1.59)	1.94 (0.79)	326.17
Sari/AF	6.99 (3.97)	85.44 (5.04)	6.53 (2.08)	1.04 (0.79)	246.58
Nelson/AM	6.03 (4.20)	87.20 (5.05)	5.50 (1.83)	1.27 (0.81)	671.08
Ucok/SAM	2.99 (4.03)	86.27 (4.29)	7.81 (1.77)	2.92 (1.23)	529.5
Gia/AF	7.96 (2.43)	82.38 (2.97)	7.07 (1.77)	2.58 (1.05)	158.00
Desi/AF	17.41 (5.00)	71.84 (5.34)	9.31 (1.46)	1.45 (1.00)	120.83
Paula/AF	15.01 (6.72)	73.32 (7.02)	9.92 (2.58)	1.74 (1.27)	461.92
Eva/AF	7.55 (3.65)	84.19 (4.69)	6.61 (2.36)	1.65 (0.85)	242.75

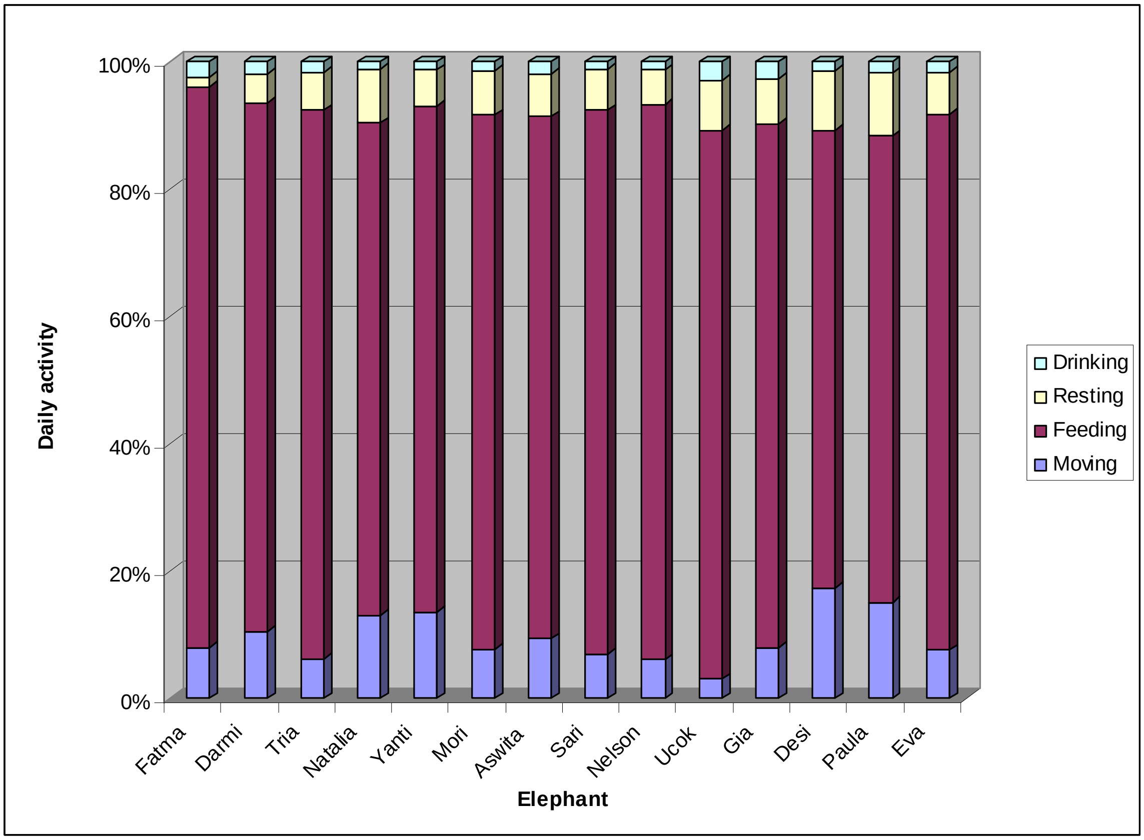

Figure 1. Activity budget of 14 elephants in Seblat Elephant Conservation Center (Seblat ECC), Sumatra

We performed one-way ANOVA statistical test to investigate if there is any difference on the activity budget among individual elephants. The results shows that average time spent for each activity were significant different among individual (Figure 2, 3, 4 and 5). This result might suggests that even though elephant have similar pattern on their daily activity but the proportion of each daily activity might be specific to each individual elephant.

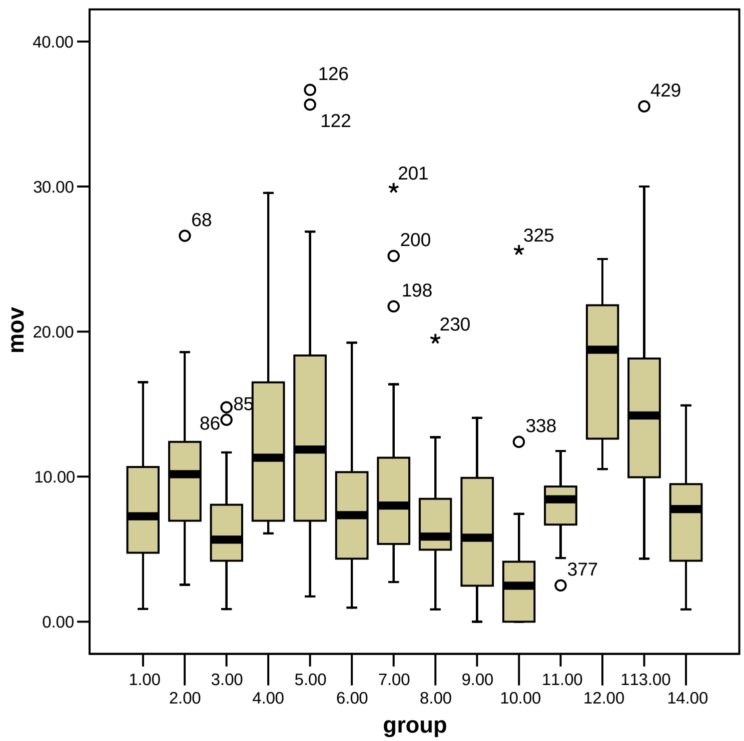

Figure 2. Comparison on "moving" activity among 14 individual elephants in Seblat Elephant Conservation Center, Sumatra

F=18.621, P< 0.01, df=13

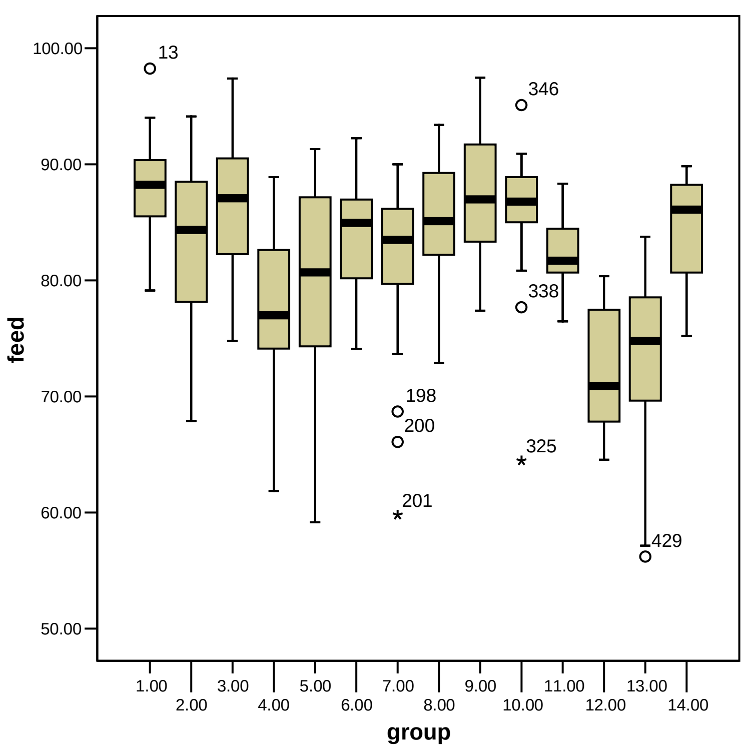

Figure 3. Comparison on "feeding" activity among 14 individual elephants in Seblat Elephant Conservation Center, Sumatra

F=23.547 P<0.01, df=13

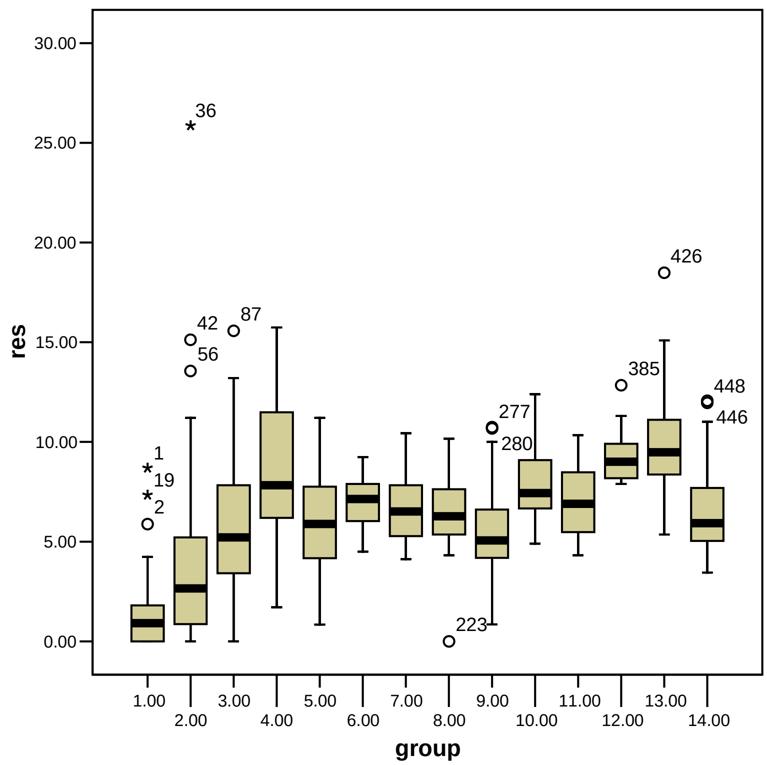

Figure 4. Comparison on "resting" activity among 14 individual elephants in Seblat Elephant Conservation Center, Sumatra

F=21.380, P<0.001, df=13

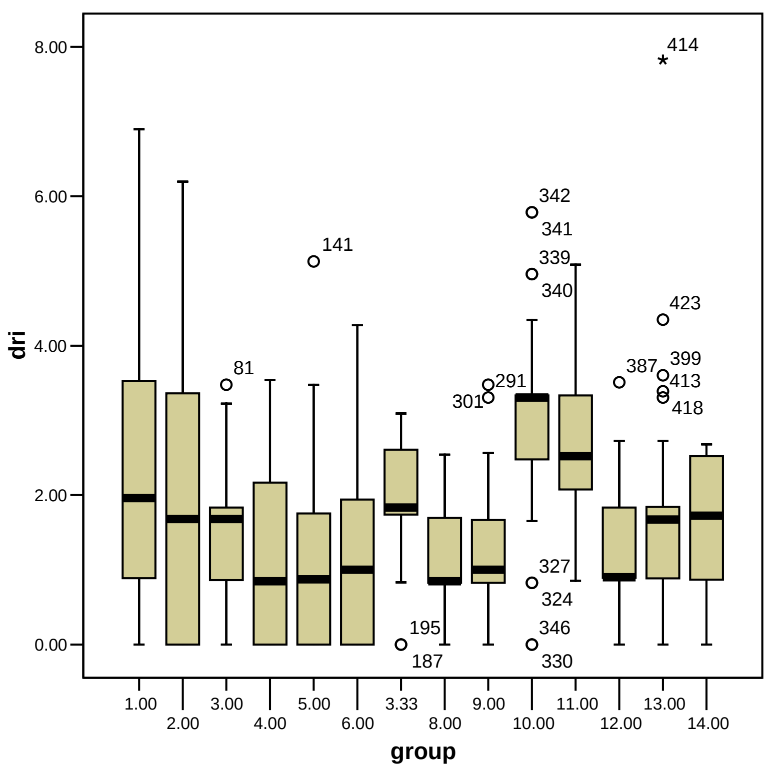

Figure 5. Comparison on "drinking" activity among 11 individual elephants in Seblat Elephant Conservation Center, Sumatra

F=8.234, P<0.001, df=13

To identify which individual elephant had different time-activity budget compared to other individual elephant, therefore we conduct post hoc TUKEY- HSD statistical test. The results show that in general, Paula has significant different time-activity budget on “feeding” and “moving” compared to other individual elephant while Fatma has significant different on “resting” with the majority of individual study elephant (Table 3).

Table 3. Statistical comparisons among individual elephant on their four main activity budget

	Fatma	Darmi	Tria	Natalia	Yanti	Mori	Aswita	Sari	Nelson	Ucok	Gia	Desi1	Paula	Eva
Moving														
Fatma		ns	ns	ns	**	ns	ns	ns	ns	**	ns	**	**	ns
Darmi			ns	ns	ns	ns	ns	ns	**	**	ns	**	*	ns
Tria				**	**	ns	ns	ns	ns	ns	ns	**	**	ns
Natalia					ns	ns	ns	*	**	**	ns	ns	ns	ns
Yanti						**	*	**	**	**	*	ns	ns	**
Mori							ns	ns	ns	**	ns	**	**	ns
Aswita								ns	ns	**	ns	ns	**	ns
Sari									ns	ns	ns	**	**	ns
Nelson										ns	ns	**	**	ns
Ucok											ns	**	**	*
Gia												**	**	ns
Desi													ns	**
Paula														**
Eva														
Feeding														
Fatma		*	ns	**	**	ns	**	ns	ns	ns	ns	**	**	ns
Darmi			ns	ns	ns	ns	ns	ns	*	ns	ns	**	**	ns
Tria				**	**	ns	ns	ns	ns	ns	ns	**	**	ns
Natalia					ns	*	ns	**	**	**	ns	ns	ns	**
Yanti						*	ns	**	**	**	ns	**	**	ns
Mori							ns	ns	ns	ns	ns	**	**	ns
Aswita								ns	**	*	ns	**	**	ns
Sari									ns	ns	ns	**	**	ns
Nelson										ns	ns	**	**	ns
Ucok											ns	**	**	ns
Gia												**	**	ns
Desi													ns	**
Paula														**
Eva														

Resting

Fatma		**	**	**	**	**	**	**	**	**	**	**	**	**
Darmi			ns	**	ns	**	ns	ns	ns	**	ns	**	**	ns
Tria				ns	ns	ns	ns	ns	ns	ns	ns	**	**	ns
Natalia					*	ns	ns	ns	**	ns	ns	ns	ns	ns
Yanti						ns	ns	ns	ns	*	ns	**	**	ns
Mori							ns	ns	ns	ns	ns	ns	**	ns
Aswita								ns	ns	ns	ns	ns	**	ns
Sari									ns	ns	ns	ns	**	ns
Nelson										**	ns	**	**	ns
Ucok											ns	ns	**	ns
Gia												ns	**	ns
Desi													ns	ns
Paula														**
Eva														

Drinking

Fatma		ns	ns	*	**	**	ns	**	**	ns	ns	ns	ns	ns
Darmi			ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
Tria				ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
Natalia					ns	ns	ns	ns	ns	**	**	ns	ns	ns
Yanti						ns	ns	ns	ns	**	**	ns	ns	ns
Mori							ns	ns	ns	**	**	ns	ns	ns
Aswita								ns	ns	**	ns	ns	ns	ns
Sari									ns	**	**	ns	ns	ns
Nelson										**	**	ns	ns	ns
Ucok											ns	**	**	**
Gia												ns	ns	ns
Desi													ns	ns
Paula														ns
Eva														

Note: (**): Significant level P< 0.01 (*): Significant level P<0.05, (ns): Not Significant

1.2 Seasonal Changes on Feeding Habits

Grazing and browsing is the most common type of elephant feeding technique. In this study we classify grazing is the feeding type where elephant consumed grass and small herbaceous plants. Grass commonly consumed by elephant not just the leaves but also the entire clumps. Browsing we classify where elephant consumed foliage from shrubs, young tree, bark of the tree, and bamboo clumps. Several studies in highly seasonal environment as in South India and Southern Africa that elephant might shift their feeding habits in response to the food availability. For example; study in Kidepo Valley National Park, Uganda shows that elephant tends to browse more during the dry months (71.4%) and graze more during the wet months (57.1 %; Field and Ross, 1976). In Southern India, elephant feeding habits also shows similar pattern where about 70% of feeding in browse rich habitat during dry seasons (Sukumar 1989). In this study we investigate if the similar situation also occurs in the more stable environment like Sumatra.

The result of this study that there are negative relationship between rainfall and grazing (*F=6.25*, $R^2 = 0.36$, $P<0.05$; Figure 6). Or on the other word that elephants tend to less grazing during the rainy seasons.

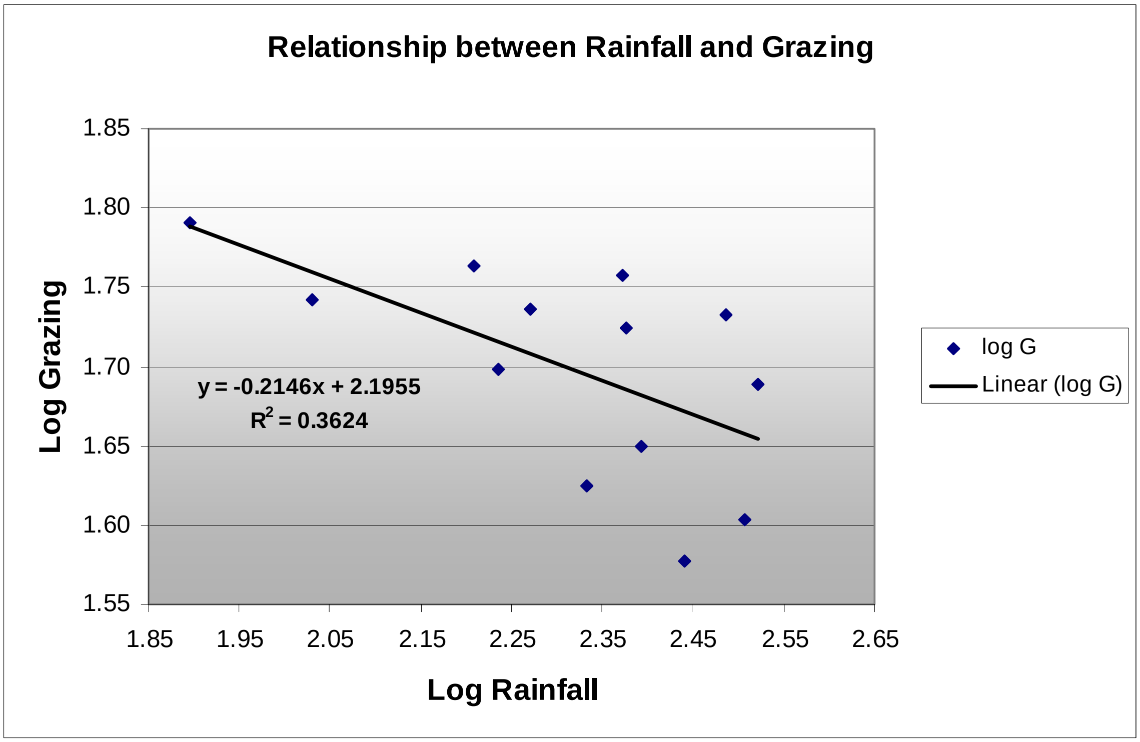

Figure 6. Relationship between rainfall (log rainfall) and grazing (log grazing)

In reverse we found elephant tend to browse more when rainfall increasing (*F=8.48*, $R^2 = 0.44$, $P<0.05$; Figure 7). The reverse relationship between grazing and browsing to the rainfall is expected as browsing and grazing is related observation. The finding from these studies is different from other elephant study in African and Southern Asia. Sukumar (1990) suggested from his study that elephant predominately grass diet during a wet seasons was related to the seasonally changing protein content of grasses. This probably true in Southern India where dominant grass species is tall grass such as *Themeria sp*. In this study we found protein content in grass species in Sumatra is less than 2% (Figure 9) therefore protein contents in grass might have small impact to overall feeding habits. Furthermore, overall rank of protein contents in plant family on elephant diet shows that grass family ranked in the 17^{th} (Familiy: Poaceae) over 24^{th} of other plant families (Figure 9). The rank analysis concludes that, grass in overall, might have small contribution to fulfill protein needs in elephant diet. On the other hand browse species have higher protein contents (Figure 9; eq Fam:Annonaceae, Burseraceae) than grass species (Figure 9; Fam; Poaceae) therefore if protein contents of browse species increase when rainfall increase (as explained from Sukumar 1990) thus there is a possibility that elephant prefer more browse diet then grass diet during the wet month in Sumatra.

Tabel 4: Proportion of browse and grass during the study in the elephant diet for each individual focal elephant in Sumatra

Elephant	Grass (%)	Browse (%)	Rainfall (mm)	Season
Natalia	55.22	44.78	107.00	dry
Yanti	49.85	48.14	172.33	dry
Paula	57.93	41.78	161.93	dry
Desi	61.71	37.63	78.50	dry
Eva	54.55	45.38	186.30	dry
Fatma	37.79	62.21	276.35	wet
Aswita	48.88	50.88	332.67	wet
Tria	53.05	46.95	237.65	wet
Nelson	44.63	51.33	247.00	wet
Ucok	57.21	42.23	236.17	wet
Sari	42.15	57.85	215.50	wet
Mori	40.15	59.83	321.50	wet
Gia	54.02	45.85	306.30	wet

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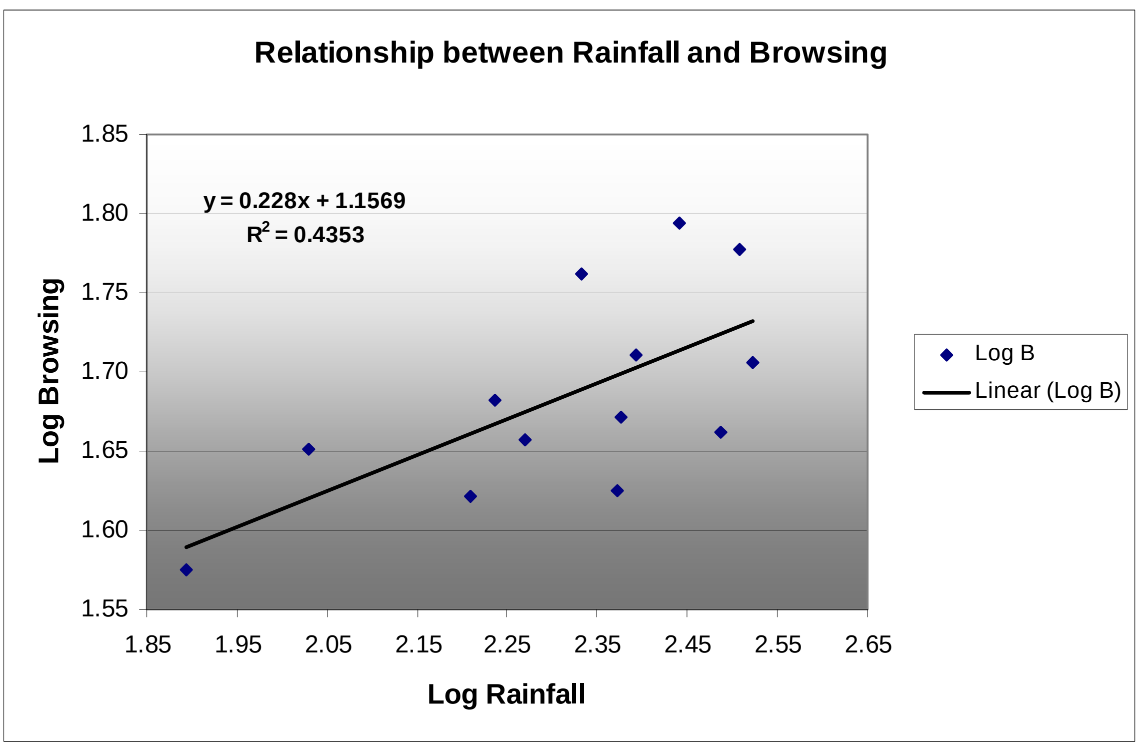

Figure 7. Relationship between rainfall (log rainfall) and browsing (log browsing)

1.3 FEEDING RATE

During the study period, we assess elephant feeding rate while grassing. Average elephant feeding rate on grass in Seblat ECC is **0.86** trunkful per minute (*SD=0.33 N= 39*). This finding is similar with the result found by Sukumar in Biligirirangans, India. This result might suggest that even though Indian and Sumatran elephant live in two different environmental character but they have similar feeding rate. This similarity is probably because Indian and Sumatran elephant has similar anatomical and physiological character. In contrast, compare to African elephant species, Asian elephant feed relatively less rapid (Table 5). Sukumar (2003) argue that as a quantity grass per trunkful is substantially higher in Asian elephant compare to African thus daily intake that expressed, as a percentage body weight is relatively similar. The important factor might affect the different feeding rate is probably because the species of grass eaten in African is relative different than grass species in Asia. We found in Sumatra grass availability in the elephant habitat mostly occurs in the riparian or swampy area. Elephant cleaned the root of the grass in the water or splash them into their feet before the grass consumed. This type of feeding behavior might not necessarily occur in Africa as the species of the grass is probably different.

Table 5. Comparison of feeding rate in Africa and Asian elephant from various studies and this study.

Locality	Sex	Season	Time of Observation	Trunkful/ minute (Grass)	Source
Sengwa (Zimbabwe)	F	Wet	Daytime	3.7	Guy (1975)
	M	Wet	Daytime	3.0	
	F	Dry	Daytime	2.0	
	M	Dry	Daytime	1.5	
Gounda-St Floris (Central African Republic)	F/M	Wet	Fulltime	5.2	Ruggiero (1992)
	F/M	Dry	Fulltime	5.0	
Amboseli (Kenya)	F	Wet	Fulltime	5.7	Lindsay (1994)
	M	Wet	Fulltime	5.4	
	F	Dry	Fulltime	3.5	
	M	Dry	Fulltime	4.4	
Gal Oya (Sri Lanka)	F/M	Wet/Dry	Daytime	1.4	McKay (1973)
Biligirirangans (India)	F/M	Wet	Daytime	0.8-1.7	Sukumar (1989a)
	F/M	Dry	Daytime	0.8-1.7	
Seblat (Sumatra)	***F***	***Dry***	***Daytime***	***0.86 (sd=0.33)***	***This study***

1.4. ELEPHANT NATURAL DIET

From March 2007 to February 2008 of study period we determined **189 species** of elephant diets that belongs to 56 families (Figure 8). Part eaten include, short and tall grass, bark, roots, liana forbs, twigs and leaves. From the identified sample we found the majority of elephant food in the natural habitat represented from the family of *Moraceae* (the mulberry family-18 species), *Fabaceae* (the legume family-18 Species) and *Arecaeae* (the rotan family-18 Species) and Poaceae (the grass family-16 Species; Figure 8). Similar finding was determined in Srilanka where plant from *Fabaceae* and *Poaceae* family is classified as important elephant diet in the natural habitat (Samansiri & Weerakoon 2007). For comparison, Robert Olivier (1978) listed over 400 species (+/- 78% were palms: *Arecaceae family*) as potential food for Asian elephant in Peninsular Malaysia in three years of his study period.

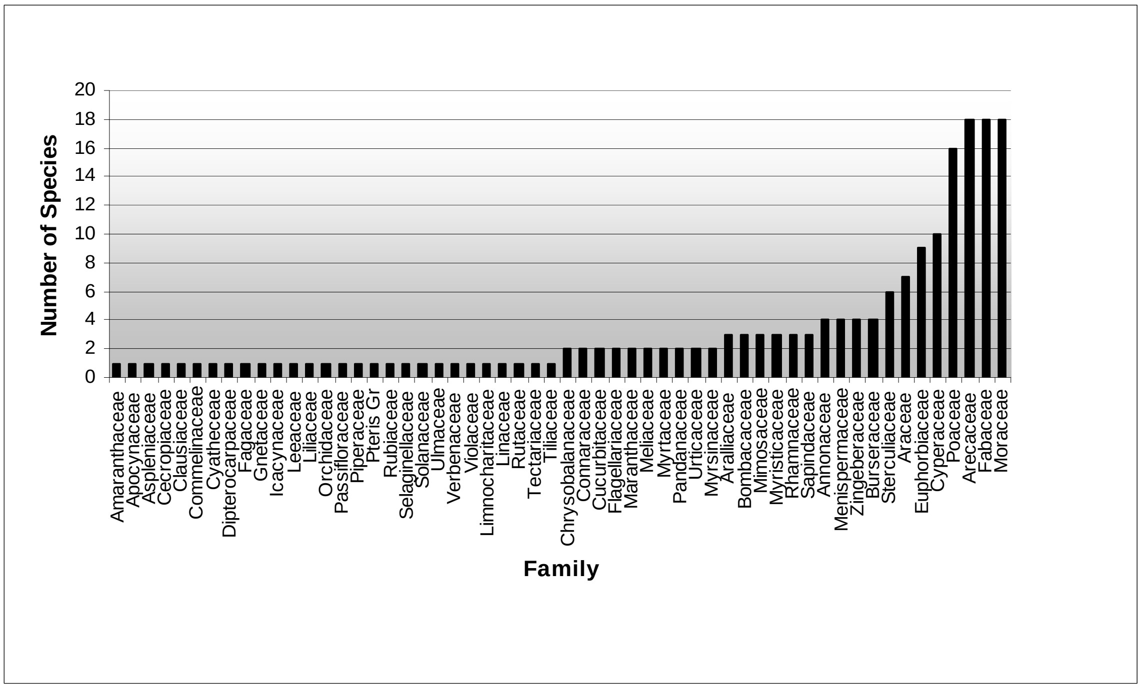

Figure 8. Elephant food in the natural habitat at the SECC, classified based on the taxonomic family.

1.5. CHEMICAL CONTENT ON ELEPHANT NATURAL DIET

We measure several chemicals content and Gross Energy of elephant diet to determine their importance in the wild habitat. Chemical content measured were Protein, Calcium, Phosphor. From the 71 samples measured we found elephant diet from family *Annonaceae* has the highest protein and Phosphor content compared to the other family, while *Palmae* family has the highest content of Calcium (Figure 9, 10 and 11). Gross Energy examination shows that plant from family of *Palmae* has the highest content of energy compare to other family (Figure 12).

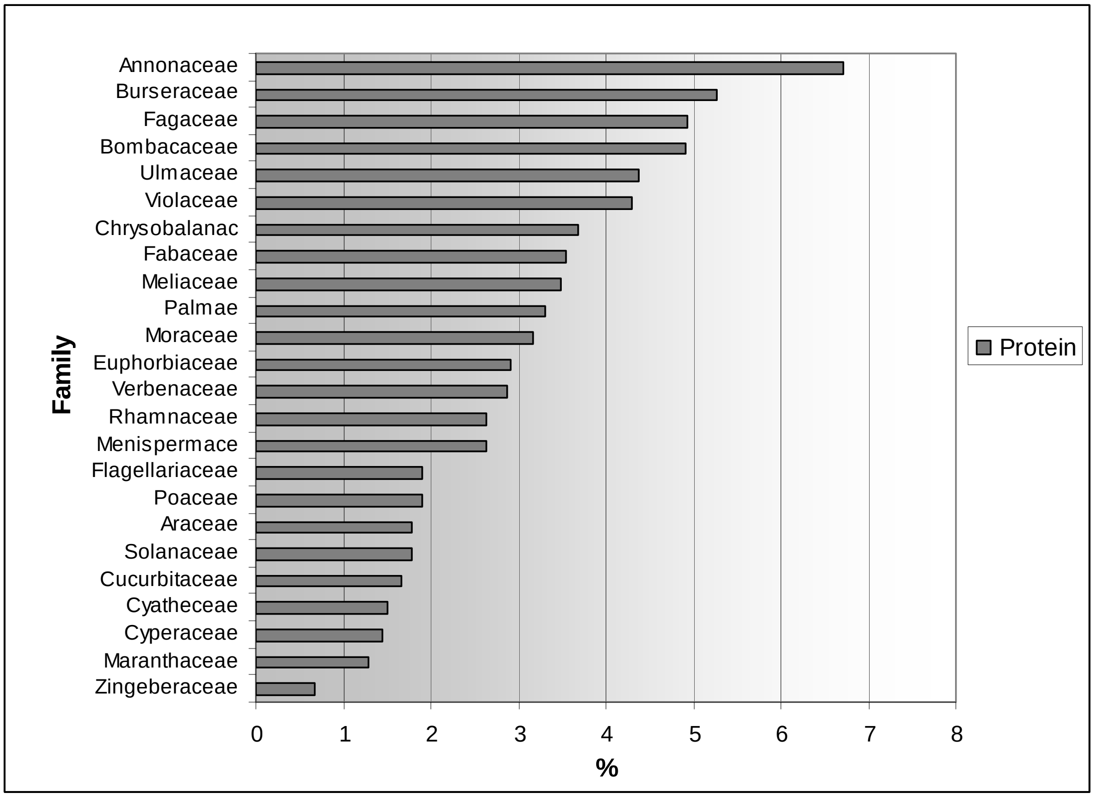

Figure 9. Various protein contents among elephant natural diet in SECC area.

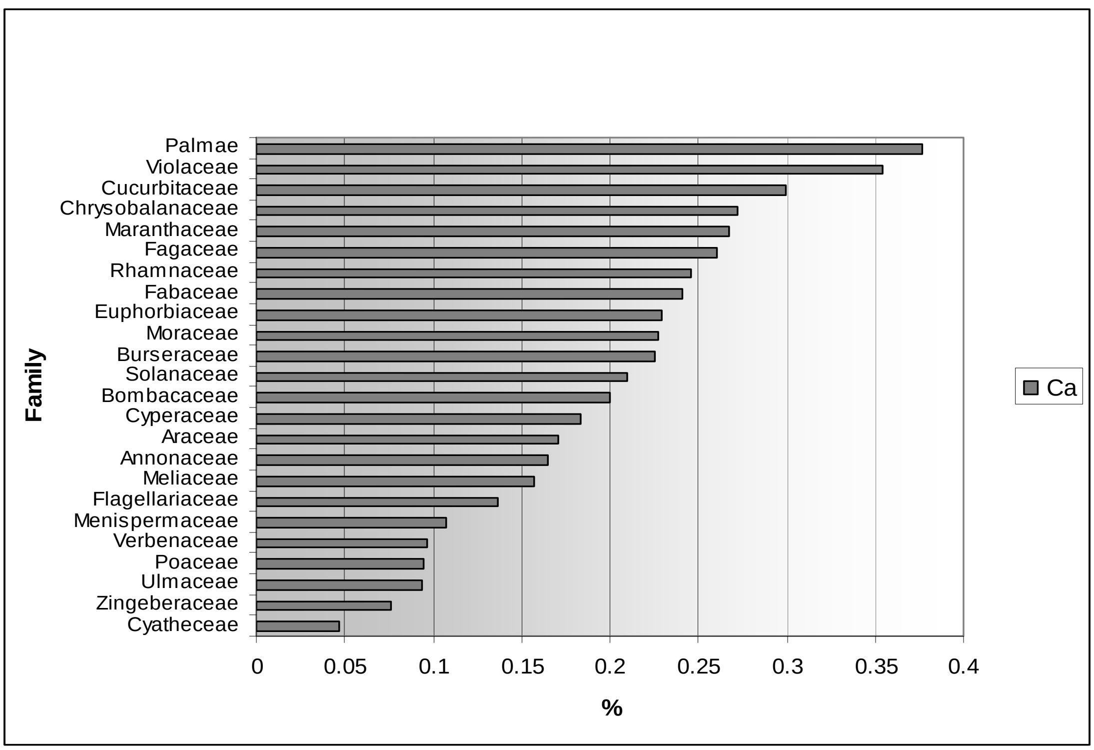

Figure 10. Calcium contents among elephant natural diet in SECC area

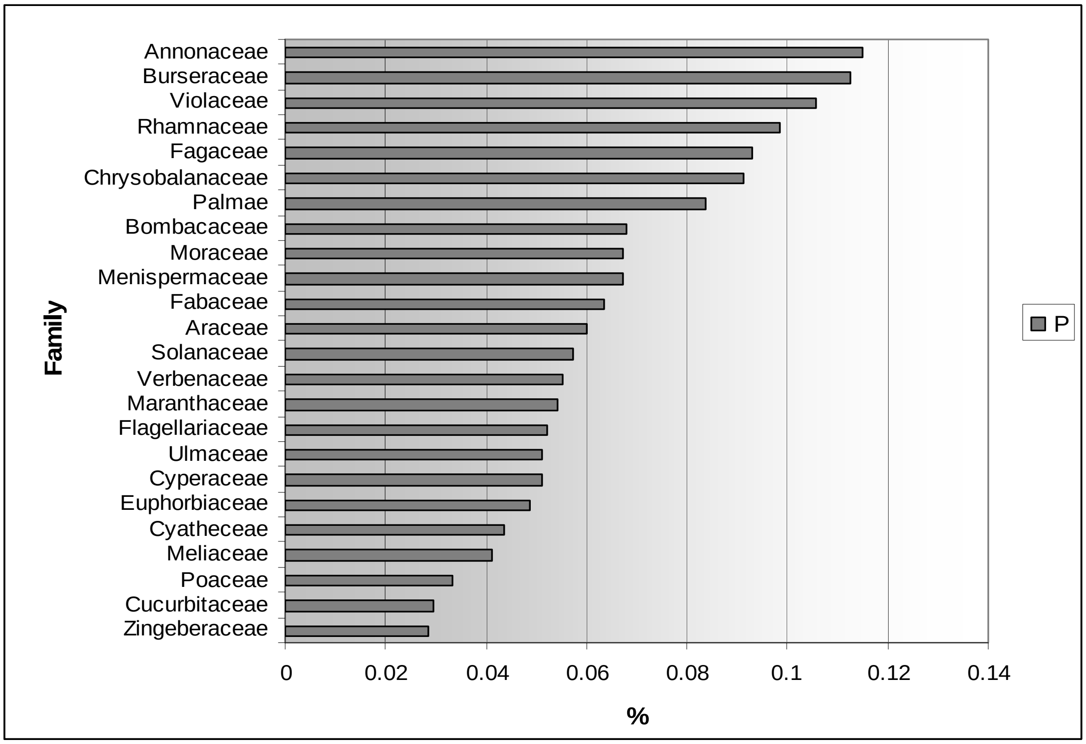

Figure 11. Phosphors contents among elephant natural diet in SECC area

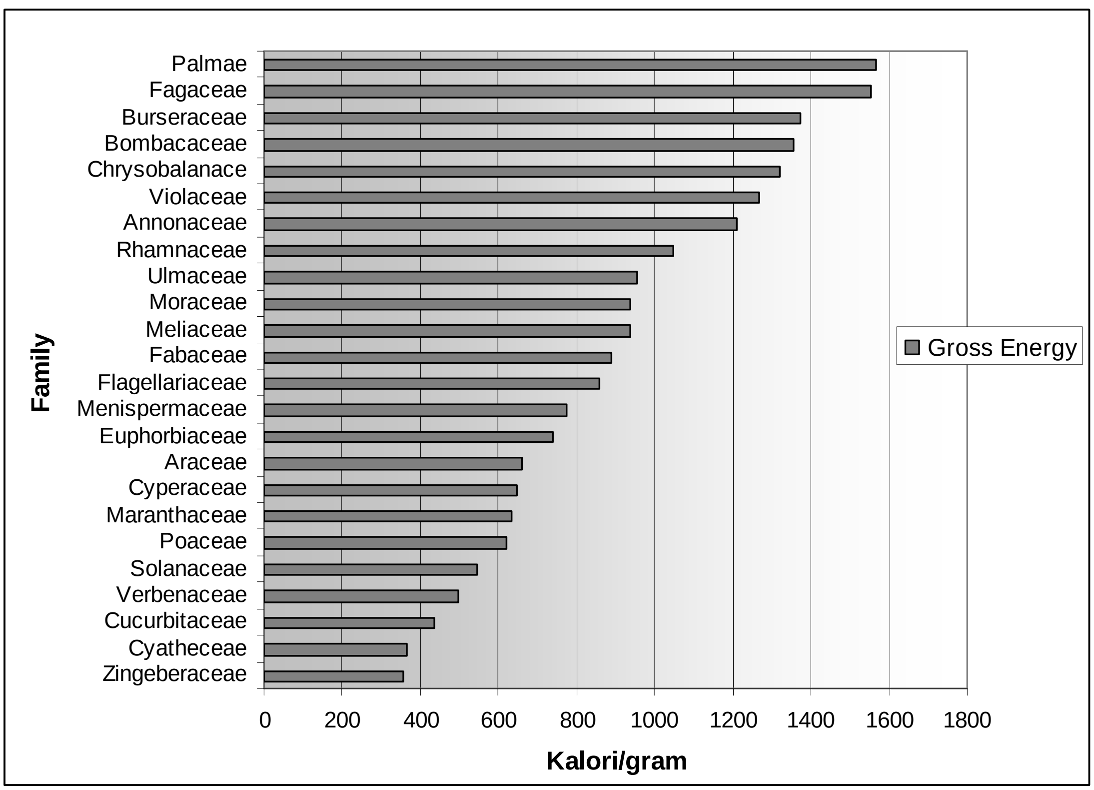

Figure 12. Gross energy contents among elephant natural diet in SECC area

2. HABITAT STRUCTURE

We complete setting up 30 phenology plots across study area. Within 1 km x 1 km grid we randomly locate five plots (10 m x 10 m). The spatial location of each plots were placed 100 meters apart in random direction. We tagged all tree above 10 cm dbh (**total =174 trees**). Tree density is on average of 5.8 per 100 m^2 (*SD= 1.9*). There is a strong relationship between tree diameter and tree height (*F= 237.7; df=1; P<0.001*; Figure 13). The tree structure within all sub plots shows that 90 % of the tree has dbh less than 25 cm (Figure 14). This result suggests that study area in the recovery phase after large tree were selectively logged in the past.

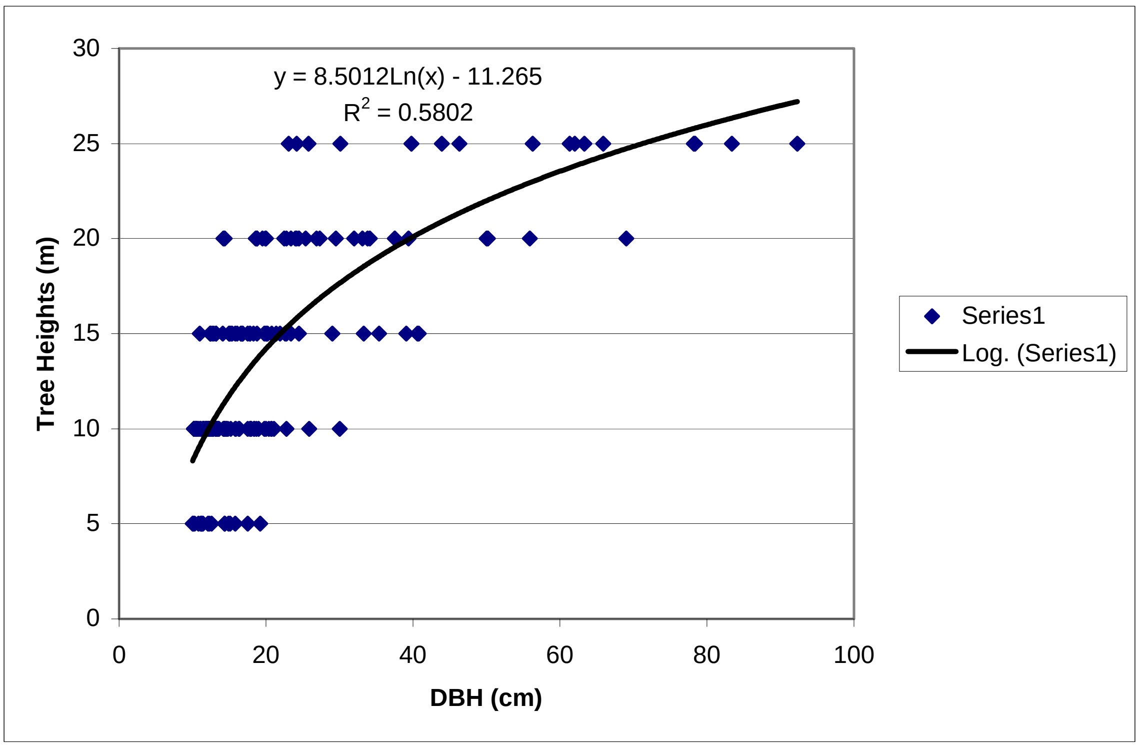

Figure 13. The relationship between tree diameter at breast height (dbh) and tree height across 30-phenology plots in SECC area.

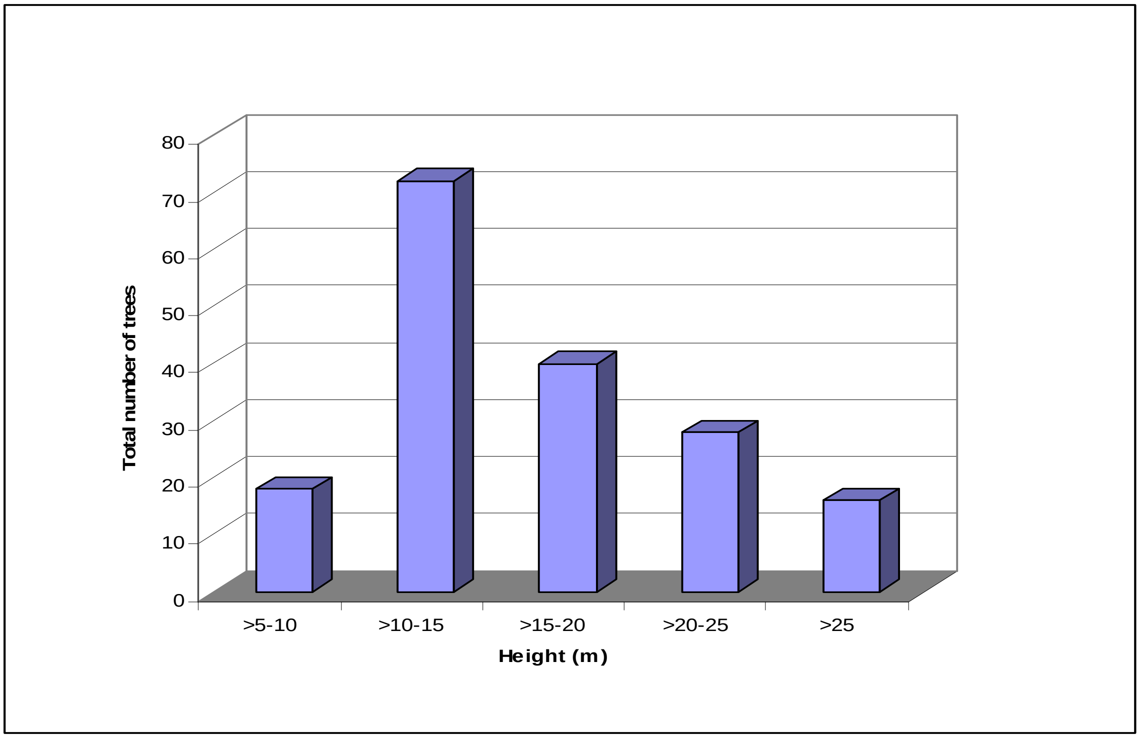

Figure 14.. Tree height distribution in 30 subplots (10 m x 10 m) across SECC area, all tree measured is in >10 cm dbh.

3. GPS TELEMETRY ON WILD ELEPHANT

3.1 Seblat elephant population

In August 2007, we successfully collared one adult female elephants in Seblat ECC. The adult female was found with male infant about 5 years old. We use GPS collar manufactured by African Wildlife Tracking (South Africa) and use Global Track satellite service provider. The collaring process was conducted in collaborative effort among CRU team (IEF, BKSDA and FFI Project), Forest Ranger from BKSDA Bengkulu, a staff from Way Kambas National Park (Nazaruddin) and a professional veterinarian (Wisnu Wardana, DVM). The collaboration work results successful collaring process. The whole process only took place in about 2.30 hours and is probably the fastest collaring process ever in the whole Asia. Collared elephant named **SENARA** and she was collared in northeastern part of SECC area (47 S 0801510 UTM X and 9657390 UTM Y; Figure 15).

We use standing sedation technique by applying 7 ml Xylazine (100 mg/ml), intra muscular, using long-range rifle tranquilizer gun. Elephant darted in the left part posterior of dorsal ilium (*gluteus maximus muscle*). We apply 4 ml Ketamine Hydrocloride 100 mg/ml, intra muscular using local injection technique to make sure that the elephant are fully sedated and save to be collared.

In the post collar process, we apply antibiotic 50 ml Penstrep (Procaine Penicillin G 200.000 IU & Dihydrostreptomycin sulphate 200 mg), intra muscular at the area were darting applied to make sure there will not be any infection from the sedation process. Garamycin ointment was applied to both elephant eyes to avoid eyes exposed to dehydration. Medical examination during the collaring process shows the respiration is 6 pulses per minute, heartbeat is 32 pulses per minute and body temperature is 36.1 ^{o}C. Blood sample (10 ml) was also taken for further health examination. We send the sample to the medical laboratory for EDTA and CBC test. Finally physical measurements were also conducted. Circumference of front leg (FL) is 120 cm; rear leg (RL) is 125 cm; shoulder height (SH) 217 cm; total body length (TBL) is 280 cm; and breast circumference is 350 cm.

After the collaring process we then start monitoring the elephant movement using global track online satellite system (www.globaltrack.co.za). Data on point location are collected three times per day in eight hours interval. Data collected at 02.00 hours GMT, 10:00 hours GMT and 18:00 hours GMT. GPS login time per data collection was set up in 9 minutes period. GPS login time will be evaluated in the next three months period and will be increased if necessary. We linked the data to Google Earth (http://earth.google.com) for visualisation in the map and we found that within seven days after collaring process, Senara moved at least 11 km from the collaring location.

3.2 Pondok Suguh elephant population

In April 2008 we collared another adult female in the area of Batu Setepah, Pondok Suguh, Muko-muko District. We use same technique as we applied before with the first elephant. Elephant was located at the (47S 0778870 UTM X and 9679340 UTM Y). Medical examination during the collaring process shows the respiration is 20 pulses per minute, heartbeat is 40 pulses per minute and body temperature is 37.2 ^{o}C. Blood sample (10 ml) was also taken for further health examination. We send the sample to the medical laboratory for EDTA and CBC test. Finally physical measurements shows: Circumference of front leg on left side (FL) is 106 cm; rear leg on left side (RL) is 101 cm; shoulder height (SH) 194 cm; total body length (TBL) is 240 cm; and breast circumference is 290 cm. Female elephant called **SUGUH.**

We encounter a problem during the collaring process when one of the team members lost the weight to balance the GPS collar while we search for wild elephant. We decided to continue fitting the GPS collar without the weight as we expect the collar will stay balance if the tightness of the collar is appropriate to maintain the balance. However, the GPS collar does not seems work properly without weight attached to the collar.

During period of June 2008 until December 2008 we conduct ground telemetry to locate SUGUH. Steep terrain and thick vegetation prevent us to locate the elephant. During six month period (1200 tracking days) we only locate her once in July 2008. We found the elephant 12 km north-east of the area when we collared her. After six month effort of ground telemetry we decide to stop tracking the elephant. Limited data on the second elephant prevent us to conduct more analysis.

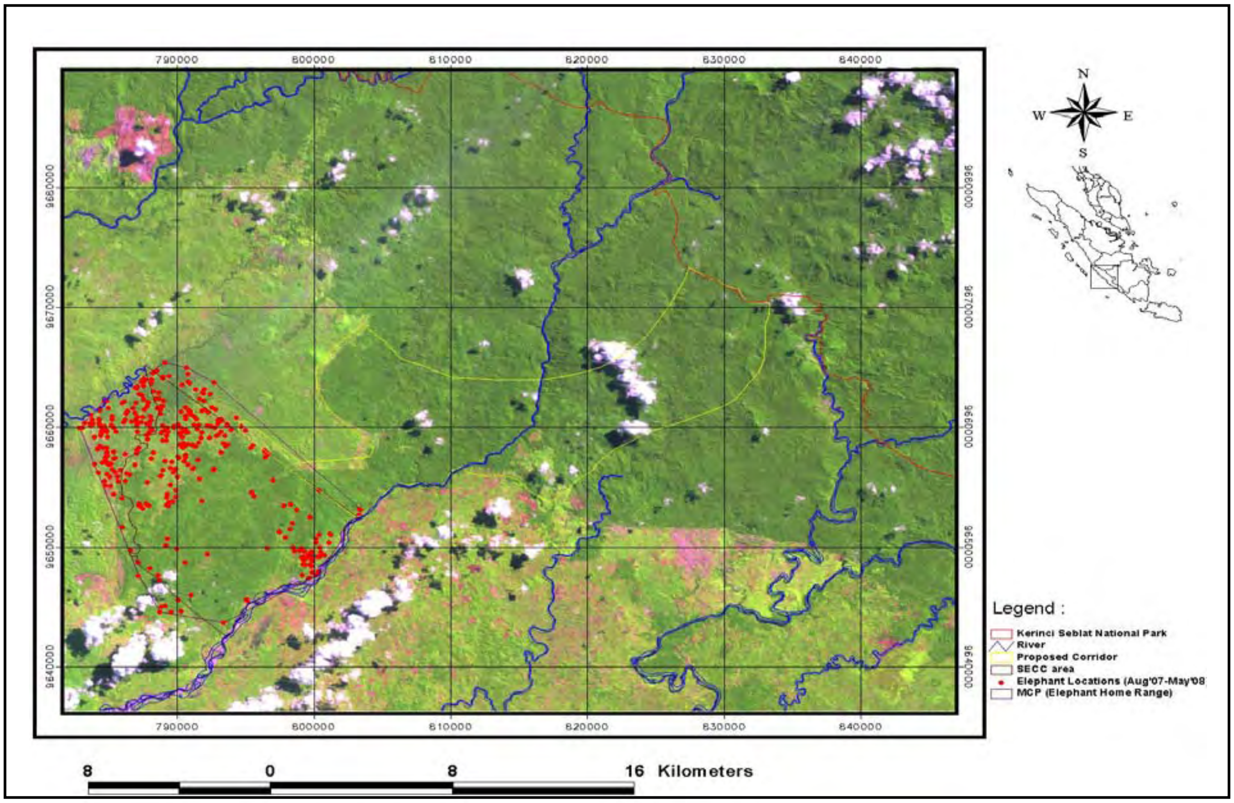

Figure 15. Elephant locations (SENARA, unit # ***DCC004EEE36*** *in SECC within the period of August 2007-May 2008.*

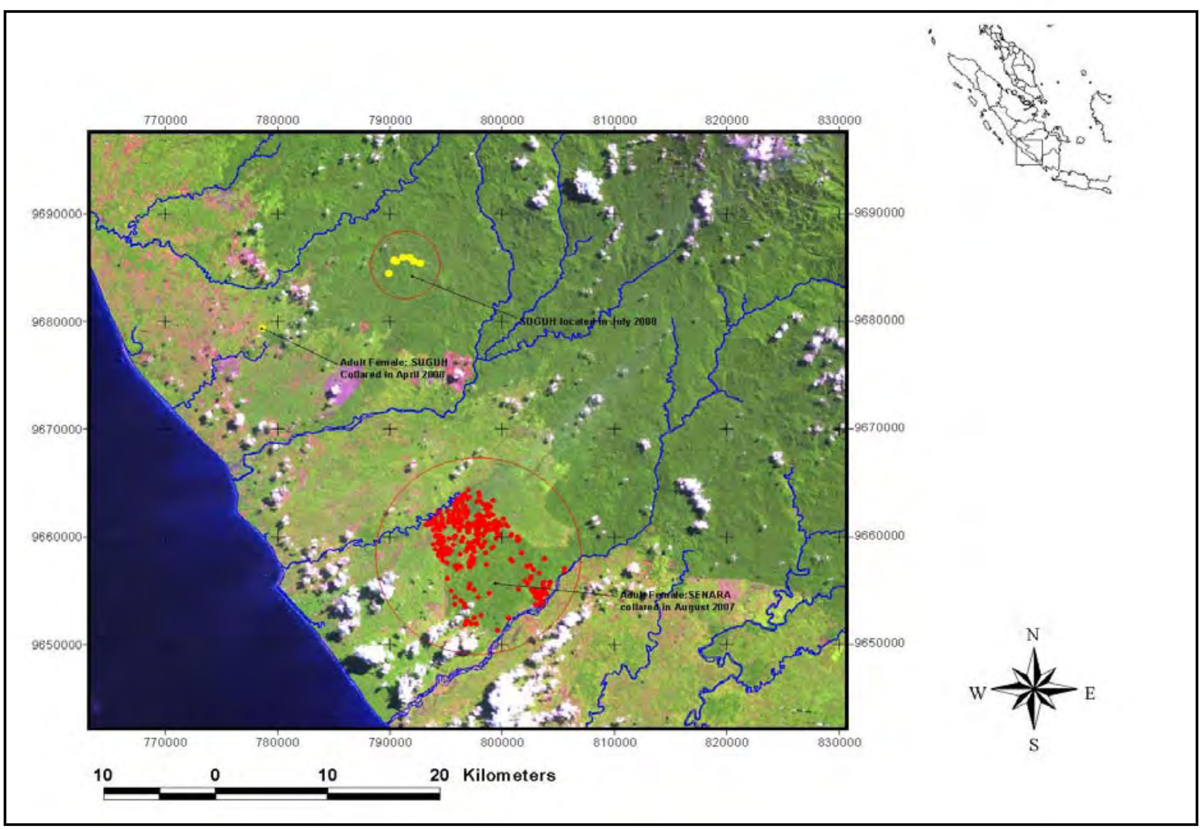

Figure 16. *Elephant locations-(Adult Female: SUGUH, unit #* ***DCC0048BFC40*** *in Pondok Suguh)*

4. HOME RANGE ESTIMATE

Total of 357 locations were collected during period of August 2007 to May 2008 for SENARA. From all the elephant location, 43.1 % (143 point locations) were determined to be the outside of the Seblat ECC area. This result shows that habitat availability in Seblat ECC area is probably not large enough spatially to support elephant population. Furthermore, elephant seems to prefer area with more open canopy (Figure 17). This result shows that open area seems to have more food than closed canopy area for elephant. Grass vegetation, herbs and shrubs is more abundant in the open forest therefore elephant is using this type habitat more often then other type of habitat

Elephant home range size was determined in three home range estimator. The tree home range size estimators are: ***Minimum Convex Polygon (MCP)***, ***Jennrich-Turner estimator*** and ***Kernel-based estimator***. Using 100% MCP method we estimate elephant home range in SECC area is 9744.27 ha (97.44 km^2). The Jennrich-Turner method (95%) estimated the elephant home range is 13,927.5 ha (139.28 km^2). The Kernel home range estimates provide elephant home range is 9496.85 ha (94.97 km^2; Figure 18). For the Kernel estimation we use 95% fixed Kernel estimate which only incorporated 95% home range used.

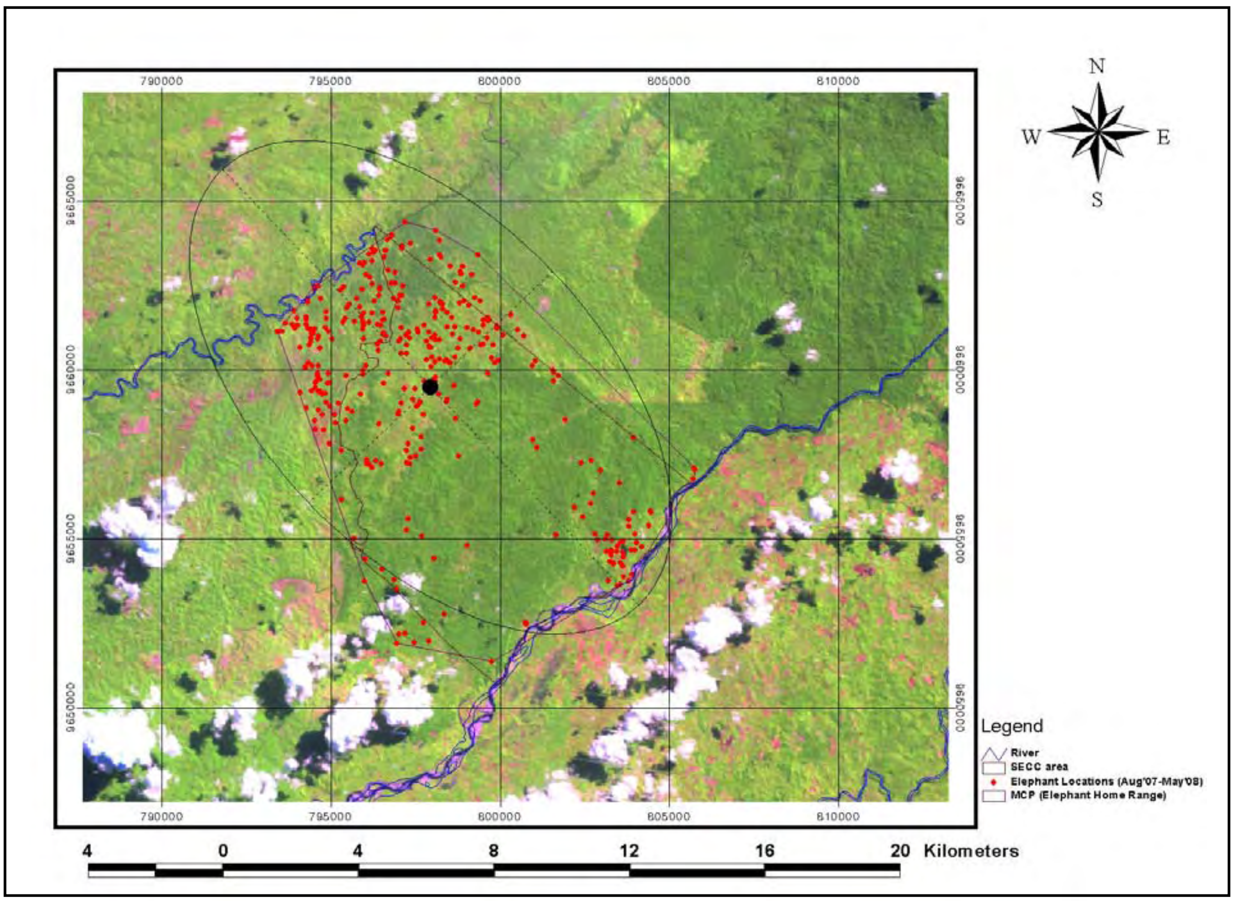

Figure 17. Elephant home range calculate using Minimum Convex Polygon and Jennrich-Turner (95%) method represent by the ellipsoid map across all point locations.

Three home range estimates used in this report gives different results because each method use different approach for calculating home range sizes. The MCP method calculates the home range size connecting the outer point of elephant location and forms a convex polygon (Mohr 1947). MCP has been widely used however the result is very sensitive to the sample size and more importantly total area estimated give no indication of use (Schoener 1981; Osborn 2004). The Jennrich-Turner method assumes the spatial model for home ranges is bivariate normal probability of distribution. The estimator assumes there is a like central mode for both x-axes and y-axes of the home range, then associate and ellipse with the x and y-axes centered at the mode with bivariate normally distributed axes (Jennrich and Turner 1969). The Kernel home range is mostly used because of non-parametric approach and home range is determines by density probability using known location. Most scientists seem to agree that Kernel method gives the most reliable estimates of animal home ranges and core areas (Worton 1989, White and Garrott 1990, Seaman and Powell 1996). The comparison of home range sizes in various studies with this study is presented in Table 5.

Table 5. Male and Female elephant home range sizes comparison from various studies in Africa and Asia. The home range size calculated using Minimum Convex polygon 100%.

Location	Sex	# elephants	Home range Size (km2)	Annual Rainfall (mm)	Reference
Asia					
South India	Male	2	170-320	900	Sukumar 1989
Malaysia	Male	4	32-60	2500	Olivier 1978
South India	Female	2	105-115	900	Sukumar 1989
Sumatra	***Female***	***1***	***94.97***	***3005****	***This study***
Africa					
Namibia	Female	7	5800-8700	315	Lindeque and Lindeque 1991
Amboseli NP	Female	6	2756	350	Western and Lindsay 1984
Laikipia	Female	4	450-500	750	Thoules 1996
Hwange NP	Male	7	1300-2981	632	Conybeare 1991
Sengwa	Male	9	322	688	Osborn 1998
Queen Elisabeth NP	Male	6	500	900	Abe 1994

Note:
(*) Rainfall from April 2007-March 2008 (12 months)

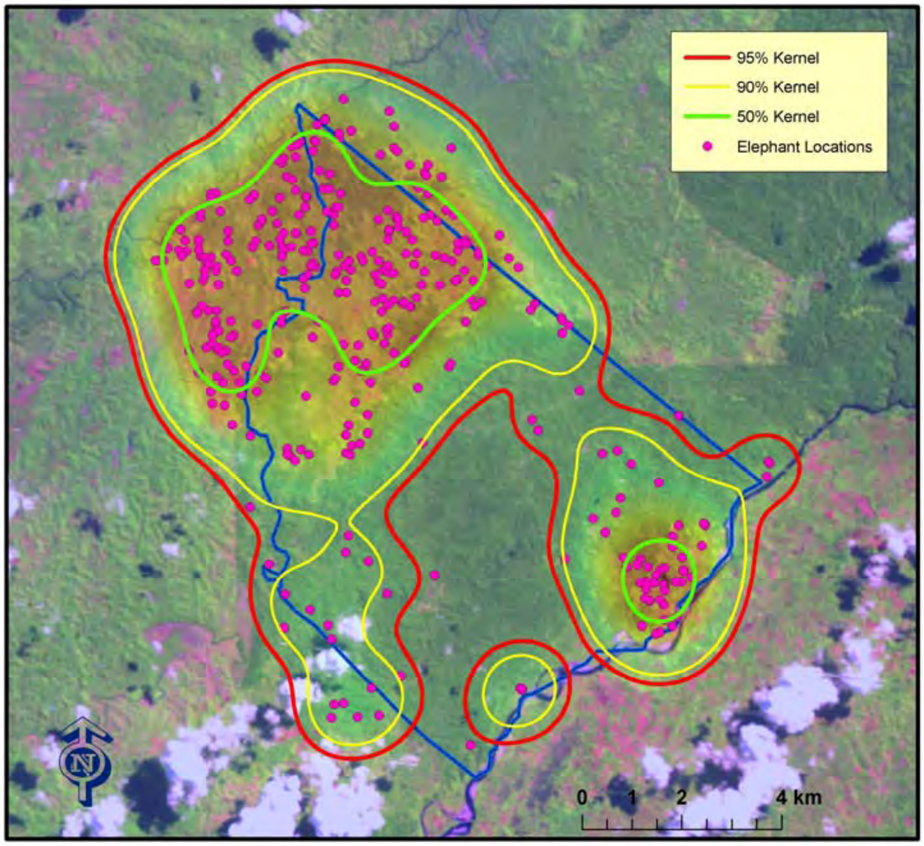

Figure 18. Elephant home range using Kernell estimator (fixed 95%, 90% and 50% home range estimate)

4.1. MOVEMENT AND RAINFALL

In this study we investigate the relationship between total elephant movement per month with monthly rainfall. We use Spearman correlation test to investigate the relationship between the two parameters. The results show that there is no relationship between total elephant movement and monthly rainfall $R_s = 0.310, P=0.456, n=8$. This result shows that water availability in Sumatran rainforest probably relative stable in year around; therefore elephant movement might not affected by water availability. Telemetry data shows that elephant in Seblat prefer open habitat rather than closed canopy habitat and concentrate in Seblat ECC area. There were no seasonal movement within Seblat ECC area. We predict human activities in surrounding habitat play important role one determining elephant movement. High human activities (palm oil plantation and encroachment) clearly limit elephant to move further from Seblat ECC. Elephant can only move only as far to the natural boundary of Air Rami river in the north- east side of Seblat ECC area (Figure 18). Elephant could not move further across the river is as the plantation company build electric fences. High human activities in the palm oil companies in the north-west and south-east of Seblat ECC also limit elephant to move beyond that area. Based on this result we conclude that Seblat ECC is the only available habitat left for wild elephant in this area. In size little over than 6000 ha is clearly not enough to support elephant population. Immediate, management intervention is needed to ensure elephant population to move further from isolated habitat such as in Seblat.

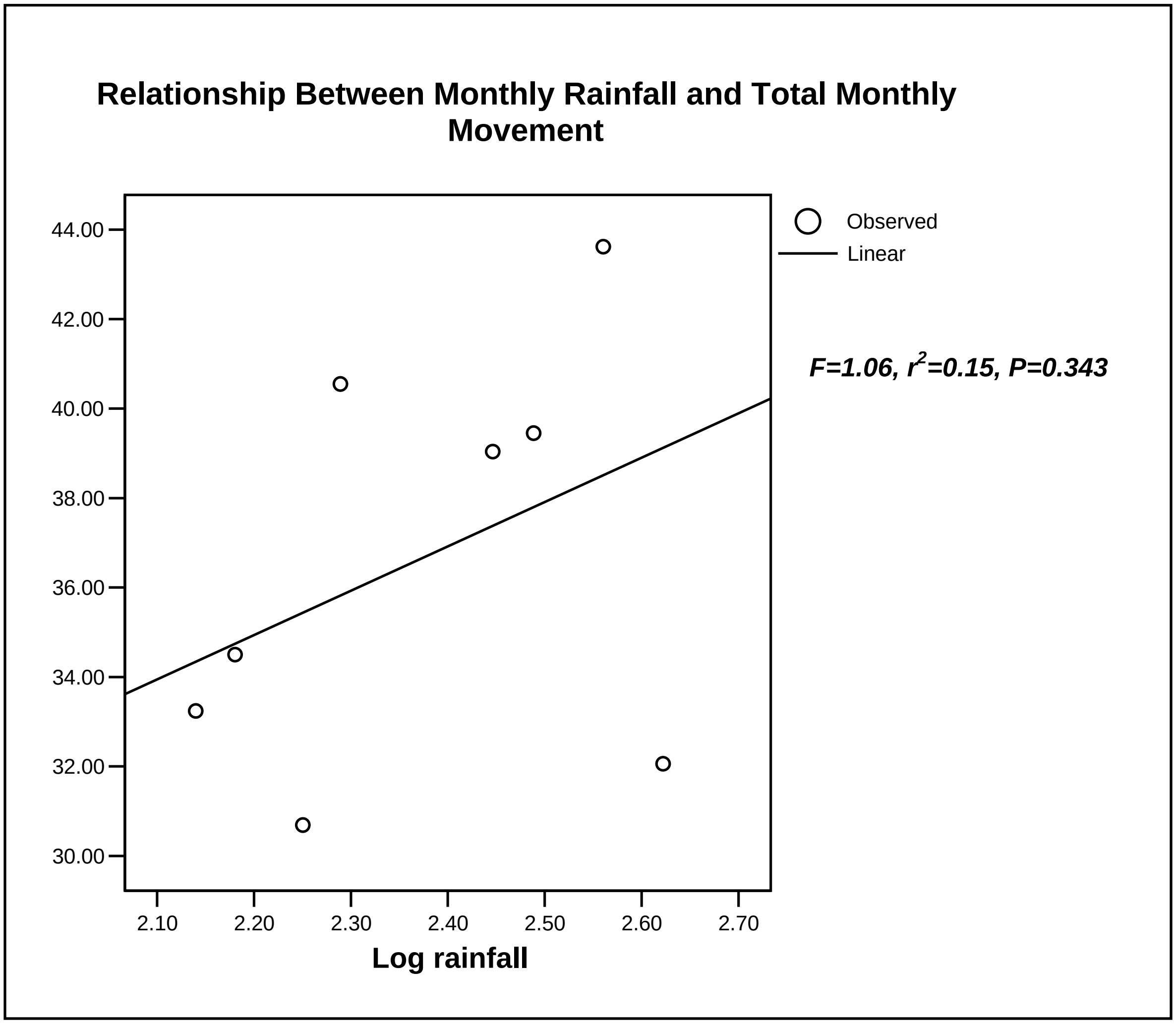

Figure 18. Regression test shows there is no linear relationship between total monthly rainfall and total monthly elephant movement (km).

4.2 HOME RANGE AND RAINFALL

Compilation data from several studies of elephant ranging studies in Asia and Africa shows there is weak correlation between rainfall and home range sizes (Osborn 2004). The studies shows that probably there are more factors may influence home range size than just rainfall and primary productivity (Osborn 2004). This study shows similar results, where rainfall might have no effect to elephant home range (Figure 19). Osborn (2004) argues that in Africa human settlement might have play important role on determining elephant range. This study supports that argument, where elephant in Seblat Elephant Conservation Center, could not expand their range due to the high intensity of human activities around their habitat (ie. palm oli plantation and encroachment).

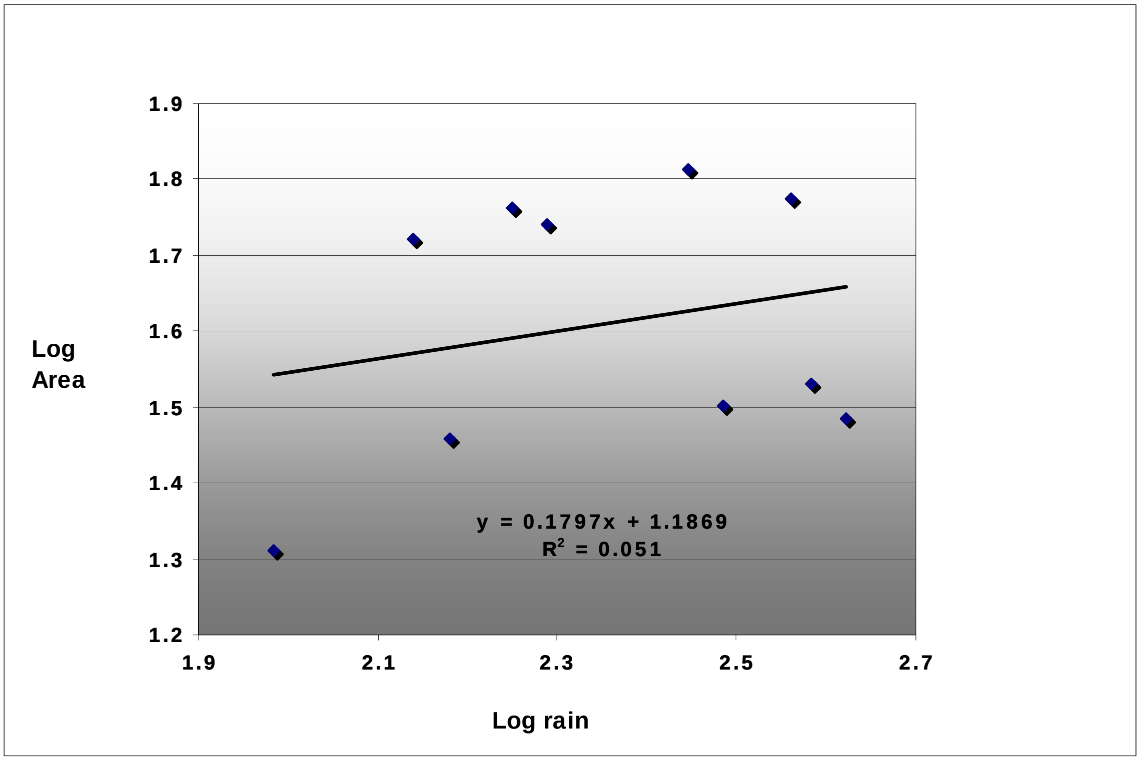

Figure 19. Monthly home range (Kernell 95%) compared with monthly rainfall in Seblat. Sumatra.

5. CROP RAIDING PATTERN

We collect data on crop raiding by elephant around Seblat ECC area. During this study we did not found any conflict around the village near Sebla ECC area. Instead conflict is more often occur in the palm oil plantation adjacent to the Seblat ECC area. Total of 17 incidents during period of February 2008 to March 2009 was recorded (Figure 20). During this period it was estimated about 2800 young palm oil tree was damage by elephant. Total economic loss duet to this incident estimated about US $ 14,000 (assuming cost per tree is US$ 5 per tree planted). Currently there are no significant human elephant conflict mitigation have been taken by the company.

Human elephant conflicts are rarely occurring in the villages adjacent to Seblat ECC are is partly because of the Seblat river act as a natural barrier preventing elephant to move across. Furthermore, study in Way Kambas National Park, shown that elephant are much more attracted to crop such as rice, and corn (Sitompul 2004). Local community lived adjacent to Seblat ECC area mostly plant palm oil and most of these trees already in a mature stage therefore is most likely less palatable to the elephant. Elephant is more attracted to the young palm oil tree rather than to the mature one. Based on this result we identify that human elephant conflict is not a critical problem for the local community lived in the adjacent villages. Small number of elephant incidents during the periods results that developing predictive model for crop raiding by elephant could not be done.

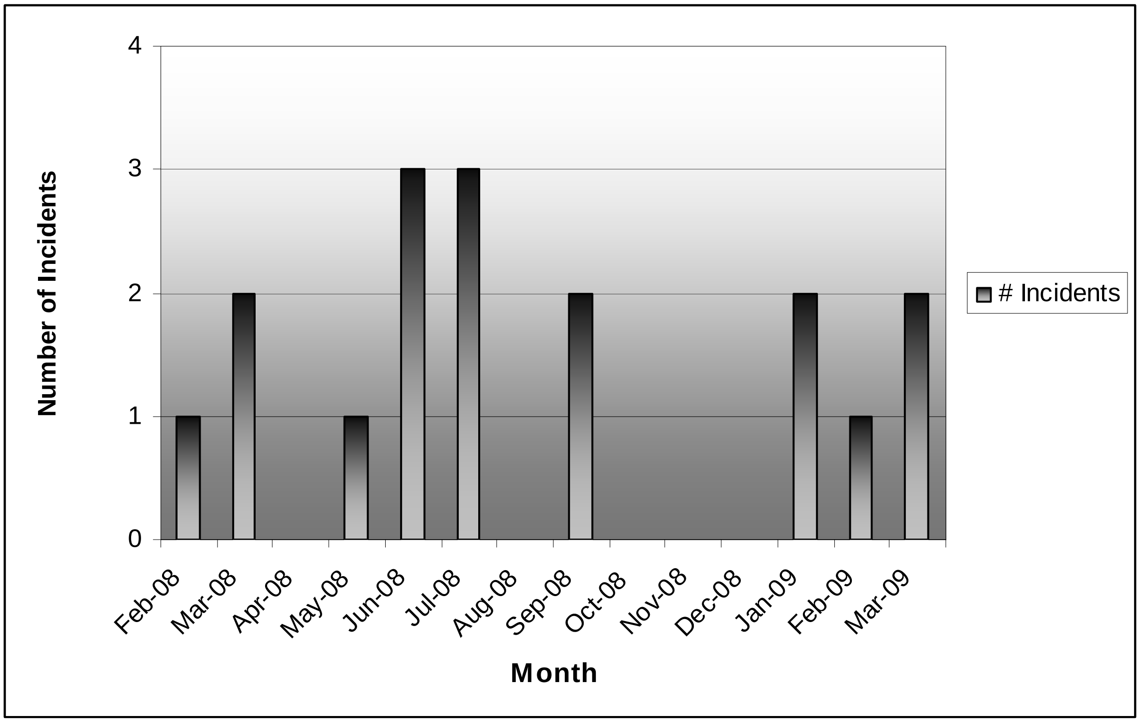

Figure 20. Elephant incidents on the Palm oil plantation PT. Agricinal during period of February 2008 to March 2009.

6. SEBLAT CORRIDOR

The GPS locations data shows that elephant population in Seblat ECC did not use corridor area that connects Seblat ECC to Kerinci Seblat National Park (Figure 16). This situation most likely caused of the high human activity within the corridor and surrounding area. Until January 2008 we found at least 400 families encroach the corridor area. Furthermore, palm oil plantation (P.T ALNO AGRO UTAMA) in the North-East area of the Seblat ECC intensively convert elephant habitat into palm oil plantation. This large scale habitat conversion caused more likely elephant in Seblat ECC could not move to the area further north towards Kerinci Seblat National Park. In the North-West area, another palm oil plantation PT. DAYA DHARMA PRATAMA also prevents elephant population in Seblat ECC to move to the northwest area across of Air Rami river. In the South-West, PT AGRICINAL also expands the palm oil plantation to the adjacent boundaries of SECC. This activities cause high human elephant conflict, where hundreds of oil palm plants raided by elephant each year. Based on this study we found no evidence that elephant using the corridor area. However, it still premature to conclude corridor area is not suitable habitat for elephant. We argue, human activities in the corridor area are most likely preventing elephant to use the corridor. In the past, survey conducted by CRU found elephant sign in the corridor area (Heidi Riddle *pers.com*). Thus is most likely high intensity of encroachment in the corridor area prevent wild elephant using corridor area as their habitat.

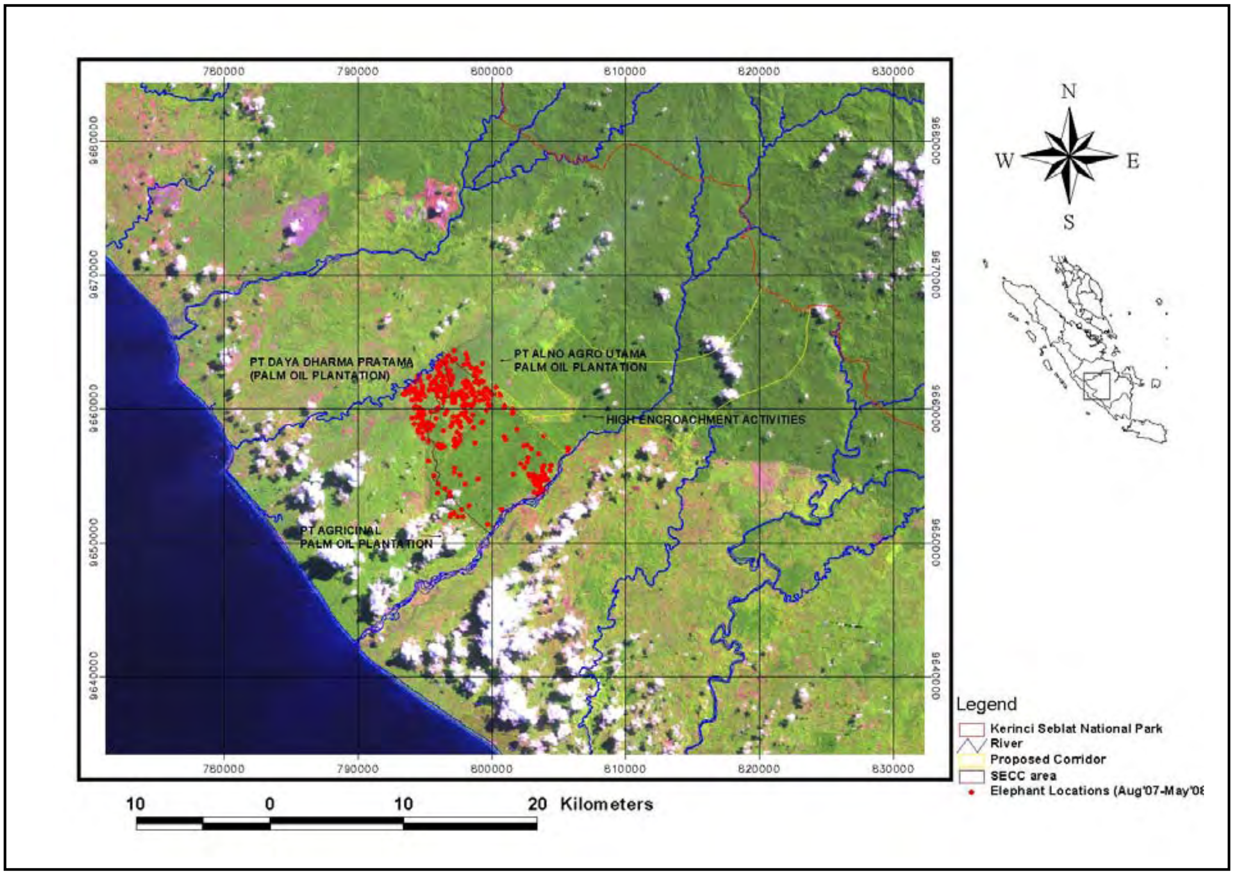

Figure 20. Elephant population in SECC area and human activities in the surrounding area.

7. OTHER ACTIVITIES

- Project investigator (PI) has been actively involved in the discussion on elephant conservation at the national level. The PI had been appointed as a key speaker to represent elephant scientist group on the Sumatran and Kalimantan Elephant and Sumatran Tiger National Action and Strategic Plan Workshop. The workshop was held in three stages and hosted by Indonesian Government, Ministry of Forestry. The first and second workshop called Focus Group Discussion (FGD I and II). FGD I, was held in Cisarua, West Java on the 25-26 July 2007, FGD II was held in Taman Safari Cisarua, West Java on the 21-22 of August 2007, and the final workshop was held in Padang, West Sumatra on the 29-31 of August 2007. The main objectives of this workshop are to develop action and strategic plan for Elephant and Tiger Conservation in Indonesia and also to develop conflict mitigation protocol.
- In January 2008, PI led socialization of the National Action and Strategic Plan for Sumatran and Kalimantan elephant document in Riau province. The meeting was held by Indonesian Minsitry of Forestry, Directorate General of Forest Protection and Nature Conservation. As a result of this socialization process, Riau Natural Resource Conservation Agency (BKSDA Riau) has agreed to stop capturing wild elephant as response to mitigate human elephant conflict in Riau province. In the last ten year BKSDA Riau have already capture 221 elephant from the wild.

- In October 2008, PI was invited to attend range-wide mapping and strategic conservation planning workshops for Asian Elephants in Cambodia. PI attends the meeting with the representative from Indonesian Ministry of Forestry and other conservation organization who works on elephant conservation in Sumatra. The results of this meeting is an update of distribution maps, a detailed status report, and a conservation strategy for Asian Elephants in both South and South-east Asia

8. PROBLEM ENCOUNTERED

There are some problems encountered during March 2007- December 2008 period.

1. There were few delayed on elephant feeding ecology study in the month of August due to the half of the total mahouts (15 out 30) were sent to North Sumatra Province for government staff recruitment training program in three weeks. This situation had significant impact to our observation schedule. Mahouts who stayed in camp need to handle all elephants (21 elephants) for bathing, and moved them to the feeding ground, therefore there were not any mahouts available to accompany this study.
2. Earthquake in Bengkulu province area on the 12 September 2007 damaged a few of our mahout's house. The epicenter was located in 80 miles east west of Bengkulu Province coastline. However none of the mahouts and their family was found injured. Some delay on feeding ecology study occurred because of this event.
3. In the period of 19-25 April 2008, Veterinary Society for Sumatran Wildlife Conservation (VESSWIC; represented by Mr. Christopher Stremme) conduct de-worming medication on 13 SECC's elephant without any coordination beforehand with the Project Investigator. De-worming medication causing unusual behavior to the elephant used in this study. The behavioral effect found such as loose appetite, tremor and loose of coordination. Poor coordination by Vesswic cause some delay in this project as we need wait until elephant condition back to normal condition.

9. CONCLUSION

Several important finding was determined from this study. From this study we now have better understanding on elephant behaviour ecology particularly on feeding ecology and habitat use in Sumatran elephant. The results of this study can be use for further management action to protect Sumatran elephant from the extinction. In this study we conclude that:

- Sumatran elephant daily activity dominated by feeding and followed by moving activity. Time activity budget of Sumatran elephant is greatly overlapped with African elephant and other sub species of Asian elephant in India and Sri Lanka. However, even the pattern of the activity budget is relatively similar, comparison of each daily activity among individual elephant shows most of the individual elephant are different.
- Sumatran elephant predominantly browse diet during wet month and with grass diet during the dry month, this was probably related to the protein contents in browse diet mostly higher than grass diet in Sumatra. Therefore, when browse diet abundant during wet seasons elephant feeding behavior was shift to browsing.
- Sumatran elephant feeding rate on grassing was relatively similar compared to Indian elephant but different to African elephant. This result is probably due to similarity on anatomical and physiological character between Indian and Sumatran elephant. In this regard, there is a possibility that anatomical and physiological character is more important than environmental character on determining elephant feeding rate.

- Sumatran elephant at least consume **189 species** that belongs to 56 families of plants in their habitat. Major elephant diets belong to family of *Moraceae* (the mulberry family-18 species), *Fabaceae* (the legume family-18 species) and *Arecaeae* (the rotan family-18 species) and Poaceae (the grass family-16 species).
- Elephant diet from family *Annonaceae* has the highest protein and Phosphor content compared to the other family, while *Palmae* family has the highest content of Calcium. Gross Energy examination shows that plant from family of *Palmae* has the highest content of energy compare to other families.
- Size of elephant home range in Seblat is depends on method used to calculate the home range. Using 100% MCP method we estimate elephant home range in SECC area is 9744.27 ha (97.44 km^2). The Jennrich-Turner method (95%) estimated the elephant home range is 13,927.5 ha (139.28 km^2). The Kernel home range estimates provide elephant home range is 9496.85 ha (94.97 km^2).
- During this study we found there was no relationship between rainfall neither with home range nor with elephant movement in Sumatra. This result shown that elephant home range and movement are not related to the dry and wet season.
- Total of 17 incidents during period of February 2008 to March 2009 was recorded in adjacent palm oil plantation company (PT Agricinal). Human elephant conflicts are rarely occured in the villages adjacent to Seblat ECC.
- Based on our telemetry data we found no evidence that elephant using the corridor area. . As the vegetation structure and topographical condition of the corridor is relatively similar to Seblat ECC, we argue that human activities in the corridor area prevent elephant to use the corridor area.

10. RECOMMENDATION FOR CONSERVATION

Seblat ECC is considered as one of the important elephant populations in Sumatra. Seblat ECC provide suitable habitat for wild elephant. However, size of the area might not large enough for elephant to move in a long term. Conservation action for elephant population in Seblat should focus on developing habitat connection to other population and restoring habitat. Habitat restoration need to prioritise on planting important vegetation for elephant diet such as plants from family *Moraceae* (the mulberry family), *Fabaceae* (the legume family) and *Arecaeae* (the rotan family) and *Poaceae* (the grass family).

Secondary growth habitat shows much more suitable habitat for elephant compare to the primary growth habitat. Better land use planning that incorporating all ex- logging concession as connected habitat for elephant is critically important. Habitat mosaic that incorporates different habitat structure is important to maintain elephant movement in a landscape level. Ex- logging concession should not be converted to plantation. In North Bengkulu District and Muko-Muko District we identify at least 5 ex-logging concessions are critical habitat for elephant. These ex-logging concessions are; **Production Forest Air Rami, Production Forest Air Teramang, Limited Production Forest Lebong Kandis, Limited Production Forest Air Ipuh 1 and Air Ipuh 2**. These ex-logging concessions are in fact is a contiguous habitat for elephant and potentially connecting elephant population in Seblat ECC and elephant population in Pondok Suguh. Finally, human encroachment in elephant habitat is clearly needed to be stopped to minimize human elephant conflict in the future. Currently, human encroachment is increasing rapidly as the logging concession is no longer operate. Local government in the provincial and district level need to work with central government in Indonesian Ministry of Forestry to manage all ex –logging concession available as an important habitat for elephant and other endangered wildlife in Bengkulu.

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