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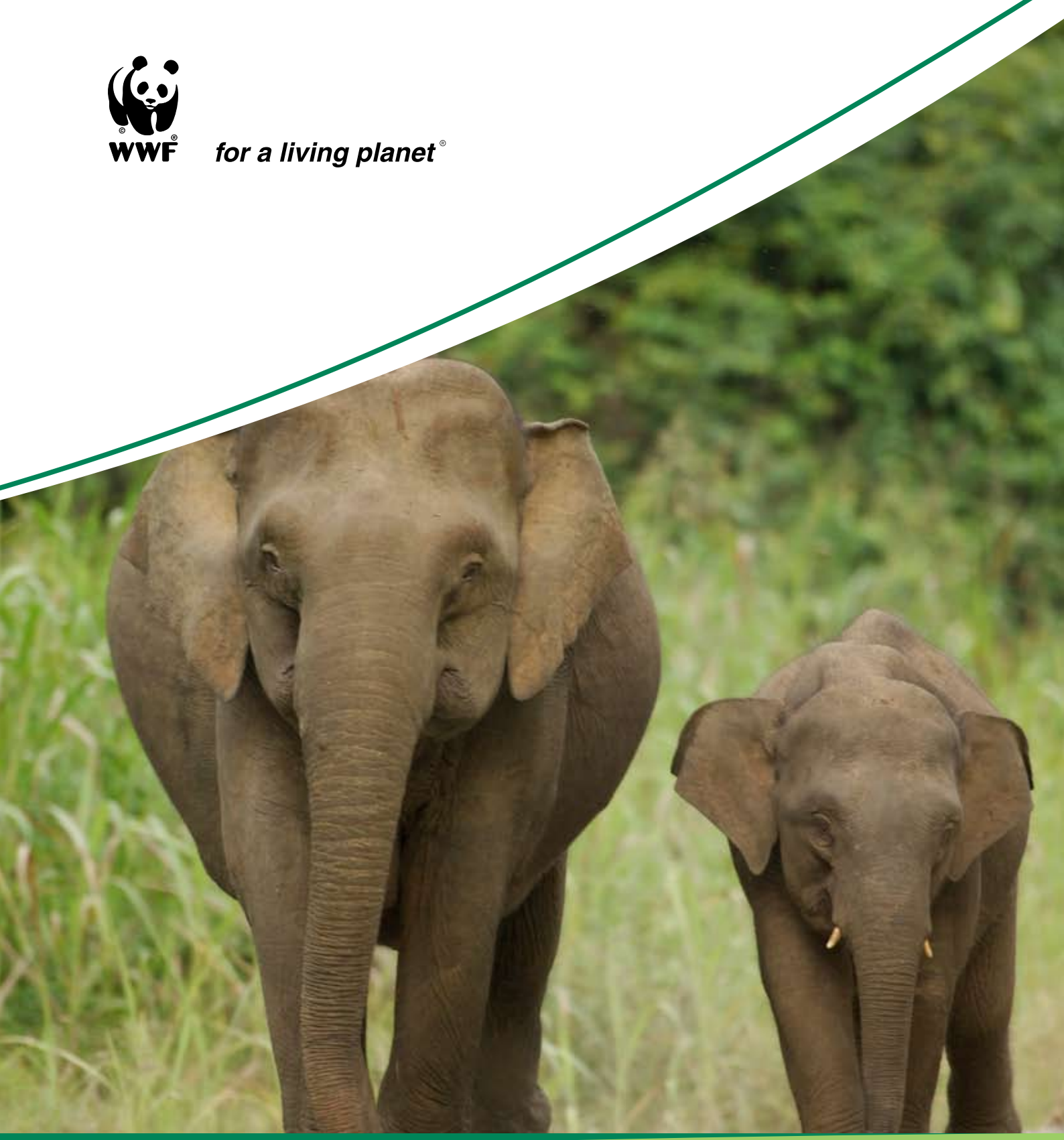

Satellite Tracking of Borneo's Pygmy Elephants

June 2005 – June 2006

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Executive Summary

Despite being among the largest land mammals on Earth, the elephants of Borneo have long remained a mystery to science. Very little is known about these gentle-natured pachyderms that live deep inside the jungles of northeast Borneo, the world's third-largest island. In 2000, WWF launched a project to learn more about the pygmy elephants of Borneo and what needs to be done to conserve them.

Pygmy elephants are found in the Malaysian state of Sabah on northeast Borneo, particularly the floodplain, tributaries and middle catchment of the Kinabatangan River, and in the Segama River catchment. Small groups may also move periodically across the border into the Indonesian state of East Kalimantan to the south as well.

Borneo's climate favours dense tropical vegetation and biodiversity unrivaled by most of the world's forests. Most of Sabah's forests are evergreen rain forests and local vegetation includes a wide variety of trees unique to the region, as well as palms, lianas and epiphytes. Because these forests are important habitat for elephants and Sumatran rhinos – along with orangutans, gibbons, clouded leopards, bantengs and many other species – WWF's Asian Rhino and Elephant Action Strategy programme (AREAS) has chosen this region as a priority landscape to work in. It is also part of the interior of the island covered by the "Heart of Borneo" declaration, which the three nations on the island committed to protecting in February 2007. The Heart of Borneo is the last place remaining in Southeast Asia where tropical rainforests can still be conserved on a very large scale.

The elephants here were long considered to be a low conservation priority as the population was believed to be the feral remnants of a domesticated herd given to the Sultan of Sulu in the 17th century – a belief fostered by their non-aggressive and seemingly semi-tame nature. But in 2003, WWF and Columbia University researchers determined them to be genetically distinct from other Asian elephants, having been isolated from the mainland population perhaps for as long as 300,000 years. This makes them a high conservation priority. Once more research is done on the population they are likely to be declared a new subspecies.

WWF spent more than 36 months tracking the elephants on the ground to determine their presence and absence in specific forests in Sabah. This information was useful in understanding the range of the Borneo pygmy elephant.

Among our findings from three years of ground surveys:

- **Elephant movement is governed by the availability of water sources.** No sign of elephants was found more than 7 kilometres from a river, strongly suggesting the population is dependent on waterways and associated riverine habitats. On several occasions, elephant groups crossed the Segama and Kinabatangan rivers, indicating that major rivers in the study area do not restrict movement of the elephants.
- **Elephant presence was most often recorded in lowland forest.** The frequent presence of elephants in lowland forest – most of which is secondary, or previously logged, forest in the study area – is most likely due to higher food availability there, and to the higher quality of plant foods on fertile lowland soils.

However, because of the difficulty of visual tracking in the dense forests of Sabah, it was not possible to collect information about the areas that specific individual groups or adult males use, called home ranges, and understand the factors that influence which habitats are critical to these elephants. WWF then decided to track the elephants by satellite.

In June 2005, WWF and the Sabah Wildlife Department set out on an expedition to tranquilize several pygmy

© WWF / Raymond Alfred. Borneo's elephants were once thought to be descendants of domesticated elephants let loose in the jungles of Sabah.

elephants and outfit them with specially designed equipment that would allow us to better understand these elephants and their ecological needs. In the largest satellite tracking project of elephants ever undertaken in Asia, five Borneo pygmy elephants were outfitted with collars that send their GPS coordinates to a satellite up to twice a day, allowing WWF to track the elephants' movements as we study the elephants and their habitat. The five female elephants were chosen from five different herds across Sabah to provide us with data from a wide range of habitat types, herd size and geographic range.

One collar failed within three weeks and two others stopped sending reliable data after a few months for unknown reasons, but two of the five collars were still transmitting data after one year on the elephants.

The most urgent goal of this research project is to determine which forests and habitat types are crucial to the pygmy elephants' survival, to help inform land use decisions when forest is converted to commercial uses. This is important because plantations, of any crop, cannot sustain elephants, yet plantations produce more commercial products per acre per year than forests and so create economic incentives to convert forestland. This applies to all crops, and commercial interests will always prefer to maximize yields.

Among our findings from both field tracking and satellite tracking:

- **The lowland forests of Sabah are the most important habitat for pygmy elephants.** As was found during on-the-ground tracking, the tracked elephants were observed to use lowland forests with flat ground or with gentle slopes, below 400 meters elevation, which is mostly covered by secondary forest. The elephants spent most of their time in mixed secondary forest that contained grassy areas, with a minimum movement distance of half to 1 kilometre per day. The lowland forests are also the area where the most intensive logging activity has taken place in Sabah.
- **Human activity and forest disturbance have a measurable impact on the elephants' movement.** The herds were found to cover greater distances than normal under three circumstances:
  - when the elephants are affected by elephant control activities, such as villagers driving them away from crops with firecrackers and drums;
  - when the elephants enter into unsuitable forest habitat like swamp areas and upland forest, probably due to limited food sources;
  - when the elephants are forced to travel through narrow habitat corridors, sometimes as narrow as 30-50 meters along rivers, that are bordered by oil palm plantation.
- **Satellite information showing the home range of one of the collared pygmy elephants, Bod Tai, suggests that the remaining forest in the Lower Kinabatangan area may already be too small and fragmented to support a viable population of wild elephants in the long term.** If further research finds that to be the case, a solution must be sought to protect the long-term viability of the elephant group there, which appears to be one of the largest intact groupings in Sabah. This is crucial to maintain the genetic viability of Sabah's elephants into the future and reduce human-elephant conflict in that area, as elephants may be forced to leave their forest habitat more frequently in the future in search of food.

© WWF / A. Christy Williams. Rozelis with the collar next day.

Biology

Little is known about the biology of Borneo pygmy elephants. They are smaller than other Asian elephants with shorter trunks and smaller, rounder faces, making their ears appear larger. They are more rotund in appearance when compared to mainland Asian elephants. They also are less aggressive than other elephants, leading to the theory held by many for years that they were tamer than other elephants because they descended from a domesticated herd gone feral. This theory was also supported by the fact that there is no evidence the elephants ever dispersed beyond the northeast of Borneo to other parts of the island.

The theory that the elephants were the remnants of a domesticated herd given to the Sultan of Sulu in the 17th century was dispelled in 2003, when WWF and Columbia University researchers conducted a DNA analysis using elephant dung collected across Sabah. The study found them to be genetically different from other Asian elephants and a separate "evolutionarily distinct unit" that had been separated from mainland elephants perhaps for as long as 300,000 years. Classification as a new Asian elephant subspecies is likely in the future once further research on the population is conducted.

WWF estimates that there may be fewer than 1,500 pygmy elephants on Borneo, although no population surveys have been conducted yet.

Threats

The primary threat to these elephants is the loss of continuous forests in Sabah. Mammals of their size require large feeding grounds and viable breeding populations with appropriate male-to-female ratios.

Over the last 40 years, the Malaysian state of Sabah has lost about 40 percent of its forest cover to plantations and human settlement, but it still has one of the largest contiguous areas of habitat for elephants left in Asia. In the 1980s and '90s, large tracts of these forests were divided into "forest management units" (FMUs), of around 1,000 square kilometres each, which were leased for up to 100 years to be managed for sustainable wood production. However, years of unsustainable logging before the 1990s had taken their toll, making many of these big concessions commercially unviable in the short to medium term. Therefore, some of the FMU concessionaires have been converting part of their holdings into wood or oil palm plantations. The conversion of forests to plantations remains the biggest threat to Sabah's elephants, because no plantation can provide the types and amounts of foods necessary to sustain breeding populations of elephants. In 2006, in a landmark decision for elephant conservation, the Sabah government made a commitment to keep 300,000 hectares of critical elephant habitat under natural forest management. This includes the areas where the elephants Nancy and Tailiwas were collared.

© WWF / A. Christy Williams. The Bornean rainforests clothed with an early morning mist.

Apart from simple conversion of natural forests to plantations, other threats include fragmentation of habitats (by conversion to commercial plantations, thereby isolating elephant groups from each other in pockets of habitat) and the increase in human presence close to these forest blocks when the oil palm plantations come into operation. This rapid increase in human population may lead to pressure on the forests through small-scale encroachments, increased hunting in the form of snaring for deer and other game and increased human-elephant conflict because of displaced elephants.

Conflict with people is already increasing as the elephants' habitat shrinks. In the Lower Kinabatangan Wildlife Sanctuary, it is estimated that 20 percent of resident elephants have sustained gruesome injuries from snares set illegally in the forest – often by plantation workers – to catch smaller game animals.

The Collaring Expeditions

During a six-week period in June and July 2005, a veterinary team and rangers from Sabah Wildlife Department joined with WWF elephant experts from Malaysia and Nepal to track and collar five pygmy elephants in key areas across Sabah. When a herd was located in each forest area, the team tracked them on foot until the ranger, armed with a tranquilizer gun, could accurately fire a dart into one of the adult female members of the herd. It was important to consider the size and health of the animal, as we did not want to unnecessarily stress an unhealthy individual.

Once sedated, the team worked quickly to attach a 10-kilogram leather-and-metal collar around each elephant's neck and to take measurements of each, along with noting any distinguishing marks or scars.

An antidote to the tranquilizer was then administered quickly and the elephant left to return to her herd, usually within 30 minutes of the sedative first taking effect and the collaring operation begun.

As elephants live in matriarchal groups, an adult female elephant was collared in each herd. In some cases, the rest of the herd stayed nearby throughout the attachment of the collar, while other herds fled. In all cases, the collared elephant was able to return to her herd either immediately or within a few days.

During the satellite tracking, data was compiled based on the collared elephants' GPS locations, which could be transmitted to a satellite as often as twice a day. In reality, locations were recorded far less often since Borneo's elephants spend much of their time in dense forest cover and the GPS locations could only be transmitted when elephants were in the open, with minimal canopy cover between their collar and the satellite.

The study sought to determine:

(i) Home range (that is, the extent and location of the area used over a period of at least one year) of pygmy elephants in continuous forest and in fragmented habitats.

(ii) Minimum period of elephant tracking needed to determine the home range.

(iii) Typical elephant movement patterns and how they might be affected by human-elephant conflict control activities and habitat conditions.

© WWF / A. Christy Williams. Rozelis under the influence of the drug after darting.

Rozelis

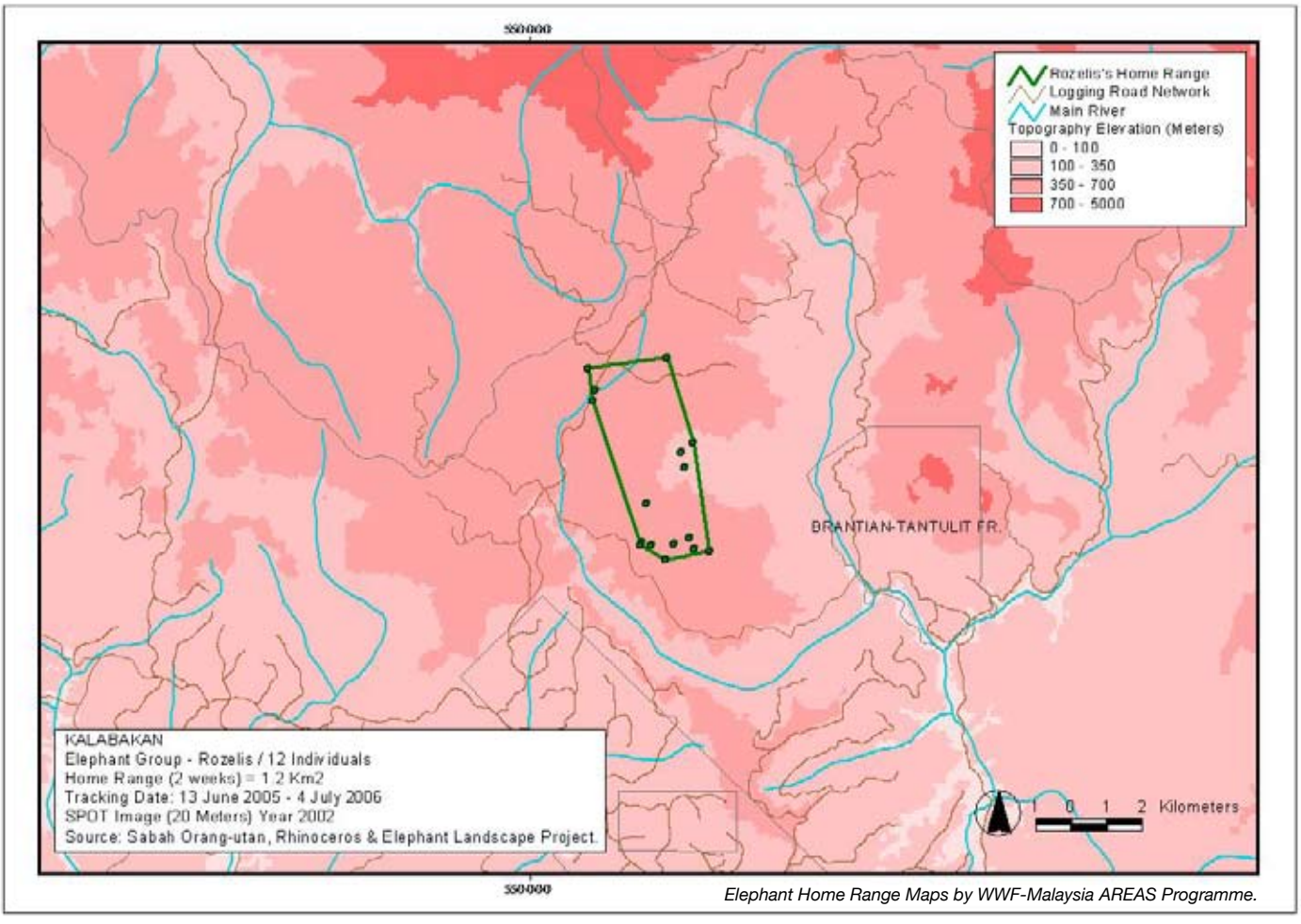
Estimated Age: 20-25 years old

Location: Collared in Kalabakan Forest Reserve; habitat is a mix of industrial timber plantation, logged forest and virgin jungle reserve

Rozelis is the collared elephant we know least about. Her collar stopped transmitting data after just three weeks, for unknown reasons. Rozelis's herd size when she was observed during the tracking expedition was small, just 12 elephants. Her movement rate during the first three days after being collared was observed to be high – 4 kilometres per day – probably because of the satellite collaring activity, which temporarily separated her from her main group as they moved away from the operation. On the sixth day after the collaring, Rozelis's movement was observed to return to a rate subsequently observed in the other collared elephants – half to 1 kilometre per day – after she reconnected with her herd.

© WWF / A. Christy Williams. Rozelis with the collar the day after.

Map 1



Elephant Home Range Maps by WWF-Malaysia AREAS Programme.

Tailiwas

Estimated Age: 35-40

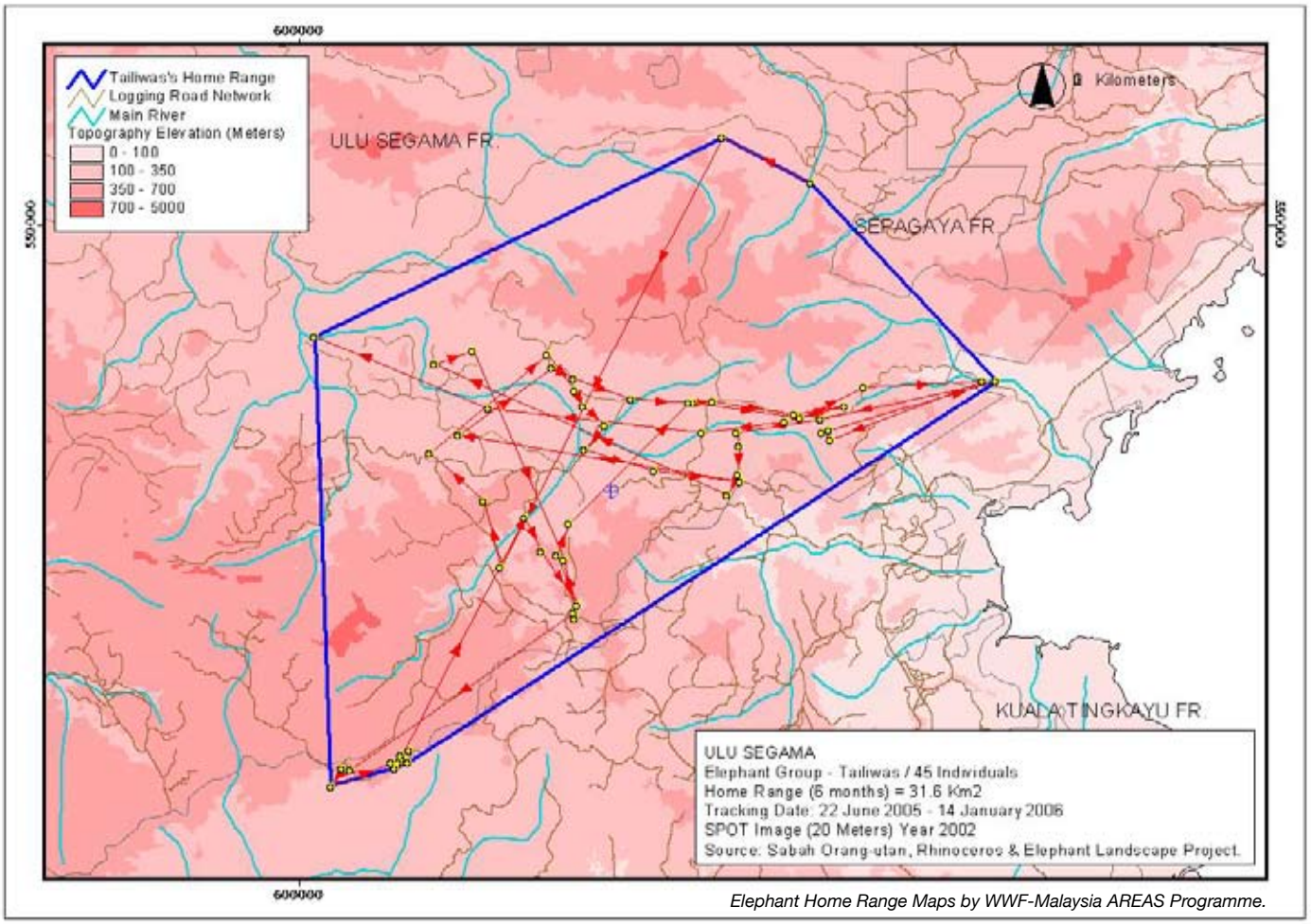
Location: Collared near the Taliwas River in Ulu Segama Forest Reserve; the forest habitat is in good condition.

Tailiwas was named after the river in the forest where she was darted and collared, Taliwas, but her name was spelled with a twist because part of her tail had been cut or bitten off at some point in her life. Tailiwas's movement rate during the first three days after collaring as observed from field tracking activities was normal (about 400 meters per day).

Her herd of about 45 elephants normally moved between 0-2 kilometres a day. The longest distance they moved was detected in September 2005, after the herd entered Dewata village in the Lahad Datu district, and subsequently moved 6.4 kilometres in a single day. As determined by on-the-ground field tracking, this movement was due to villagers chasing the group away from their crops using loud noises and fireworks. In a period of 12 months, she and her family have entered villages at least two times.

© WWF / Cede Prudente. Tailiwas with calf two days before she was collared.

Map 2



Elephant Home Range Maps by WWF-Malaysia AREAS Programme.

Nancy

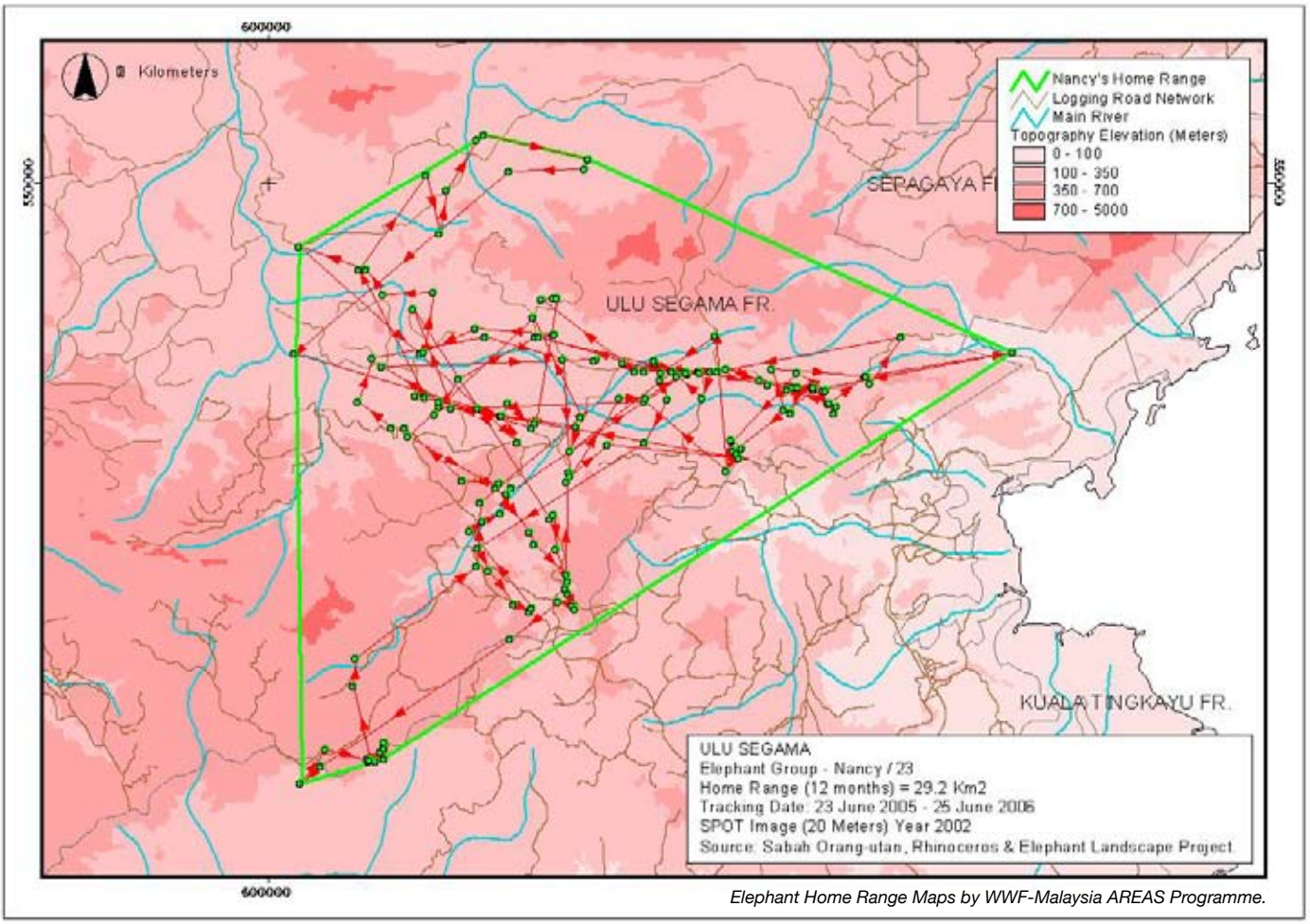
Estimated Age: At least 40 years old and the matriarch of her herd

Location: Collared at Taliwas, Ulu Segama Forest Reserve; habitat consists of virgin jungle reserve and secondary forest

The movement and ranging patterns for Nancy's elephant group of about 23 is similar to Tailiwas's herd, with the two groups traveling separately but along the same routes. But Nancy's family group seems to be more sensitive to human disturbance than Tailiwas's group and has only once entered a village area, entering Dewata Village in September 2005 with the Tailiwas group. But based on visual tracking in the field, Nancy's group traveled more than 12 kilometres over two days after being chased from the village area, thus retreating twice as far as Tailiwas's group.

© WWF / Raymond Alfred. Nancy and her herd.

Map 3



Elephant Home Range Maps by WWF-Malaysia AREAS Programme.

Bod Tai

Estimated Age: 25-30

Location: Collared in Lower Kinabatangan Wildlife Sanctuary; habitat is composed of fragmented and very damaged forest.

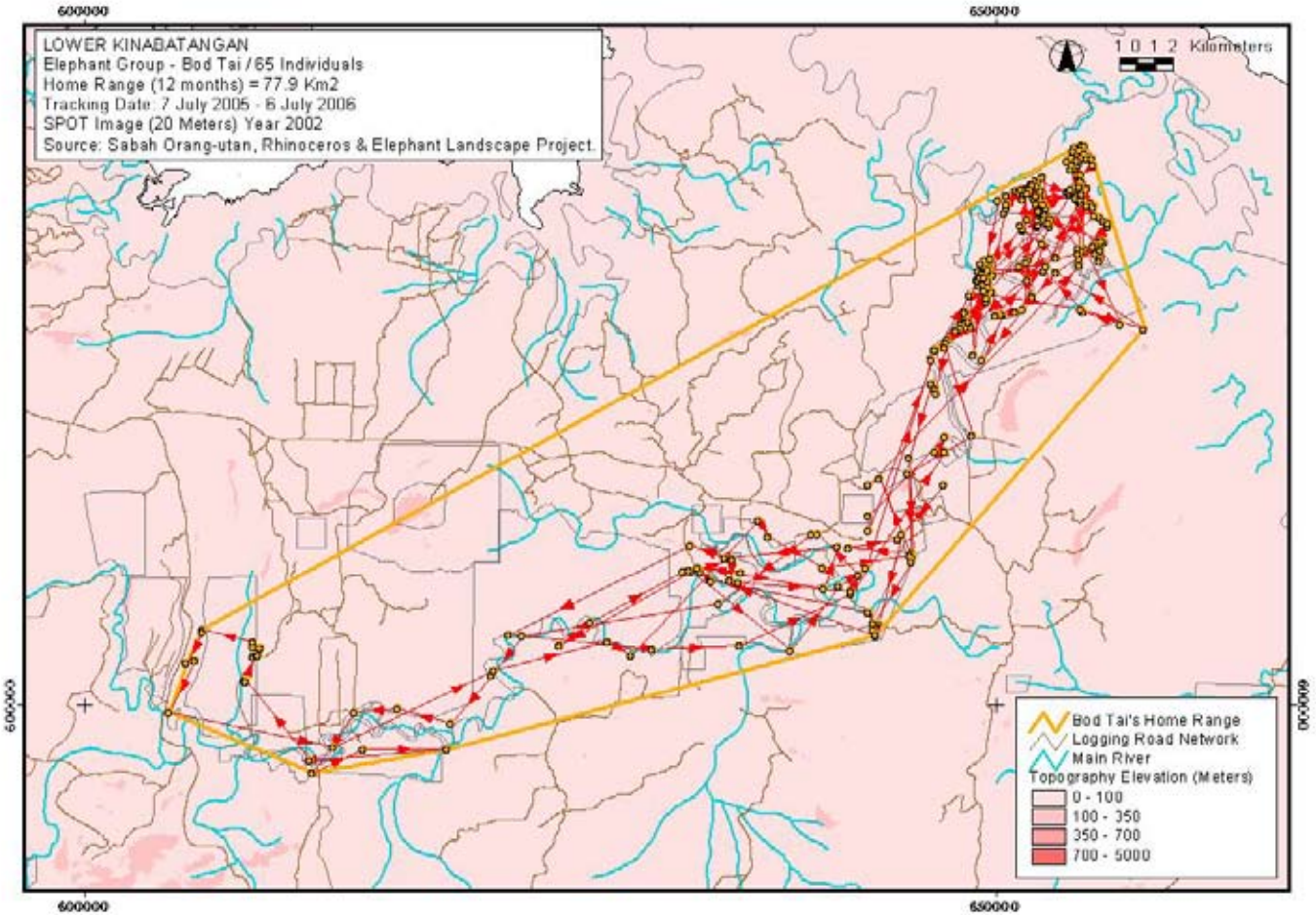
Bod Tai's group of about 65 elephants lives in forest that is narrow, bounded by the Kinabatangan River, and heavily fragmented.

The group's movement pattern during the first few days after being fitted with the transmitter was affected considerably by the collaring activities. After the collaring, Bod Tai's group moved at least 3.6 kilometres from the collaring site in just one day. Two days after the collaring, their movement distance slowed to about 1-2 kilometres per day in a good, relatively undisturbed habitat patch within Kinabatangan Wildlife Sanctuary, which is a normal rate of travel when compared to other elephant groups like Tailiwas's and Nancy's.

Overall, however, the average rate for Bod Tai's movement -- more than 5 kilometres per day -- was highest among the five elephants collared. This difference is believed to be related to the fragmented nature of their habitat. The elephants have to move frequently between separate patches of forest, through plantations and villages, in order to secure their food. At one point, Bod Tai's group moved more than 9.5 kilometres in one day after the group was chased away from Sukau Village. Data also shows that the movement of this elephant group was higher when they were moving through a narrow space, such as a riverbank bordered by an oil palm plantation, and through swamps, where elephants sink into soft mud and where there is not much food. Bod Tai's group showed a more leisurely rate of movement of half to 1 kilometre per day when entering an area mainly covered by mixed secondary forest and grassland.

© WWF / Engelbert Dausip. Bod Tai after being collared in Kinabatangan, with Raymond Alfred of WWF and Elis Tambing of Sabah Wildlife Department.

Map 4



Elephant Home Range Maps by WWF-Malaysia AREAS Programme.

Penelope

Estimated Age: 35-45

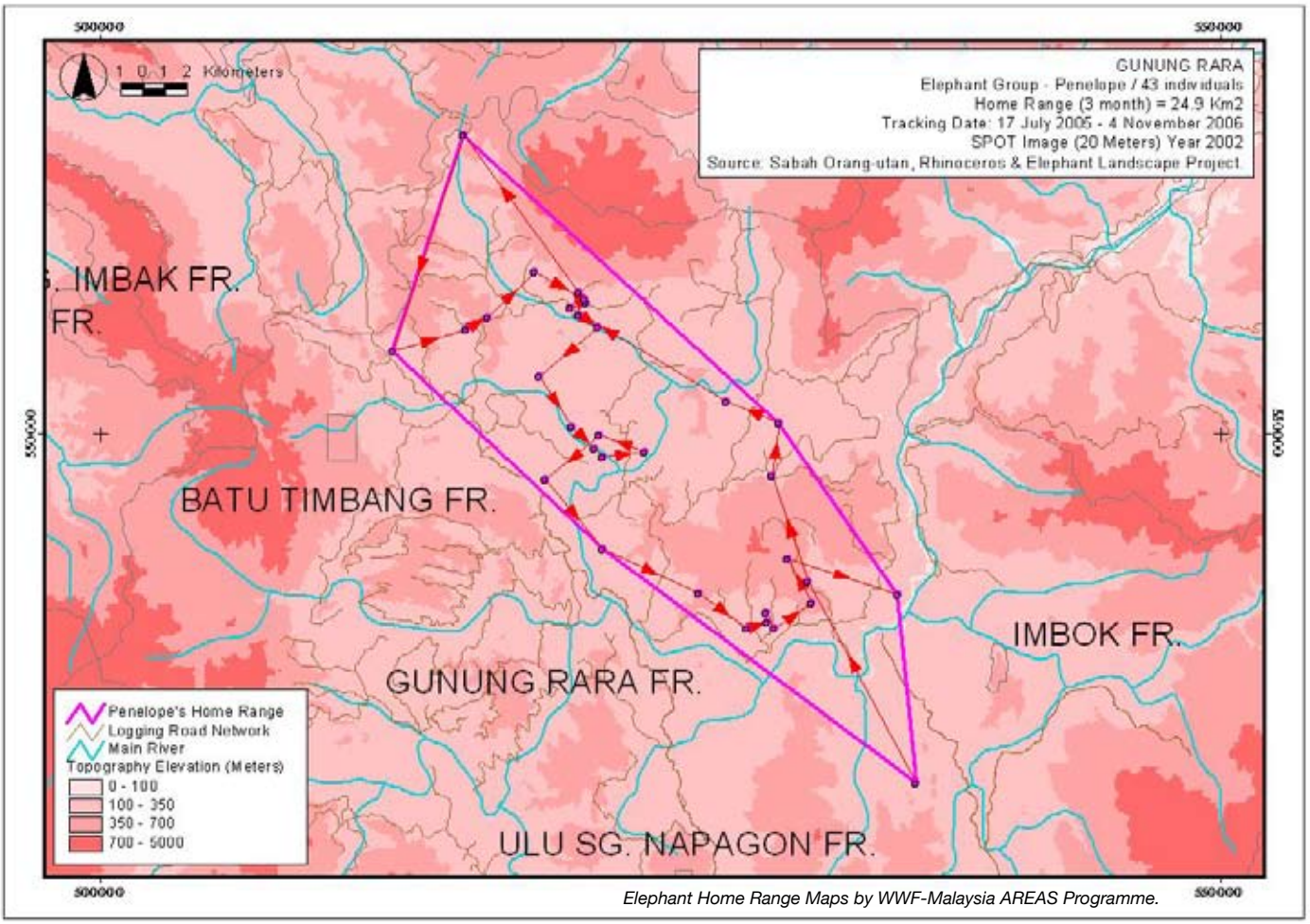
Location: Gunung Rara Forest Reserve; habitat is logged forest

Penelope's movement pattern, unlike the other four collared elephants, did not increase after she was collared. This is likely due to the fact that Penelope had a calf below one year of age and there were another two or three calves in the group of 43 elephants, which would slow the herd's movements. Thus, any response to the collaring activity was not obvious.

The movement of this elephant group was higher at one point when they were found to be crossing an area of upland forest using an abandoned logging road. It was observed that they walked at least 5 kilometres per day from one lowland area to another, crossing the upland forest. This suggests that elephants may prefer the easier way to travel, such as logging roads or abandoned logging roads, even if it requires them to travel faster, for instance if water sources are limited. The average distance covered per day for this group ranged from 500-1,000 meters.

© WWF / Raymond Alfred.
Penelope and calf.

Map 5



Elephant Home Range Maps by WWF-Malaysia AREAS Programme.

Four satellite tracking programmes were established in the central forest of Sabah (combination of secondary forests and recently logged forests with patches of old growth forest) and one in the Lower Kinabatangan river region (fragmented forest blocks).

Following the recommendations of Jennrich and Turner (1969) , the data acquired from these have been subjected to the standard minimum convex polygon method for estimating home range. This involves drawing the smallest polygon that contains all the location points for a herd or an individual and using this area for calculating the home range.

The results of the satellite tracking programmes annually and monthly are summarized in Table 1 and Table 2 respectively.

Table 1 – Summary of results of the annual satellite-tracking programmes

Name of Group	Group Size	No. of Herds	No. of days When GPS location is	Duration of tracking (days) (Km^2)	Area of minimum home range	Dates	Illustration of home range
Rozelis (Young Female)	12	1	16	21	12.0	13/6/2005 – 4/7/2005	Map 1
Tailiwas (Adult Female)	45	6	58	216	316.0	22/6/2005 – 14/1/2006	Map 2
Nancy (Adult Female with calf)	23	3	165	365	292.0	23/6/2005 – 21/6/2006	Map 3
Bod Tai (Young Female)	65	8	277	365	779.0	7/7/2005 – 7/7/2006	Map 4
Penelope (Adult Female with calf)	43	7	32	110	249.0	17/7/2005 – 4/11/2005	Map 5

Table 2 – Approximate monthly area covered by each elephant group (in square kilometres)

Month	Rozelis	Tailiwas	Nancy	Bod Tai	Penelope
July 2005	10.19	30.11	-	10.34	-
Aug 2005	-	40.39	30.76	100.43	70.53
Sept 2005	-	50.05	50.22	60.84	40.60
Oct 2005	-	70.03	90.73	50.16	50.70
Nov 2005	-	-	40.70	60.9	-
Dec 2005	-	30.47	50.08	40.89	-
Jan 2006	-	-	50.22	50.41	-
Feb 2006	-	-	40.56	110.69	-
Mar 2006	-	-	20.44	560.46	-
Apr 2006	-	-	40.34	30.46	-
May 2006	-	-	40.81	150.61	-
June 2006	-	-	20.48	160.88	-
July 2006	-	-	-	-	-
Average home range (Kilometers2) per month	-	40.61	40.76	120.09	50.94

The satellite tracking data provide an opportunity to examine the relative rates at which the elephants moved around their home ranges in several types of habitats. The relative elephant group movement can be derived simply by dividing the distance moved by the time between successive locations, as shown in Table 3.

Table 3 - Mean distance moved per day and type of habitat

Habitat Type	Name of group	No. of Elephant	Number of positive locations	Intervals between consecutive locations		
				Number of (days)	Distance (Km	Mean rates (Km/Day)
Industrial Timber plantation and heavily logged forest, combined with one patch of virgin jungle	Rozelis	12	16	21	18.6	0.89
Forest area assigned as water catchment with several patches of virgin jungle	Tailiwas	45	58	216	185.5	0.86
Forest area assigned as water catchment with several patches of virgin jungle	Nancy	23	165	365	331.6	0.91
Several patches of virgin jungle and fragmented secondary forest	Bod Tai	65	177	365	574.9	1.58
Logged Forest surrounded by good upland forest	Penelope	43	32	110	99.1	0.90

Olivier (1978) quotes that elephants in groups appear to be more mobile than the lone animal, and groups of elephants in primary forest in his study in Peninsular Malaysia had a greater rate of movement than in secondary forest, although the opposite result was observed for lone males. However, during the period of this study, only five satellite collar devices were available and the field team was unable to find a solitary elephant during the period made available for collaring.

Size of Home Ranges

With five home ranges determined in this study for the pygmy elephant of Borneo, statistical tests of their relative sizes can be made. And there are a number of elements of constancy between the results for all five elephants that could strengthen the interpretation.

It is not known how closely the minimum home ranges plotted from the satellite data approach actual home range size or how standard this would be for similar-sized groups in a given habitat type. Previously published data are of little help in this evaluation. Nancy's group plotted almost the same size home range in the first six months (289 square kilometres) as the home range established over 12 months (292 square kilometres). No disturbance, such as logging activity, was recorded during the study in Nancy's home range. Tailiwas's group also plotted a nearly identical 285 square kilometres in the first six months. This is due to the fact that Tailiwas and Nancy have different family groups but belong to the same, larger group of elephants at the south part of Ulu Segama forest reserve and move in similar patterns.

The size of an elephant's home range gives an indication of the availability of essential resources such as water and food (White 1996). Our data show that secondary forests, the habitat type where elephants spend most of their time, have fewer trees and lower tree species diversity than old growth forests, but the secondary forests have a variety of plant types that are consumed by elephants and that are rare or absent in old growth forests. Such plants include grasses, gingers, shrubs, climbing bamboo, creepers and slender woody climbers.

Elephant home ranges recorded so far vary widely depending on the elephant population and the ecological conditions under which they were studied. Most studies on African elephants have showed a strong relationship between rainfall and home range size. Home ranges of elephants in areas of higher rainfall (Tsavo west: 750 square kilometres) were smaller than the ranges of elephants in areas of low rainfall (Tsavo east: 1600 square kilometres2). Thouless (1996) showed similar results from his study in northern Kenya, where the home ranges varied between 102 square kilometres (High rainfall area) to 5527 square kilometres (Low rainfall area). However, human disturbance also played a significant role in influencing the range sizes. The home ranges of two adult females tracked in northern Cameroon were 3066 square kilometres and 2484 square kilometres respectively (Tchamba, Bauer and Jongh 1995) and it is thought intensity of the elephant-human conflict forced the two elephants to migrate long distances resulting in large home ranges. De Villiers and Kok (1997) estimated, after 6 years of radio tracking in two nature reserves adjacent to Kruger NP, that female home ranges varied between 115 square kilometres and 342 square kilometres, whereas male home ranges were between 150 square kilometres and 342 square kilometres. They showed that availability of water played an influencing role on the size of the elephant home ranges in the two reserves. In Asia, however, home range sizes reported (males:160-400 square kilometres; females: 40-650 square kilometres) are much lower due to the elephants living in mainly forested habitats with higher rainfall than recorded across many of the African studies sites (Joshua and Johnsingh 1995, Baskaran et al. 1995, Williams, et. al. In press). Thus the home ranges for elephants recorded in Sabah seems to fall within the ranges known for Asian elephants and one can assume safely that the search for water is not a determining factor in the size of the home ranges.

Using the minimum convex polygon method to estimate the home range size of Bod Tai, the elephant in the fragmented habitat, gives a figure of 779 square kilometres. However, this figure is misleading because it incorporates extensive areas of oil palm plantation and permanent swamp forest, which the elephants rarely or never enter. By simply drawing a line around all the records of this group, including areas where the elephants travel periodically through plantations, gives a home range of only 284 square kilometres, an area similar to that for the other elephants in contiguous forest habitat. It is difficult with existing circumstances and available data to know how to interpret the results for Bod Tai. Essentially, the amount of suitable elephant habitat remaining in lower Kinabatangan may now be too small and too fragmented to support a healthy elephant population in the long term.

Elephant Movement

It is theoretically possible to test the mean rates of movement shown in Table 3 for statistically significant differences, provided their component data are independent. However, heavy canopy cover limited the uploading of GPS data to the satellite from the elephants' collars to times when the elephants ranged into more open areas. Therefore, the locations of each study group were irregularly and sometimes widely spaced in time, so it was feared that any comparative statistical analyses based on rates of movement between consecutive locations would be questionable.

At times, the collars' GPS units were only able to transmit locations to the satellite at intervals as far apart as 15 days. In that time, the elephants could have and probably had moved many times compared to the recorded distance.

Habitat Utilization

To analyse habitat utilization, only home range data that were collected for a period of more than three months was interpreted, which excluded the Rozelis Group.

The following table shows what percentage of time each group spent in each habitat type within its home range (determined by using minimum convex polygon).

Table 4 – Percentage of time spent by elephants in different forest types based on gross habitat type maps, satellite records obtained, and application of the minimum convex polygon method to estimate extent of home ranges

Elephant Group	Tailiwas	Nancy	Bod Tai	Penelope
Home Range Size (Kilometers^2) based on minimum convex polygon method	316	292	779	249
Heath Forest	-	-	-	0.3 %
Forests on dry land below 300 metres above sea level*	54.2 %	57.3 %	40.4 %	93.3 %
Ultramafic Forest (based on overlaying geological maps and minimum convex polygon method)**	29.4 %	25.1 %	-	2.0 %
Dryland Forests above 300 m asl *	16.1 %	17.5 %	12.0 %	4.4 %
Freshwater Swamp Forest	0.3 %	0.1 %	30.7 %	
Limestones Forest	-	-	1.4 %	
Mangrove Forest	-	-	0.4 %	
Peat Swamp Forest	-	-	15.1 %	

* These consist mainly of logged dipterocarp and secondary forests on soils derived from sedimentary rocks.

** It is unlikely that elephants spend much or any time in ultrabasic forests, which have few water sources and few elephant food plants, plus toxic heavy metals in leaves, derived from the metal rich ultrabasic soils; the inclusion in this table is linked to application of the minimum convex polygon method to data points.

Based on Table 4, the majority of each elephant group's home range encompasses lowland forests below 300 metres altitude, on non-swampy and non-ultrabasic soils. It is likely that low altitude forests are favoured for a combination of reasons including (a) higher soil fertility, linked to greater production and quality of food plants, than at higher altitudes, (b) proximity to permanent water sources and (c) gentle terrain. Furthermore, due to the previous logging activities concentrated in the lowland forest, these areas provide various secondary food plants for the elephants. The density and diversity of the elephant food plants in different forest quality will be analysed during 2007.

Table 5 – Estimated percentage of time spent by the elephants in different altitude classes (metres above sea level)

Elephant Group	Home Range Size (Kilometers^2)	0 – 300 m asl	300-500 m asl	500-750 m asl	> 750 m asl
Tailiwas	316	48.9 %	41.6 %	9.2 %	0.3 %
Nancy	292	50.7 %	39.2 %	9.6 %	0.5 %
Bod Tai	779	100 %	-	-	-
Penelope	249	62.9 %	30.2 %	6.7 %	0.2 %

Recommendations

Based on the findings from the first study of Borneo pygmy elephant movements and their use of habitat types, WWF recommends the following:

- All remaining lowland forests which support wild elephants should be retained under natural forest management and not converted to plantations.
- Forest disturbance needs to be minimized wherever wild elephants occur. In timber production forests, this can be achieved by limiting the extent and frequency of logging operations in any given management compartment. In any forests (protection or timber production) adjacent to plantations, the entry of plantation workers into the forest must be strictly limited. (In most cases, any such entry is illegal under existing laws and policies.)
- At a minimum, another five wild elephants should be fitted with satellite tracking devices in order to cover elephant habitats not covered by the previous satellite tracking. Locations should ideally include the southern border area of Sabah adjacent to East Kalimantan (Indonesia), Kalabakan Forest Reserve (including the Benta Wawasan oil palm development area), Malua Forest Reserve, Deramakot Tangkulap Segaliud Lokan Forest Reserve, and the Imbak Valley area.
- Work must be undertaken to establish an estimate for Borneo's pygmy elephant population. WWF has plans to use dung counts at selected forest sites as well as DNA analysis to do this.
- The most significant "corridors" used by elephants need to be identified, maintained by law and extended or enhanced if necessary. (This will include valleys in predominantly steep and hill areas and other "bottlenecks.")
- Specific sites where elephants cross between Forest Reserves using private, non-forest land need to be identified and steps taken to maintain or recreate elephant habitat. Examples include:
  - Lower Kinabatangan area
  - Ulu Kalumpang – South Ulu Segama Forest Reserve
  - Kuamut/Malua Forest Reserve – Deramakot Forest Reserve

© WWF / A. Christy Williams. A misty morning in the Heart of Borneo.

Front cover: © WWF / Cede Prudente. Tailiwas before she was collared, walking with juvenile male.

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- promoting the reduction of pollution and wasteful consumption.

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