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A STATE-WIDE SURVEY TO ESTIMATE THE DISTRIBUTION AND DENSITY OF THE SUMATRAN RHINOCEROS, ELEPHANT AND BANTENG IN SABAH, MALAYSIA

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A STATE-WIDE SURVEY TO ESTIMATE THE DISTRIBUTION AND DENSITY OF THE SUMATRAN RHINOCEROS, ASIAN ELEPHANT AND BANTENG IN SABAH, MALAYSIA

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EXECUTIVE SUMMARY

A two-year state-wide survey to estimate the density of Sabah's three mega-herbivores, *Dicerorhinus sumatrensis*, *Elephas maximus* and *Bos javanicus*, was carried out, with particular emphasis on the critically endangered *D. sumatrensis*. Surveys were concentrated mainly in large contiguous tracts of forest, which included the Sabah Foundation Concession Area and reserves adjoining the concession, and the Lower Segama region. The Lower Segama region comprised Tabin and Kulamba Wildlife Reserves and the forested areas between them.

Techniques employed to survey for *D. sumatrensis* involved intensively and extensively patrolling all existing animal trails, particularly along ridges and waterways; these are the areas where the species reportedly frequents. Including replicate trails, a total of approximately 1920 kms of trails were walked in search for evidence of *D. sumatrensis*. These was equivalent to an area of 740 km^2 covered in 720 man-days. Conversely, a hundred and twenty-seven straight line transects for dung, measuring a total distance of 62 kms, were used to determine densities of *E. maximus* and *B. javanicus*. Techniques employed to survey the three mega-herbivores, however, depended on sightings of indirect evidence of their presence; this is more practical when assessing densities of elusive animals in dense tropical rainforests.

Surveys for *D. sumatrensis*, based on track evidence, revealed that there are at least 11 animals in the total combined areas surveyed. In combination with other evidence, there could possibly be between 23 to 33 animals in the total area surveyed, with the main population concentrated in the Sabah Foundation Concession Area, particularly in and around the Danum Valley Protection Forest Reserve. Transect surveys for *E. maximus* gave minimum density estimates of 0.02 animals per km^2 for the Sabah Foundation Concession Area, and 0.07 animals per km^2 for Tabin Wildlife Reserve and forested areas adjoining it. Results based on minimum densities were less biased, and are probably more realistic for management purposes. On extrapolation, these density estimates gave populations of 195 and 85 animals for the Sabah Foundation Concession Area and Tabin Wildlife Reserve respectively. With recent trends in habitat loss and forest fragmentation, these extrapolations might represent a more realistic population estimate. It was not possible to obtain density estimates for *B. javanicus* surveys in any of the areas surveyed, as only one dung sample was encountered in all of the transects laid implying that the species exists at extremely low densities. Index counts based on tracks, however, gave a density of 0.34 tracks/km and 0.31 tracks/km for the Sabah Foundation Concession Area and Tabin Wildlife Reserve respectively. Observations, however, indicate the presence of a possibly viable population in the western part of Tabin Wildlife Reserve.

Surveys also indicate the importance of waterways and their associated habitats, not only to these three mega-herbivores, but also to a diversity of wild fauna. Albeit all three species suffer from a dire loss of habitats, the main threat facing *D. sumatrensis* and *B. javanicus* is hunting, whereas *E. maximus* is seriously threatened by forest fragmentation. Thus, the immediate action needed to prevent the extirpation *D. sumatrensis* and *B. javanicus* is to focus all available resources on anti-poaching and law enforcement activities. Simultaneously, efforts should be made to secure additional totally protected areas to prevent further loss of viable habitats, and to prevent animals or small groups of animals from existing in isolation.

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1. INTRODUCTION

Conservationists world-wide appreciate and agree on the need to conserve large herbivores. Such species need large areas to fulfill their ecological needs, so ensuring their long-term survival in the wild will also ensure the survival of the many other wildlife species inhabiting the same habitats. Although large herbivores have been studied intensively in more open, savanna habitats, little work has been done on trying to determine their numbers in rainforests and to find out what their exact habitat requirements are. True densities, not 'guesstimates', are prerequisites towards an effective conservation management for these species. Their numbers in the wild are very low, therefore active management is likely to be needed.

In Sabah, conserving large herbivores is difficult, because of their low population densities, large ranges, crop destruction tendencies, and their value to poachers. Also, these animals, or parts of them, fetch an extremely high market price; one kilogram of rhino horn fetch US$45,000 in the international market (Bradley-Martin & Bradley-Martin, 1991). One main problem in the conservation of these large herbivores is conserving the geographical extent and the quality of wildlife habitats of their ranges. Their conservation is crucial because large herbivores directly or indirectly affect forest structure, regeneration, and consequently other animal and plant species (Sukumar, 1989). Furthermore, in Sabah large herbivores are rapidly becoming confined to a few dwindling patches in the east (Mohd. Khan, 1989; Santiapillai & Jackson, 1990).

Protection and management in Sabah of *Dicerorhinus sumatrensis*, *Elephas maximus* and *Bos javanicus* in the wild cannot be addressed without better data on their presence, distribution and densities in the remaining blocks of forests. By virtue of the above features, they are undoubtedly the three most endangered species in Sabah. Thus, understanding how best to conserve them is of the highest conservation priority in the State.

1.1 Background

At the start of the project, the densities of all three of these large herbivores in Sabah were still unknown. Faunal surveys and some studies (Davis, 1962; Davis & Payne, 1982; Payne *et al.*, 1989; Stuebing *et al.*, 1989; Ambu, 1990; Payne, 1990; Emmons, 1991; Dawson, 1992; 1993b; Sharma, 1992; Boonratana, 1993; 1996; Rajaratnam, 1995), surveys carried out for *D. sumatrensis* (Anon., 1986; Ahmad, 1987; Shukor *et al.*, 1989; Payne 1990a & b; Abd. Hamid, 1991; Jomitin, 1991; Rabinowitz, 1992; Boonratana, 1996), for *E. maximus* (Dawson, 1992; 1993a & b; Boonratana, 1996), and for *B. javanicus* (Boonratana, 1996) have provided much information on the distribution of these large herbivores. Species density estimates, however, were available for only a few areas in the state. Thus, in reality, we are still uncertain of the true status of these species. Furthermore, all available data pointed to their ongoing decline. To formulate effective management policies for these species, it was of the utmost urgency to determine their true densities and distribution.

In Sabah, currently the Tabin Wildlife Reserve and the Danum Valley Protection Forest Reserve (figure 2.2) are the only two protected areas known to contain populations of *D. sumatrensis* that might be viable in the long term (Payne, 1990a; Sabah Wildlife Department, 1993). *B. javanicus* populations are afforded some protection in Tabin and Kulamba Wildlife Reserves (WWF-Malaysia, 1986; Ambu, 1990). The only totally protected area where a sizable population of *E. maximus* was known to occur is Tabin Wildlife Reserve (WWF-Malaysia, 1986; Dawson, 1992; 1993a). The three species also occur in the proposed Lower Kinabatangan Wildlife Reserve (Boonratana, 1993; Sharma, 1992), but the reserve is possibly

too small to protect viable populations in the long term. It would be a grave error, however, to assume that these species will be safe in these reserves. Information regarding their densities and distribution is needed to prepare an effective management plan. Without full data, the exact value of currently existing totally protected areas are not known, and where active management is exactly needed. Also, viable populations might occur outside currently existing totally protected areas, therefore more surveys are needed to determine where the locations of those populations. Thus, determining where extensions to current totally protected areas and establishment of new totally protected areas, are needed.

1.2 Objectives

1.2.1 Primary Objectives

i. To survey intensively and extensively the presence, density, and distribution of *D. sumatrensis*, *E. maximus* and *B. javanicus* in Sabah;
ii. To identify areas having viable populations of any of the three species with a view to proposing new protected areas, and to assist in revising existing management plans for areas that are already protected;
iii. To provide baseline information, so that monitoring of Sabah's large herbivores can be continued by the Sabah Wildlife Department. This includes establishing a monitoring system for the abundance and distribution of these large herbivores in key areas.

1.2.2 Secondary Objectives

i. To gather basic ecological and behavioral information on the three large herbivores in Sabah;
ii. To impart training, if requested, to the staff of the Sabah Wildlife Department and graduate students of the local university;
iii. To record general information on the presence of other species of wildlife in the areas surveyed, and also recording human activities, if any, that are potentially detrimental to wildlife and wildlife habitats.

2. STUDY AREAS

2.1 Introduction

This study was carried out in the Malaysian state of Sabah, northern Borneo (figure 2.1). Sabah has a land area of 73,713 km² of which 33,486 km² (45.43%) is under natural forests, and 2,452 (3.33%) km² is designated as parks (Sabah Forestry Department, 1992). Seven categories are classified under natural forests (table 2.1), of which only two classes, Protection Forest Reserves and Virgin Jungle Reserves are fully protected.

The study focused on two main areas, the Sabah Foundation Concession Area and the Lower Segama Region (figure 2.2). All available information suggested that these two areas might possibly contain populations of *D. sumatrensis*, *E. maximus* and *B. javanicus* that might still be viable in the long term. Furthermore, these two areas form the largest forest blocks in the state, and there are two areas within the Sabah Foundation Concession Area that comprise primary forest (section 2.2). Hence, very important to these species. The study was later extended to include forested areas adjoining the Sabah Foundation Concession Area. As some of these areas still have good forest cover and are suitable wildlife habitat, there was a possibility that the mega-herbivores might still be present or range into those forested areas.

2.2 Sabah Foundation Concession Area

The Sabah Foundation Concession Area covers a total of 9,728 km² in six contiguous forest reserves in the south-eastern part of the state, equivalent to 29% of the total forest reserve area of Sabah (Marsh, 1995). These reserves are Ulu Segama, Malua, Kuamut, Sungai Pinangah, Gunung Rara and Kalabakan Forest Reserves. Contiguous with the concession area are Sapulut, Tangkulap and Dermakot Forest Reserves. Within the concession area, two areas, Danum Valley Protection Forest Reserve (438 km²) and Maliau Basin Conservation Area (390 km²), are especially important to conservation because they comprise primary forest and are not subject to timber extraction. Before it was gazetted as a Protection Forest Reserve in May 1995, Danum Valley Protection Forest Reserve was known as Danum Valley Conservation Area (Marsh, 1995).

The Danum Valley Protection Forest Reserve has a rugged terrain at moderate elevation, mostly covered with primary lowland, evergreen dipterocarp forest (Whitmore, 1990). 9.6% of the area lies above 760 m a.s.l., and 36% is at a lower elevation (Marsh, 1995). The reserve comprise 91% lowland rainforest, and the remainder made up by lower montane forest. A total of 1,295 higher plant species in 562 genera and 139 families have been recorded in this reserve, representing about 13-16% of the species of higher plant recorded in Sabah. 88% of the total volume of large trees in the reserve are dipterocarps (Marsh, 1995).

Danum Valley Protection Forest Reserve has a high density and diversity of wildlife, with 124 mammals and 275 birds recorded (Marsh, 1995). It is one of the only two known sites in Asia with ten primate species, and one of the only two known sites in the world having four sympatric colobines (Boonratana, 1993; Boonratana & Sharma, 1994). The other site, the Lower Kinabatangan, is also in Sabah.

The average annual rainfall recorded at the Danum Valley Field Center is 2,699 mm (Marsh, 1995), and the mean annual temperature is 26.7°C with a mean maximum and minimum at 30.9°C and 22.5°C respectively (Walsh, 1990).

The Maliau Basin Conservation Area has four forest types, lowland, lower montane and upper montane rainforest formation, and heath forest.

2.3 Lower Segama Region

Tabin and Kulamba Wildlife Reserves, Kuala Segama and Kuala Maruap Mangrove Reserves, and the general area in between are part of a region known as the Lower Segama (figure 2.2). Also, included in this region are some state and agricultural lands. The two wildlife reserves, Tabin and Kulamba, measure 1,205 km^2 and 207 km^2 respectively. Legally, both Tabin and Kulamba Wildlife Reserves are under the Sabah Forestry Department's jurisdiction, but wildlife protection is left to the Sabah Wildlife Department (Andau & Ambu, 1989). The main forest types found in the region are lowland dipterocarp forest, riverine forest, freshwater swamp forest, mangrove swamp forest and nipa swamp forest.

The northern and eastern sectors of the Tabin Wildlife Reserve are predominantly lowland, while the remaining comprise moderate to steep slopes about 100-300 m a.s.l., reaching up to 550 m a.s.l. towards the core area (Jomitin, 1991).

The major vegetation throughout most of Tabin Wildlife Reserve are lowland dipterocarp forest, with some hill dipterocarp forest and swamp forest (Meijer, 1962; Anon., 1993; Sabah Wildlife Department, 1993). 85 families of woody plants comprising 945 species have been recorded in the reserve (Sale, 1994). 90% of the reserve has been logged prior to its gazettement in 1983 (Mitchell, 1994). After its gazettement a further 5500 ha was illegally logged (Jomitin, 1991).

71 mammal and 220 bird species have been recorded in Tabin Wildlife Reserve (Sale, 1994). An interesting feature of the reserve is the presence of mud volcanoes and salt springs, which are frequented by many large mammals (Sale, 1994).
The annual rainfall during a 18-month study in the reserve was 2,574 mm (Mitchell, 1994), and the mean minimum and maximum daily temperatures are 22°C and 32°C respectively (Thomas *et al.*, 1976).

Kulamba Wildlife Reserve is predominantly freshwater swamp forest with nipah-mangrove and beach vegetation, and some riverine forest. Much of the reserve, estimated about 1,500 ha, was damaged by fires in mid 1987 (Payne, 1988). The general topography is flat, with a few steep hills, rising to about 70 m a.s.l.

Thirty-three species of mammals and 89 birds have been recorded for the reserve (Payne, 1985; Ambu, 1990). Prominent among these records were evidence of *D. sumatrensis*, *E. maximus*, *B. javanicus* and *Crocodylus porosus*.

Kulamba Wildlife Reserve has a hot and humid climate with a mean daily minimum and maximum temperatures of 22°C and 32°C respectively, and an average rainfall of 3,050 mm (Payne, 1985; Scott, 1989).

2.4 New Mineral Sources

Four new mineral sources not previously reported were recorded during the survey. One salt spring was discovered during the second major survey for *D. sumatrensis* in the Danum Valley Protection Forest Reserve (appendix I). One mineral source each was discovered in the Kuamut and Ulu Segama Forest Reserves. The one in Kuamut Forest Reserve (117°34'E and 5°04'N) measured 8 m by 5 m, and was adjacent to a tributary of the Malubuk River.

Signs of larger mammals observed were made by *E. maximus*, *S. barbatus*, *C. unicolor* and *T. javanicus*. The other mineral source, in Ulu Segama Forest Reserve (117°49'E and 8°11'N) measured 10 m by 7 m, was located about 200 m from the Segama River. Signs of larger mammals observed at the mineral source were made by *D. sumatrensis*, *S. barbatus*, *C. unicolor* and *T. javanicus*.

A mud volcano was 'rediscovered' in the Tabin Wildlife Reserve, located at 118°33'E and 5°19'N, and measured 29 m by 17 m. Although this mud volcano was known to some workers from the nearby Tomanggong Estate, and visited in mid-1991 and early 1992, its location and access route was never recorded. Thus, a search for the mud volcano was made on September 16, 1994 by myself and two personnel of the Sabah Wildlife Department, Mr. Supin Tadsun and Mr. Mohammed Tidong. As it was unnamed, we decided to name it 'Tagas-tagas Kecil' as it is close to a river of the same name. Signs of larger mammals observed at the mud volcano were made by *E. maximus*, *Sus barbatus*, *Cervus unicolor* and *Tragulus napu*. Also, there were signs of recent human intrusion, most likely animal poachers, on the trail from Tomanggong Estate towards this mud volcano.

Table 2.1 A summary of land classification and forest reserves in Sabah (Sabah Forest Department, 1992)

Land Classification	Area (ha)	% Total Land Area
PERMANENT FOREST RESERVES I Protection Forest Reserves (250,868 ha) II Commercial Forest Reserves (2,530,099 ha) III Domestic Forest Reserves (7,355 ha) IV Amenity Forest Reserves (20,767 ha) V Mangrove Forest Reserves (316,457 ha) VI Virgin Jungle Reserves (90,442 ha) VII Wildlife Reserves (132,653 ha)	3,348,641	45.4
NATIONAL AND STATE PARKS National park (139,919 ha) State parks (105,253 ha)	245,172	3.34
MUNICIPAL WATER CATCHMENTS	2,590	0.03
PLANTATION FORESTS	503,387	6.86
FORESTS DUE TO BE CONVERTED TO AGRICULTURE	366,855	5
Total Forested Area	4,486,963	60.63

Figure 2.1 Political map of Sabah and SE Asia (inset)

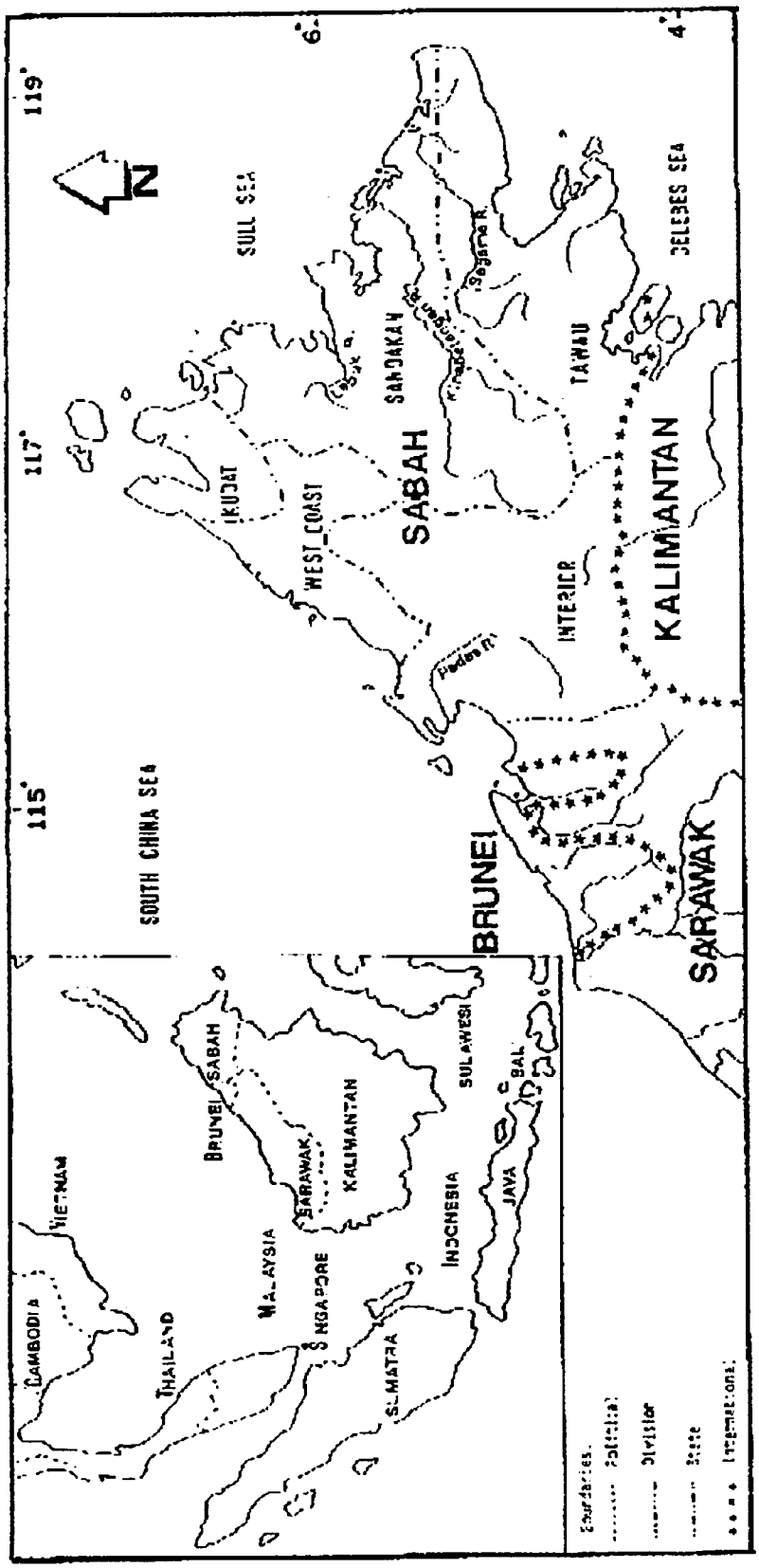
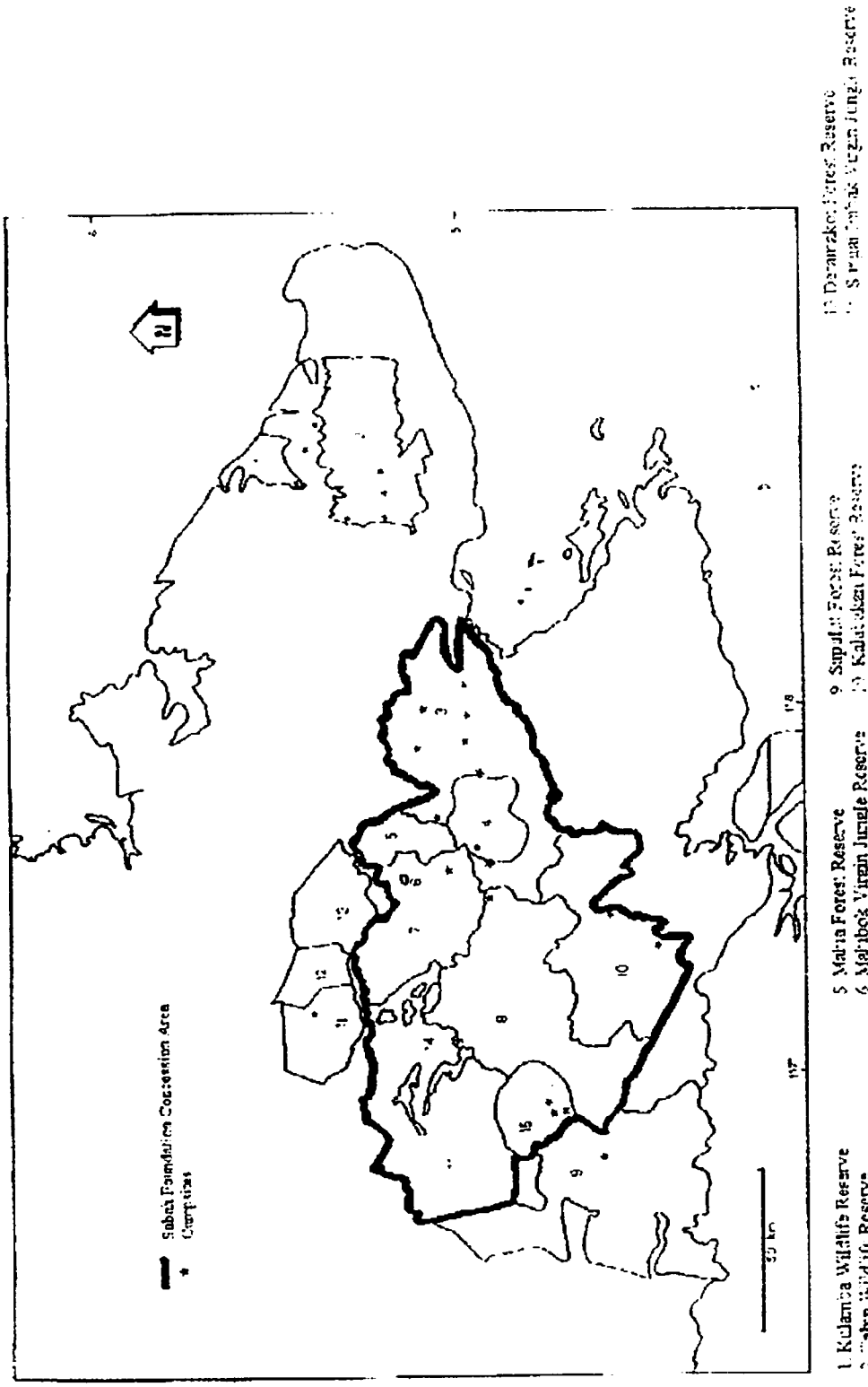


Figure 2.2 Map of eastern and southeastern Sabah showing areas surveyed



3. SUMATRAN RHINOCEROS

3.1 The Study Animal

The family Rhinocerotidae comprises five extant species, two in Africa, *Diceros bicornis* and *Ceratotherium simum*, and three in Asia, *Dicerorhinus sumatrensis*, *Rhinoceros sondaicus* and *Rhinoceros unicornis*. This family is characterized by a large and stocky body, with short and stout legs, having three toes on each foot, one or two horns made of compacted hairs on top of its muzzle (Lekagul & McNeely, 1977; Payne, *et al.*, 1985), and the presence of several folds in the skin (van Strien, 1974; Lekagul and McNeely, 1977). The study animal, *D. sumatrensis*, comprises three distinct subspecies, based on skull measurements (Groves, 1967), namely *D.s. lasiotis* Buckland 1872, occurring in northern Myanmar, Assam, and Bangladesh; *D.s. sumatrensis* Fischer 1814, in Sumatra and Peninsular Malaysia; and *D.s. harrisoni* Groves 1965, in Borneo.

3.1.1 Description

Dicerorhinus sumatrensis is the smallest species of rhinoceros. It measures from 1.2 m to 1.4 m at shoulder height, has a head and body length of from 2.2 m to 2.6 m (Peacock, 1933; Hubback, 1939; Lekagul & McNeely, 1977; Payne *et al.*, 1985), and weighs from 900 kg to 1000 kg (Peacock, 1933; Lekagul & McNeely, 1977). The general coloration varies from light buff to brown to dark brown (Peacock, 1933; Hubback, 1939; Lekagul & McNeely, 1977; Payne *et al.*, 1985). Young animals have a coat of long, thick and soft brown hairs (Peacock, 1933; Lekagul & McNeely, 1977; Payne *et al.*, 1985). In adults, these hairs are reduced to short black bristles, except on the ears and at the tip of the tail where they remain long (Peacock, 1933; Lekagul & McNeely, 1977). It is the hairiest of all the living rhinoceroses, hence sometimes it is known as the 'woolly' rhinoceros. The front horn of male *D. sumatrensis* averages 19 cm and rarely exceeds 30 cm in length, while the posterior horn averages 7.6 cm (Peacock, 1933; Payne *et al.*, 1985). Front horns of females average 7.6 cm, while the posterior ones are small knob-like structures (Peacock, 1933).

3.1.2 Distribution

Dicerorhinus sumatrensis was once found from Bhutan's Himalayan foothills and eastern India, through Myanmar, Thailand, Peninsular Malaysia, and on the islands of Sumatra and Borneo. There have also been unconfirmed reports of the species in Cambodia, Laos and Vietnam (Talbot, 1960; Groves & Kurt, 1972; Lekagul & McNeely, 1977; Mohd. Khan, 1989). Currently, the species persists in small, isolated sub-populations in Ulu Selama Forest Reserve, Taman Negara National Park, and Endau Rompin State Park, and Ulu Belum Forest Reserve in Peninsular Malaysia; Gunung Leuser National Park, Barisan Selatan National Park, Kerinci Seblat National Park, and Way Kambas National Park in Sumatra; and Danun Valley Protection Forest Reserve and Tabin Wildlife Reserve in Sabah (Asian Rhinos, 1995a & b; UNDP, 1995). *D. sumatrensis* has been recorded throughout Borneo (Harrisons, 1956; Davis 1962), but recent evidence show their confirmed existence only in eastern Sabah. The species, however, was recorded in Sarawak in 1987 (Labang, 1987), but there are no definite records since (Wildlife Conservation Society & Sarawak Forest Department, 1996). To conserve the subspecies *D.s. harrisoni*, efforts must concentrate in Sabah. In this context, Sabah is therefore of global importance.

3.1.3 Social Organization and Ecology

D. sumatrensis are solitary animals, except for the period it spends with its mother (Peacock, 1933; Lekagul & McNeely, 1977; Borner, 1979; van Strien, 1986). The home range of different animals overlapped greatly and home ranges have been reported from ten to 30 km^2 (Strickland, 1967; van Strien, 1986). They are found in a wide-range of habitats, from the lowlands to the steep montane areas (Strickland, 1967; Lekagul & McNeely, 1977; van Strien, 1986), although preferring dense primary rainforests (Peacock, 1933; Borner, 1979; Strickland, 1967; van Strien, 1986). *D. sumatrensis* are browsers, feeding on a wide range of plant species, mainly leaves and stems of broad-leaved herbs, shrubs and trees (Strickland, 1967; Borner, 1976; van Strien, 1986).

3.1.4 Legal Status

Dicerorhinus sumatrensis is currently listed as 'Critically Endangered' in the IUCN's Red Data Book (1996). It is also included in the Appendix I of CITES, therefore all international trade of the animal or its parts is banned except for non-commercial conservation reasons, such as the exchange of animals for captive breeding. In Sabah, *D. sumatrensis* is classified as a 'Protected Animal' under the Fauna Conservation Ordinance 1963 and its subsequent amendments (Jabatan Hidupan Liar, 1988). Hunting, killing or capturing a protected animal is illegal without a special license issued only by the Director of the Sabah Wildlife Department. This special license, however, will never be issued for two protected animals, *D. sumatrensis* and *Pongo pygmaeus* (Jabatan Hidupan Liar, 1988).

3.1.5 Animals in Captivity

Among the extant species of rhinoceros, only two, *D. bicornis* and *C. simum* have bred well in captivity. Only one, *D. sumatrensis* have not. Its dire status in the wild meant that there have been attempts, largely using 'doomed' animals. Attempts to captive breed *D. sumatrensis* by western zoos in the 1980s had failed (Rabinowitz, 1995). In peninsular Malaysia several animals were caught, including one pregnant female which later gave birth in captivity (Rabinowitz, 1995). Otherwise, there is no animal that have successfully been bred in captivity.

The number of *D. sumatrensis* in captivity in Sabah from 1987 to 1995 has been eight males and two females. All were captured from the wild (Bosi, 1996). Out of these ten animals, four males died and another male attached with a defective radio-collar was released in the Tabin Wildlife Reserve (table 3.1). This radio-collared animal was reportedly sighted about 30 km from its release site (Bosi, 1996), about eight months after its release (M. Andau, pers. comm.). It has not been seen since. Currently, there are still three males and two females in captivity.

3.2 Methods

Both intensive and extensive surveys were conducted at selected areas to determine the presence, abundance and distribution of *D. sumatrensis*. Areas were selected on the basis of habitat quality, remoteness from human habitation, and recent published, unpublished and anecdotal reports. One of these areas, the Danum Valley Protection Forest Reserve, was the focus of two major surveys for *D. sumatrensis* (appendix I). Census techniques employed to estimate the density of *D. sumatrensis* were based on signs made by the species. Use of indirect evidence is favored and is more practical when assessing densities of elusive animals in dense tropical rainforest habitats. The presence of *D. sumatrensis* is best assessed by

studying indirect evidence made by the animals (Strickland, 1967; Borner, 1979; van Strien, 1986).

Observing *D. sumatrensis* in its natural environment is extremely difficult, by nature of its shyness and sensitivity to human presence (Flynn, 1978; Borner, 1979). Also, the possibility of encountering the animal is very remote due to their extremely low numbers. Furthermore, counting indirect evidence give indices of population abundance, which are useful to management (Wiles, 1980; Sale *et al.*, 1990; Rodgers, 1991; Rabinowitz, 1993).
Interviews with village elders, hunters and loggers were also conducted, as such interviews provided some information on past distribution and density of animals, current and past threats. Observations on the direct and indirect impacts of human activity on forests and wildlife in the different areas were also recorded.

Surveying for *D. sumatrensis* involved the thorough patrolling of existing animal trails (trails that showed use by animals, evidenced from tracks and other signs), particularly along ridges and waterways in forested areas for indirect evidence such as tracks, dung, wallows, feeding and marking signs. Information gathered were recorded onto a data sheet (see appendix III). Also, using the animal trails is probably the best way to cover large areas (Borner, 1979; Ammann, 1986; van Strien, 1986; Rabinowitz, 1992). If the animal is in an area, the possibility of encountering its signs is higher when patrols are carried out along waterways and ridges (Borner, 1979; van Strien, 1986). Furthermore, mineral licks, important to many large mammals such as *D. sumatrensis*, are usually found near waterways.

Survey routes were determined from 1:50,000 topographic maps ahead of surveys. Routes normally took the shape of irregular loops, originating and terminating at camps, to cover as much area as possible. Speed of travel along survey routes was maintained at not more than a kilometer an hour, so as not to miss signs (tracks, dung, rub marks, twisted and broken saplings, etc.) of *D. sumatrensis*. Thus, up to an average of eight kilometers was covered in a single survey day. A survey team comprised 2-3 persons to ensure that signs made by the species were not missed. Team members simultaneously searched for evidence of *D. sumatrensis* presence. Field assistants were given intensive training at start of the study, and the same assistants were used throughout the study, therefore data collected was consistent and reliable.

Tracks of *D. sumatrensis*, when encountered, were measured and plaster casts were made. Although tracks of *D. sumatrensis* are highly distinctive, care was taken when identifying their tracks, as tracks of young *Elephas maximus* can easily be mistaken for that of *D. sumatrensis* (see appendix I). Doubtful tracks which might have been made by young *D. sumatrensis* were dismissed if tracks of an adult *D. sumatrensis* were not in the vicinity. This is because a young *D. sumatrensis* travels with its mother until almost adult-size (van Strien, 1986). Also, any unclear track which might have been *D. sumatrensis* was dismissed as that made by *E. maximus*, if *E. maximus* tracks of the same age were in the vicinity.

Measurements of tracks (see appendix III) followed that of Rabinowitz (1992), which was adapted from van Strien (1986). Attempts were made to identify and age individuals from the track measurements, particularly from the front toe (van Strien, 1986; Rabinowitz, 1992). The location using a Global Positioning System (GPS) where feasible, in combination with a compass, an altimeter and maps, and direction of the tracks were recorded and mapped. Whenever possible, tracks were also followed, to gain some insight into the behavior and

ecology of the species (Borner, 1979; Ammann, 1986; van Strien, 1986; Ahmad, 1987; Abd. Hamid, 1991).

There is considerable variation in the track measurements of different individuals, particularly in the width of the front hoof; therefore, with several sets of track measurements (see appendix III) alongwith plastercasts of those tracks, most individual animals can be easily recognized (van Strien, 1986). Thus, the density of *D. sumatrensis* in any one area was calculated from the number of individuals that could be identified from tracks found during a survey. This can be regarded as a count of the minimum number of animals that were present in the area at the time of survey. Also, differences in size of the tracks, and the age and minimum distances between tracks with similar measurements were taken into consideration when estimating the minimum number of *D. sumatrensis* present in the areas surveyed (Ammann, 1986; van Strien, 1986).

Wallowing is an important activity of *D. sumatrensis* and the presence of mud wallows made by *D. sumatrensis* are major features of their areas, therefore an important indicator of their presence. Wallowing behavior in *D. sumatrensis* might serve to moisten the skin and to protect the animals against ectoparasites (Schenkel & Schenkel-Hulliger, 1969; Hoogerwerf, 1970; Borner, 1979; Ammann, 1986; van Strien, 1986), and possibly assist in thermoregulation (Schenkel & Schenkel-Hulliger, 1969; Ammann, 1986). Thus, the presence of mud wallows in the areas surveyed made either recently or in the past were recorded. Other species, *Sus barbatus*, *Cervus unicolor* and *Elephas maximus*, also use these wallows, but not as frequently as used by the study animal. Mud wallows that are frequently used by *D. sumatrensis* have a definite form; their shapes and sizes determined by the study animal's wallowing activities (van Strien, 1986).

Information on plants associated with the animal was also recorded such as feeding and marking signs, their girths, height where plant was twisted, etc. Samples of food and marked plants were collected for later identification at the Sabah Forestry Department's Research Division.

Marking behavior in *D. sumatrensis* apparently is a mean of indirect communication, probably to facilitate orientation, demarcate territories and advertise a female's estrous state (Schenkel & Schenkel-Hulliger, 1969; Flynn, 1978; Borner, 1979; van Strien, 1986).
Data on signs other than tracks, made by *D. sumatrensis* were basically used as an indicator of the species' presence. In calculating densities, these signs were used in estimating the possible and probable number of animals present. It should be noted that only those signs, other than tracks and dung, that were accompanied by at least one other evidence were confirmed as those made by *D. sumatrensis*.

Remote photography using camera traps was also employed to record the presence of this rare and elusive species along major trails in areas suspected to harbor the species. Each camera trap unit comprised an active infrared trail transmitter and receiver, and a camera kit.

3.3 Results

3.3.1 Population Estimates

Including replicate routes, a total distance of 1920 kms of trails was surveyed during the study. This represented a total sample area of approximately 740km^2 from 14 reserves, covered in 720-man days (table 3.2).

As *D. sumatrensis* is already on the verge of extinction, the exact locations of signs confirming the species' presence observed during this study will not be mentioned in this report. This is to prevent unscrupulous persons from misusing the information for selfish gains at the cost of reducing the species' survival chances in the wild. The monetary value attributed to the species' horns and its body parts are extremely lucrative (section 3.1.4) and currently far outweighs the risks involved in harvesting them. Only those reserves where signs of the species were encountered are presented here, but not further details of their locations.

Danum Valley Protection Forest Reserve (DVFPR)

Evidence of the species' presence was observed in all areas of the DVFPR surveyed, mainly in the form of mud wallows. Most wallows, however, did not suggest that they were recently used by *D. sumatrensis*. Alternatively, evidence of *D. sumatrensis* at some of the wallows could possibly have been obliterated by other animals using those wallows. The signs commonly observed at the wallows were those that were made by *Elephas maximus*, *Cervus unicolor*, *Sus barbatus*, and *Muntiacus* spp. Signs observed at some of the wallows suggesting that the wallows were used by *D. sumatrensis* were tracks, feeding and marking signs. Rarely, these signs were also observed along animal trails. There were also several recent scrapes along a ridge trail within a stretch of approximately a kilometer. This area did not reveal any recent evidence during the second major survey (appendix I), carried out several months earlier. The appearance of the scrapes along with some feeding and marking signs of the same age strongly suggested that they were all made by *D. sumatrensis*. Also, there was photographic evidence of the species taken by remote photography along the same ridge trail. Measurements of clear scrapes were taken, the largest was 18 cm by 39 cm and the smallest was 15 cm by 20 cm. A twisted sapling and a few trees that had rhino horn rubbings were found in the vicinity of one recently used wallow. This wallow was located on a saddle. Only a single dung sample was found in the reserve, and this was during the second major survey.

Besides tracks encountered during the first and second major surveys, no additional tracks of the species were encountered during other surveys in the reserve. Thus, based on track evidence obtained during the second major survey conducted during this study period (appendix I), there were at least five but probably ten individuals in the total area surveyed. The reserve, however, could possibly harbor between six to 13 animals (appendix I).

Ulu Segama Forest Reserve (USFR)

Only one set of fresh tracks was encountered near the Segama River. When followed, these tracks led to a mineral source. No recently used wallows were encountered in the areas surveyed. The other evidence of recent rhino presence was feeding signs, albeit in different localities. Some of the feeding signs were accompanied by twisted saplings. Only tracks of *S. barbatus* and *C. unicolor* were observed at both the wallows. Otherwise, tracks of animals usually observed at the other wallows were *E. maximus*, *C. unicolor*, *S. barbatus*, *Muntiacus* spp. and *Tragulus* spp. Thus, based on this evidence and the distance between signs at different localities, there was at least one *D. sumatrensis* and possibly three present in the reserve.

Maliau Basin Conservation Area (MBCA)

Four wallows made by *D. sumatrensis* in the past were observed, but none showed any recent use by the species. Almost all were covered with thick layers of leaf litter. A single track was

reported along a ridge trail several months after I surveyed the area (Patricia Mobilik, pers. comm.). Thus, based on this information, there is at least one individual in the area.

Kuamut Forest Reserve (KFR) & Malubuk Virgin Jungle Reserve (MVJR)
Neither tracks nor dung of the animal were encountered during surveys. Although several wallows were encountered in both the reserves, particularly close to trails along ridges, none showed any recent use by *D. sumatrensis*. Also, it could not be determined with certainty whether feeding signs that were encountered were made by *D. sumatrensis* or not. A recent twisted sapling was, however, encountered in the Malubuk Virgin Jungle Reserve, and an old one in the Kuamut Forest Reserve. Thus, at least one individual was present in the two combined areas.

Gunung Rara Forest Reserve (GRFR)
Two old *D. sumatrensis* wallows were found in the reserve, close to ridge trails and in the saddles. None showed recent use by *D. sumatrensis*, and no other evidence was observed.

Malua Forest Reserve (MFR)
The only evidence to suggest the presence of *D. sumatrensis* in the reserve was a twisted sapling. This evidence was, however, quite recent, therefore suggesting the presence of an individual.

Tangkulap Forest Reserve (TFR)
Only one old *D. sumatrensis* wallow was observed during surveys in this reserve. This wallow was on the side of a ridge trail. The only recent signs seen at the wallow were that of *S. barbatus*.

Tabin Wildlife Reserve (TWR) & Lower Segama Region (LSR)
D. sumatrensis wallows were not uncommon throughout the areas surveyed. Most of the wallows encountered were old. Only two of the recent ones had tracks of *D. sumatrensis* associated with them, while the rest usually had tracks of *E. maximus*, *S. barbatus*, *C. unicolor* and *Muntiacus* spp. Also, there were signs of feeding and marking in the vicinity of both these wallows. Marking signs observed were twisted saplings and mud smears. At one of the wallows, there were some horn marks against the walls of the wallow. Thus, based on tracks that could be distinguished, there were at least three individuals in the areas surveyed. Two fresh *D. sumatrensis* tracks were also reported in the region between Tabin and Kulamba Wildlife Reserves (Rajanathan, 1995).

3.3.2 Ecology and Behavior

Some of the plant samples associated with *D. sumatrensis* were identified (table 3.3). Only those plant samples whose association with *D. sumatrensis* were confirmed are included. Confirmation was based on evidence distinctive to the animal (e.g. twisted sapling) and/or the presence other evidence found close to the plant sample and were of approximately the same age to the feeding signs observed on those plant samples.

Wallows were generally encountered in most areas surveyed, although the frequency of encounter varied between areas. Measurements of mud wallows that were, or probably, or possibly used by *D. sumatrensis*, averaged 1.9 m (range 1.85 m - 2.2 m) in width, and 2.6 m (range 2.5 m - 3 m) in length. Heights of the walls of wallows averaged 1.4 m (range 1 m - 2.3 m). The shapes of the wallows range from almost round to oval to almost 'capsule-like.'

Wallows were generally located at saddles, along contours, on ridges, and on slopes close to the ridges.

3.3.3 Current Threats

The drastic decline of *D. sumatrensis* in Borneo the past century was attributed to hunting by the native rural people, which was encouraged by the government which regarded *D. sumatrensis* horns as a forest product (Payne, 1990b). The high value for the horns, priced at US$45,000 per kilogram (Bradley-Martin & Bradley-Martin, 1991) undoubtedly continued the species declination into this century to a critical level. In Sabah, *D. sumatrensis* is severely threatened by loss of habitat due to forest fragmentation, logging, agriculture, and conversion of large forested areas to oil palm plantations; and particularly hunting for trade. In more recent times, loss and fragmentation of forested areas contributed to the species' further decline in Sabah. As logging operations and vast forest clearance for plantations proceeds, more areas are made accessible to poachers. Furthermore, disturbance associated with logging operations inevitably scare animals away, therefore disrupting reproduction. Thus, the combined pressures of habitat destruction and poaching are both reducing and fragmenting wild *D. sumatrensis* populations. In spite of increased efforts to conserve the species, poaching is still identified as the single major threat to *D. sumatrensis* in Sabah (Andau & Payne, 1982; Andau, 1987; Anon., 1993; Sabah Wildlife Department, 1993).

3.4 Discussion

3.4.1 Population Estimates

Survey results show that, based on track evidence, there were at least 11 *D. sumatrensis* present in the combined surveyed areas. In combination with other evidence, there could possibly be between 23 and 33 animals (table 3.2). Data confirmed previous observations that there appeared to be two main populations, concentrated in the Danum Valley Protection Forest Reserve and Tabin Wildlife Reserve (section 1.1).

The Danum Valley population could, however, possibly be from 18 to 24 animals, as the Sabah Foundation Concession Area and Tangkulap Forest Reserve form one contiguous forested area.

The population in the Lower Segama region, might possibly harbor between five to nine animals. A recent estimate for the region placed the figure between nine to 20 animals (Malim & Ambu, 1995). This difference in estimates for Tabin Wildlife Reserve is probably a result of the latter survey having several teams simultaneously searching for signs of *D. sumatrensis*. The tracks reported by Rajaratnam (1995; section 3.3.8) suggest a possible movement between Tabin and Kulamba Wildlife Reserves.

A comparison of estimates, showed that the total number of *D. sumatrensis* in the Danum Valley Protection Forest Reserve is higher than in the Lower Segama region. Even when comparing with estimates obtained by Malim & Ambu (1995) the population estimate of the Danum Valley Protection Forest Reserve is still higher than that of Tabin Wildlife Reserve. The former is pristine habitat with several contiguous forest reserves acting as buffers; this might contribute to this difference. By contrast, the Lower Segama region is mostly logged forest almost totally enclosed by oil palm plantations. The fact that *D. sumatrensis*, a browser, can find food and survive in secondary forests, merely imply that its presence is probably determined by the relative safety of an area (Rabinowitz, 1992).

No tracks of young animals were ever encountered, which could seriously imply that the animals were not breeding. Also, sex ratio in the wild could not be determined as it was not possible to determine sex of animals based on track evidence. Based on the history of capture for Sabah Wildlife Department's captive breeding program, the sex ratio of *D. sumatrensis* is one female to every four males. This doesn't necessarily mean that the sex ratio of wild population is equally skewed. From a recent hunting study, the ratio of hunted *S. barbatus* is extremely skewed, i.e. far more males hunted (E.L. Bennett, A.J. Nyaoi & J. Sompud, unpublished data). This is fairly common in hunting studies, and is a reflection of the difference in males' and females' behavior, as much as a real sex difference. In the event, however, that the disparity in sex composition of wild populations of *D. sumatrensis* is great, it seriously indicate a great danger of decline given the generation time and other factors
A fresh set of tracks was observed in a degraded section of the Ulu Segama Forest Reserve, very close to an oil palm plantation. Likely reason is that the animal was visiting a mineral source and a major river located in the area.

The Maliau Basin Conservation Area, albeit a pristine area, did not yield much evidence of *D. sumatrensis*. Although the area was remote and relatively inaccessible, there still exist signs of poaching, which might explain the lack of *D. sumatrensis* signs. Anther possible explanation is that the leaf litter is very thick almost throughout the whole area. Direct observations on a few *S. barbatus* in the area showed that the animals' tracks were hardly visible when foraging along trails covered with thick leaf litter. This, however, still does not explain the lack of other evidences such as wallows and twisted saplings Conversely, *D. sumatrensis* might be using other parts of the conservation area at time of survey. This, however, is subject to confirmation.

None of the wallows encountered in the montane region of Kuamut Forest Reserve, showed any recent signs of *D. sumatrensis* might be due to the high level of human disturbance and noise in the reserve. Two roads were being constructed to extend the 'main line west' of the Sabah Foundation Concession Area all the way up to the Kuamut River, and logging was occurring in several parts of the reserve. The construction of the roads and logging operations employed heavy machinery that were extremely noisy. Also, logging activities might have destroyed mineral sources, food plants and wallows. Even signs of the generally common wildlife species were scarce. In a much earlier survey, Payne (1990a) reported finding old large wallows in the reserve presumably made by *D. sumatrensis*.

Although wallows in Gunung Rara Forest Reserve were not recent, they nevertheless suggest the possible presence of *D. sumatrensis* in the area. An earlier survey reported finding tracks of the species in the reserve (Ambu, 1995). Evidence of the species in Malua and Tangkulap Forest Reserves suggest that animals might occasionally use the reserve. Positive evidence of *D. sumatrensis* was recorded in Malua Forest Reserve in the mid 1980's (Anon., 1986), and in Tangkulap Forest Reserve in the early 1980's (Payne, 1990a).

3.4.2 Habitat Preferences

Observations indicate that *D. sumatrensis* can occupy a wide range of habitats, from the lowlands to the mountains, in both primary and secondary forests. Surveys, however, found more evidence of the species in the primary than secondary habitats, suggesting a preference for the former. This is supported by some earlier observations (Peacock, 1931; Borner, 1973; van Strien, 1986). Strickland (1967), however, observed that *D. sumatrensis* had a strong

preference for secondary and fringe plant species. Conversely, the general availability and abundance of food plants in disturbed forests undoubtedly allows browsers to survive. In addition to food, however, the presence of *D. sumatrensis* in secondary habitats might actually be that the species are merely reasserting their former ranges. Lowlands are usually the first area to be encroached upon by humans, whereas the mountainous regions have suffered least. Thus, the species would probably return to low-lying areas where forests were allowed to regenerate, provided there were no other discouraging factors. Furthermore, most mineral sources, important to herbivores, are in the lowlands.

3.4.3 Ecology and Behavior

Measurements and shapes of wallows observed in this study conformed to those reported by Borner (1979) and van Strien (1986).

The feeding signs observed support the observation that *D. sumatrensis* are browsers (van Strien, 1974; 1986), and suggest that they are possibly selective feeders, at least in terms of plant parts. Data still are lacking to suggest they are selective feeders in terms of plant species. Also, most food plants were saplings, similarly observed by a few other workers (Hubback, 1939; Strickland, 1967; van Strien, 1974; Borner, 1979). The only possible explanation for this is that the animals can easily access the preferred plant parts.

All but one of the twisted saplings were twisted clockwise (n=9). Also, except for three samples, all observed twisted saplings made by *D. sumatrensis* ranged from 1.2 cm to 8 cm in girth, and were usually twisted at about 60 cm to 80 cm above ground. A study in Sumatra reported similar findings (Borner, 1979). In the same study, trees that showed signs of feeding were usually broken between ground level at 40 cm above the ground (Borner, 1979), therefore similar to the single observation made in this study.

As evidenced from the plant samples that were associated with *D. sumatrensis* with certainty, not all twisted sapling were food plants. This implies that, beside scrapes, urine and dung, some plants were twisted for marking purposes (Borner, 1979; van Strien 1986).

The rarity with which marking signs were observed in this study implies extremely low population densities, supporting the low figures obtained from observation on tracks. Borner (1979) suggested that the species will totally abandon the marking system, if the population density declines to certain level, either because of poaching or other human activities driving the animals from their traditional ranges.

Table 3.1 Summary of captive *D. sumatrensis* in Sabah (adapted from Bosi, 1996)

Capture Date	Sex	Status	Remarks
March 28, 1987	Male #1	Dead	This male was captured at Linbar of Kinabatangan District, eastern Sabah, but died in the pitfall trap during the capture process. Internal injury and respiratory failure was cited as the cause of death.
August 14, 1987	Male #2	Dead	This animal died at the Sepilok Rhino Breeding Center in Sandakan, eastern Sabah on April 22, 1992, almost five years after capture. The location of capture was in the Lower Kinabatangan, eastern Sabah. Hindgut obstruction was cited the cause of death.
May 24, 1988	Male #3	Dead	This animal died in the pitfall trap during capture. Information on the location of its capture is not available. Capture trauma was cited as the cause of death.
April 22, 1989	Female #1	Alive	This female was mated with male #5 on October 28, 1995, but no birth occurred so pregnancy was unlikely. This female had wandered into a village about 11 km from Lahad Datu, a town in eastern Sabah, before it was captured. This female is currently at the Sepilok Rhino Breeding Center.
May 5, 1991	Male #4	Dead	This male died at the Sepilok Rhino Breeding Center on May 8, 1995, four years after capture. Tetanus was cited as cause of death. Location of capture is not available.
August 27, 1992	Male #5	Alive	This male was mated with female #1 and female #2 on October 28, 1995 and October 26, 1995 respectively. No information is available on the location of capture. This male is currently at the Sepilok Rhino Breeding Center.
June 5, 1993	Male #6	Uncertain	This male was caught at Bulud, Sukau in eastern Sabah and later transferred to Tabin Wildlife Reserve, where it was fitted with a radio-collar. It escaped on November 30, 1993 prior to its proposed release. The radio-collar proved to be defective, so the animal could not be followed. The animal was spotted in June 1995, 30 km from its release site (Mahedi Andau, pers. comm.).
August 20, 1993	Male #7	Alive	It is currently at the Sepilok Rhino Breeding Center.

June 17, 1994	Female #2	Alive	This female was mated with male #5 on October 26, 1995. Again, no subsequent birth, therefore pregnancy unlikely. This female is currently at the Sepilok Rhino Breeding Center. Location of capture is not available.
November 22, 1995	Male #8	Alive	Captured at Malbumi Estate in Sukau, and is currently located at the Sepilok Rhino Breeding Center.

Table 3.2 Population estimates of *Dicerorhinus sumatrensis* in surveyed areas

Criteria for categorizing *D. sumatrensis* numbers:
i. Known - based on minimum number of identifiable tracks.
ii. Probable - based on number of track sets and recent presence of other evidences.
iii. Possible - based on presence and location of other evidences.
Note: criteria ii and iii based on potential home range of the species, i.e., from 20-30 km^2 (van Strien, 1986).
* considered separately from the second major survey in the area (see appendix I).

Location	Area covered (km^2)	Known	Probable	Possible
Danum Valley Protection Forest Reserve*	72	5	10	13
Ulu Segama Forest Reserve	210	1	3	3
Maliau Basin Conservation Area	90	1	2	3
Kuamut Forest Reserve & Malubuk Virgin Jungle Reserve	30	1	2	2
Gunung Rara Forest Reserve	60	0	0	1
Tangkulap Forest Reserve	12	0	0	1
Tabin Wildlife Reserve & adjoining areas	210	3	5	9
Malua Forest Reserve	18	0	1	1
Sungai Pinangah Forest Reserve & Sungai Imbak Virgin Jungle Reserve	10	0	0	0
Kalabakan Forest Reserve	16	0	0	0
Sapulut Forest Reserve	12	0	0	0
Total	740	11	23	33

Table 3.3 Identified plant samples associated with *D. sumatrensis*

Plant Species	Remarks
Alangiaceae *Alangium ebenaceum*	Food sample, comprising terminal twigs, leaf shoots and young leaves. The terminal end of this sapling was totally bitten off at 1.35 m from base of the plant. The girth of this sapling measured 4 cm at breast height. This sapling was on a major animal trail along a ridge. Several scrapes were found along the trail.
Dilleniaceae *Dillenia* sp.	Food sample, comprising small branches, terminal twigs, leaf shoots, young leaves, and the apical ends of some mature leaves. This small tree which had a girth of 12 cm at breast height, was broken at 35 cm from base of the plant. The animal appeared to have pushed the tree over either with the forehead or chest, and walked over it, pressing the tree under its belly. Rub marks on the tree suggested that the initial pressure was applied at 55 cm from the base of the plant. The girth of the tree immediately below the break was 17 cm. This tree was along a major animal trail.
Dipterocarpaceae *Dipterocarpus caudiferus*	Twisted sapling, having a girth of 8 cm immediately below the twisted portion. The sapling was twisted clockwise at 75 cm from base of the plant. This sapling was in the vicinity of a wallow. There was no evidence of feeding on this plant.
Dipterocarpaceae *Hopea ferruginea*	Twisted sapling, with no signs of feeding. The sapling was twisted clockwise at 1.25 m from its base, and its girth measured 4 cm immediately below the twist. This sapling was in the vicinity of a wallow.
Euphorbiaceae *Baccaurea stipulata*	Twisted sapling, twisted clockwise at 76 cm from base of plant, and the terminal ends were totally bitten off. Young leaves and terminal twigs were eaten. The girth immediately below the twist was 3.8 cm. This sapling was in the vicinity of a wallow.
Euphorbiaceae *Mallotus* sp.	Twisted sapling with young leaves eaten. Sapling was twisted clockwise at 72 cm from its base and had a girth of 6 cm immediately below the twist. This plant was near a mud wallow.
Euphorbiaceae *Aporusa* sp.	Twisted sapling with signs of feeding. Plant was twisted clockwise at 60 cm and 70 cm from its base, and had a girth measuring 1.2 cm immediately below the first twist.
Lauraceae *Litsea oppostifolia*	Twisted sapling with signs of feeding. Terminal ends of the sapling totally bitten off, and parts eaten were young leaves and terminal twigs. Sapling was in the vicinity of a wallow. The sapling was twisted clockwise at 1.35 cm from its base, and had a girth of 7 cm, located near a mud wallow.
Melastomaceae *Melastoma mabathricum*	Twisted sapling with its terminal twigs, small branches, and young leaves eaten. The sapling was twisted clockwise at 1.66 m from its base, and had a girth of 4.5 cm immediately below the twist. This sapling was in the vicinity of a mud wallow.
Myrtaceae *Eugenia* sp.	Food sample, located near a mud wallow. Plant parts eaten were terminal twigs, small branches, leaf shoots, young leaves, and apical end of some mature leaves.

Oleaceae *Chionanthus pluniflorus*	Twisted sapling, with no signs of feeding, in the vicinity of a wallow. Sapling was twisted clockwise at 1.46 m from its base, and had a girth of 4 cm immediately below the twist.
Rubiaceae *Urophyllum glabrum*	Twisted sapling, with young leaves and some mature leaves eaten. Sapling was twisted anticlockwise at 68 cm from its base, and had a girth of 7 cm immediately below its twist. Sapling was in the vicinity of a wallow.

4. ASIAN ELEPHANT

4.1 The Study Animal

Belonging to the family Elephantidae and a monotypic genus, *Elephas maximus* Linnaeus 1758, is one of the two living species of elephants. It is the only elephant in Asia, and is also the largest terrestrial mammal in Asia (Payne *et al.*, 1985).

4.1.1 Description

Both male and female *E. maximus* have a distinctive shape, a grayish brown to almost black coloration, and a long trunk which ends in a single pointed 'lip' or 'finger'. Two protuberances are clearly visible on its forehead, and the upper rims of its ears are extended almost level with its forehead. *E. maximus* usually have four toe-nails on the hindfoot and five toe-nails on the forefoot (Peacock, 1933; Tun Yin, 1967; Corvanich, 1976). Male *E. maximus* have shoulder heights measuring from 1.7 m to 2.6 m, whereas females measure from 1.5 m to 2.2 m (Payne *et al.*, 1985). In Myanmar, the average height of *E. maximus* males is 2.74 m, and females is 2.44 m, but males may reach a maximum height of 3.2 m (Peacock, 1933). Most adult males have tusks that measure from 0.5 m to 1.7 m long, and weigh 1.5 kg to 15 kg (Payne *et al.*, 1985). Tusks of *E. maximus* have been known to attain a length of 2.67 m, and a girth of 47.6 cm. Tuskless males are often bigger than males with tusks (Tun Yin, 1967; Corvanich, 1976). Females as a rule lack tusks, but often bear small tushes that may protrude as much as 15 cm beyond the lips (Peacock, 1933).

4.1.2 Distribution

Once widespread throughout Asia, *E. maximus* is now restricted to parts of India including the Andaman Islands, Bhutan, Bangladesh, Nepal, Sri Lanka, China, Myanmar, Laos, Vietnam, Thailand, Cambodia, Sumatra and Kalimantan, and Peninsular Malaysia and Sabah (Payne *et al.*, 1985; Sukumar, 1989). The Bornean form *E.m. sumatrensis*, is found between the Sugut River in northeastern Sabah and the Sembakung River in northern East Kalimantan (Davis, 1962; Payne *et al.*, 1985; Sukumar, 1989).

The origins and restricted distribution of *E. maximus* in Borneo is debatable. It was suggested that present-day populations of *E. maximus* in Borneo might have descended from captive animals that were presented to the Sultan of Sulu in 1750 (Olivier, 1978). As late as the mid-1960's, several *E. maximus* trained for logging operations were brought from Thailand into Borneo by a firm operating in both Thailand and Borneo (Corvanich, 1995). There was, however, no mention as to where in Borneo the animals were brought to, and what the fate of the animals were, except that their work performance declined as a result of incompatibility with the native fodder. A single fossil record (Hooijer, 1972), and sighting of domesticated *E. maximus* in Borneo dating back to 1521 (de Silva, 1968) appears to suggest the indigenous origins of these animals. There is, however, a possibility that the species were brought to Borneo by man prior to this (Davies & Payne, 1982). Until more fossil evidence are found and/or DNA analysis are carried out, their origins will still remain debatable. As to their limited distribution, it was suggested that the animals were once widespread, but were exterminated by man; or that the animals' distribution were restricted by the availability of one or more minerals (Davies & Payne, 1982). Whether introduced or indigenous, *E. maximus* have been in Borneo for several hundred years, and undoubtedly play an important role in the ecosystem. Thus, the question of their origins should not be a bone of contention where their conservation in Sabah is concerned.

4.1.3 Social Organization and Ecology

Social groups of *E. maximus* have been reported from two to 40 individuals, with some solitary adult males (Peacock, 1933; Lekagul & McNeely, 1977; Olivier, 1978; Sukumar, 1989), although large groups of a hundred have also been reported (Payne *et al.*, 1985. Home ranges varied greatly from 59 km^2 to 167 km^2, and occupy a wide variety of habitat, preferring the forests rather than open habitats (Olivier, 1978; Sukumar, 1989). *E. maximus* is a generalist feeder, and its diet comprise mainly the softer portions of monocotyledonous plants (McKay, 1973; Payne *et al.*, 1985; Sukumar, 1989).

4.1.4 Legal Status

Elephas maximus is currently listed as 'Endangered' in the IUCN's Red Data Book (IUCN, 1996), and in the Appendix I of CITES. In Sabah, *E. maximus* is classified as a 'Game Animal' under the Fauna Conservation Ordinance 1963, and its subsequent amendments (Jabatan Hidupan Liar, 1988), which allows the animal to be hunted for a fee. Also, according to the ordinance, a license would not authorize the hunting of female *E. maximus*, and elephants can be hunted only with a firearm below .350 caliber. No license to hunt *E. maximus* was, however, issued in recent times. In the past when the Sabah Wildlife Department was still the Game Branch of the Sabah Forestry Department, licenses were occasionally issued to farmers to shoot animals which destroyed crops (Laurentius N. Ambu, pers. comm.).

4.1.5 Animals in Captivity

There is no captive breeding program for *E. maximus* in Sabah. There are currently three 'displaced' juvenile *E. maximus* in captivity, placed at the Tabin Wildlife Reserve, and there are plans to use them for tourism.

4.2 Methods

Elephas maximus occur at low densities, is wide-ranging, and primarily a forest-dwelling species, mainly inhabiting dense habitats with poor visibility. Thus, under these circumstances, an indirect method for estimating *E. maximus* density based on dung density (Dawson & Dekker, 1992), is the most feasible method. To obtain an estimate of *E. maximus* density E, this method requires that three parameters be measured, viz.,

E = Number of elephants per sq. km;
D = Dung density i.e. dung piles per sq. km;
R = Dung decomposition rate i.e. proportion of dung piles disappearing per day;
d = Defecation rate, i.e., the number of dung piles produced per day by an animal.
Thus, $E = (D \times R) \div d$.

An important assumption made when employing this equation is that the proportion of dung piles disappearing each day equals the proportion of dung piles deposited on that same day.

4.2.1 Dung Decomposition Rate

The rate of dung decomposition depends on a combination of several factors that include the action of dung beetles, climate, exposure to these climatic factors, and the composition of the dung itself. Ideally, 50 fresh dung piles of known dates of deposition from different habitats,

representing different diets, should be monitored from the day of deposition until they completely disappear (Dawson & Dekker, 1992). Measuring the rate of decay of *E. maximus* dung *in situ* in every study area was, however, not possible as their locations were scattered over a very large area, and would therefore require much effort and time to monitor. Furthermore, in this study surveys were carried out in different parts of the state, therefore monitoring dung samples at their original locations was not feasible.

Thus, a 'dung garden' was established in a forested area at the Danum Valley Field Center to monitor the rate of decay of *E. maximus* dung. Thirty-five fresh *E. maximus* dung piles of known dates of deposition when encountered, were collected and transported to the field center. In search of fresh dung, road surveys were carried out nightly and at pre-dawn in areas where *E. maximus* groups are known to be present. Each sample dung pile was numbered and marked with a flag tied to a wooden stake. This 'dung garden' was observed at pre-determined intervals (see appendix IVc), from the day of production until they completely disappeared, assigning the status of the dung piles to their appropriate categories over time:
A = All boli intact, fresh, moist, with odour;
B = All boli intact, but dry, no odour;
C1 = More than 50% of all boli intact;
C2 = Less than 50% of all boli intact;
D = All boli broken up or in a flat mass;
E = No dung visible (fully decayed).

The 'dung garden' was monitored for eight months from December 1995 to July 1996, and comprised three groups of 11-12 dung piles. The first group was placed in dense primary forest, therefore was least exposed to sun and rain; the second group was placed in disturbed habitat, therefore partially exposed; while the third group was placed in an open grassy area, therefore totally exposed. This was to maintain the dung piles in the 'dung garden' under conditions similar to those found in the natural state. The dung decomposition rate was the reciprocal of the mean survival time (in days) of the dung piles.

4.2.2 Defecation Rate

Dung defecation rate of *E. maximus* depends on the animal's diet, which in turn depends on the habitat type and the season (Dawson, 1992). Obtaining data on defecation rates of wild *E. maximus* was not possible for obvious reasons. Thus, the closest approximation to it is monitoring free-ranging domestic or captive elephants fed entirely on natural fodder. Monitoring, both night and day, should be carried out over a continuous 12-hour time block, over a minimum of 20 time blocks (appendix IVb), and there should also be at least one individual from each age/sex class (Dawson & Dekker, 1992). This, however, was not possible as there were only three captive animals in Sabah. Furthermore, they were all very young animals. Thus, the dung defecation rate used in earlier surveys in Sabah (Dawson, 1992; 1993a & b) will be used here. This rate was based on good sample sizes, albeit the study of defecation rates were carried out in the rainforests of southern India (Dawson, 1992). The rate of 13.2033±0.789 dung piles per day was reportedly similar to the rate obtained for captive animals in Thailand that were fed with natural fodder (Dawson, 1992).

4.2.3 Dung Density Transect

The line transect sampling technique (Burnham *et al.*, 1980; Buckland *et al.*, 1993) was used to estimate dung density. Line transects systematically placed 3 km apart, were prepared

along a predetermined compass bearing, oriented perpendicular to roads, major trails, rivers or streams in forested areas. The transects were placed on both sides of the roads, trails or rivers. The starting point of the first transect was selected at random. Topographic features like rivers and roads were selected as baselines when placing transects, as they allow accessibility and adequate coverage of large census areas. This could, however, introduce a bias due to the different vegetation and/or different habitat use, and the behavior of the animals by rivers and roads. Given the time-frame, manpower, and the large area to be covered, it was more feasible to use roads and rivers as baselines.

Transects were walked only once, and data were collected while simultaneously preparing the transects. This involved a team of three individuals. One team member cut the transect. The second team member held a compass aligned to a predetermined compass bearing and ensures that the first team member cuts the transect in an absolutely straight line. A distance of four to five meters was maintained between the 'compass-bearer' and the 'transect-cutter' so that the transect lines were as straight as possible. The third team member measured the distance traveled using a Hip-chain distance measurer. Only biodegradable threads were used with the Hip-chain distance measurer. All three team members simultaneously search for dung.

Dung piles observed while walking the transects were identified, counted, aged using the same categories as for dung decomposition rate (section 4.2.1), and their perpendicular distance to the transect measured. Information gathered was recorded onto data recording sheets (appendix IVa). Perpendicular distances were measured from the center of the transect line to the center of the dung pile. Other information recorded per transect line include location, general vegetation type, weather, start and end time, compass bearing, exact location of dung pile along the transect as recorded on the Hip-chain distance measurer, and transect length. Location of transects were determined using a Magellan NAV 5000DX global positioning system, a Brunton compass, a Thommen classic altimeter and 1:50,000 topographic maps.

4.3 Results

4.3.1 Dung Decomposition Rate

The 35 dung piles, averaging 6.1 boli per dung pile, took between ten to 34 weeks to decompose completely. This gave each dung pile a mean survival rate of 153.85 days. Thus, the decomposition rate of dung piles placed at the Danum Valley Field Center is 0.0065 ± 0.0010 dung piles/day. This rate can be applicable throughout the year, as monitoring of dung decomposition was carried out through both the rainy and dry seasons. Furthermore, it took almost three-fourths of a year to monitor the decomposition process.

Decomposition rate for the three subsets (section 4.3.1) when calculated separately gave decomposition rates of 0.0098 ± 0.0016 dung piles per day for the unexposed subset (n=12), 0.0070 ± 0.0012 dung piles per day for the partially exposed subset (n=12), and 0.0047 ± 0.0003 dung piles per day for the fully exposed subset (n=11). Apparently, the rate of decomposition of dung is faster in dense primary forest.

4.3.2 Defecation Rate

The defecation rate of neither wild nor captive *E. maximus* in Sabah could be obtained. Thus, the rate of defecation, 13.2033 ± 0.789 dung piles/day, used to estimate densities of *E.*

maximus in earlier surveys in Sabah (Dawson, 1992; 1993a & b) will similarly be used to estimate *E. maximus* densities in this study.

4.3.3 Dung Density Transects

A hundred and twenty-seven straight line transects covering a total distance of 62 km were prepared and walked in the areas surveyed (table 4.1). The average length of the transects was 491 m. A higher average transect length could not be achieved due to steepness of the terrain, or thickness of the undergrowth at all the sites with secondary forests, or inability to cross deep and wide rivers.

From the table, Tangkulap Forest Reserve apparently has the highest density of *E. maximus* at 2.38 animals per km², followed by Kuamut Forest Reserve and Malubuk Virgin Jungle Reserve combined, at a density of 1.06 animals per km². *E. maximus* was frequently encountered while carrying out patrol surveys (section 3.2), road surveys (section 6.2), and transect surveys in the Kuamut, Malua and Ulu Segama Forest Reserves, and Malubuk Virgin Jungle Reserve. Malua Forest Reserve which is contiguous to Kuamut Forest Reserve and Malubuk Virgin Jungle Reserve, had a density of 0.79 animals per km².

Gunung Rara Forest Reserve apparently had the lowest density of *E. maximus*, at 0.01 animals per km². Although transect surveys in the Sungai Pinangah, Kalabakan and Sapulut Forest Reserves, Sungai Imbak Virgin Jungle Reserve and Danum Valley Protection Forest Reserve did not find any *E. maximus* dung, *E. maximus* were nevertheless present in those reserves. This was evidenced by sighting of dung and tracks while carrying out patrol and road surveys. Tracks of *E. maximus* were also observed along transects, animal trails and logging roads in those reserves.

A density of 0.29 animals per km² was obtained when all the transects in reserves within the Sabah Foundation Concession Area and contiguous to it were pooled. A lower density at 0.25 animals per km² was obtained, when calculated for the Sabah Foundation Concession Area only. A similar density, 0.26 animals per km², was obtained for the Tabin Wildlife Reserve and forested areas within the lower Segama region that are contiguous to the reserve.

To determine whether the location of transects (section 4.2.3) introduced any bias to the results obtained above, the number of dung piles were calculated with increasing distance from the rivers and roads. Thirty-four out of a total of 127 transect lines were placed perpendicular to the Segama River and its major tributaries. Observations were weighted to compensate for bias caused by varying transect lengths. From a total of 35 dung piles encountered along these 34 transects, 23.9% of the dung piles were within the first hundred meters, 30.4% within the second, 30% within the third, and 14.3% of the total dung piles were more than 500 m away from the riverside (figure 4.1). Most dung piles (>85%) were within 500 m from the river.

A total of 313 dung piles was encountered along the remaining 93 transects that were placed perpendicular to logging roads. Similarly, observations were weighted to compensate for bias caused by varying transect lengths. 50.81% of the total dung piles were encountered within the first hundred meters of the transect, 8.35% within the second, and 8.20% within the third, and 21.16% of the dung piles were encountered more than 500 m from the road (figure 4.1). Almost 80% of the dung piles were observed within 500 m from the road.

Thus, apparently the density estimates for *E. maximus* obtained above are likely to be considerable over-estimates. The animal densities were recorded near where they are greatest, i.e. beside major roads and rivers. Thus, densities of whole reserves extrapolated from transects are gross over-estimates. Obviously, this means that there are likely to be far less animals than the data indicated. To compensate for this, the maximum and minimum densities of *E. maximus* was calculated (table 4.1). The maximum using dung densities as they are within 100 m of the road and river, and minimum using dung densities as they are more than 500 m of the road or river.

It was not possible to calculate minimum densities for some reserves because there were no dung piles more than 500 m from the rivers or roads. There is obviously a great disparity in maximum and minimum densities for reserves whose minimum and maximum densities could be calculated.

4.3.4 Ecology and Behavior

Signs of *E. maximus* were more common in secondary forests than in primary forests. Although 15% of the transects were carried out in primary forests, no dung was observed along the transects. Signs other than dung was observed, but at lesser frequency as compared to the secondary forests, particularly along logging roads.

All mineral sources visited and discovered during this study had recent and old signs made by the species, implying that they were regularly visited by the animals.

Tracks and dung of *E. maximus* were commonly found along river banks, animal trails and abandoned logging roads. On several occasions, tracks belonging to what were the same animals, based on size and age of tracks, were found on opposite banks of the Segama and Kinabatangan Rivers, and their tributaries. This implies that major rivers in Sabah do not restrict movements of *E. maximus*. An ecological and behavioral study on *E. maximus* in southeastern Sri Lanka (McKay, 1973) observed that the animal is capable of swimming, and is apparently a common feature with this species. Both Peacock (1933) and Tun Yin (1967) write that *E. maximus* in Myanmar are excellent swimmers, able to cross water-bodies that are more than a kilometer wide. Also, when crossing smaller water-bodies, the animal often walked the floor with an upraised trunk for breathing (Tun Yin, 1967). McKay (1973) observed that only the top of the animal's head and the tip of its trunk were above water, while the rest of its body remain submerged when swimming.

The animals apparently bathe with mud by rolling or lying in muddy patches and mud wallows. The habit of wallowing was also evident at many mud wallows encountered in the forests. Mud smears observed on some trees near these muddy patches and mud wallows suggest that the animals frequently rub their bodies against trees after a mud bath. The presence of elongated gashes on the bark of some trees evidently suggest that the animals frequently rub their tusks against those trees. Occasionally, holes were observed in the 'walls' of some mud wallows, which apparently were made by the animals pushing their tusks into the 'walls.'

Other observations include:
Evidence of *E. maximus* found in the forested areas between Tabin and Kulamba Wildlife Reserves indicate a possible movement between the two reserves. Both dung and tracks of a

small group estimated at ten animals, were observed in the forested areas on both banks of the Segama River, almost close to the mangrove forests.
Direct observations and other evidence showed that groups of *E. maximus* moving between the different reserves of the Sabah Foundation Concession Area, and also other reserves adjoining the Concession Area.
Tracks and dung of *E. maximus* were also discovered along a ridge in the Maliau Basin Conservation Area. This is the first confirmed report of the animal's presence in the area.

- A reconnaissance trip to the Dermakot Forest Reserve in May 1996, suggested that the reserve might support a high density of *E. maximus*, based on common sighting of its dung and tracks. Dermakot Forest Reserve is contiguous to Kuamut, Malua, and Tangkulap Forest Reserves. Transect surveys were not carried out in the Dermakot Forest Reserve, as permission to conduct surveys in the reserve was granted only after I was physically disabled due to a road accident.

4.3.5 Current Threats

In Sabah, *E. maximus* are threatened with poaching for ivory, but mainly loss of habitat to forest fragmentation, logging, shifting and permanent agriculture, and conversion of large forested areas to oil palm plantations. Reports of poaching for ivory in Sabah are rare, implying that poaching for ivory is actually rare. On the other hand, much poaching that occurs are neither reported nor realized. Occasionally, *E. maximus* that damage crops are killed by the Sabah Wildlife Department and at other times the animals are killed by others. Some individuals involved in the timber and oil palm industries are known to take 'pot-shots' at *E. maximus* (Peter Chu, pers. comm.). Although these shots do not kill the animals, the animals could develop infections that are fatal. Loss of habitat, however, poses the greatest threat to *E. maximus* in Sabah.

4.4 Discussion

A mean survival time of 153.85 days per dung pile obtained from the dung decomposition experiment carried out at the Danum Valley Field Center was slightly longer than that of 140.84 days obtained from a similar experiment carried out at the Tabin Wildlife Reserve (Dawson, 1992 & 1993a). These give dung decomposition rates for the two sites at 0.0065 and 0.0071 dung piles/day respectively. Dawson's (1992 & 1993a) rate of dung decomposition was, however, closer to the rate of 0.0070 obtained for the partially exposed subset (section 4.3.1). This similarity in rates is most likely because Tabin Wildlife Reserve has an open forest (section 2.2.2).

In a study carried out in a dry tropical forest in Huai Kha Khaeng Wildlife Sanctuary, western Thailand, Srikosamatara (1993) obtained a mean survival time of 156 days, giving a dung decomposition rate of 0.0064 dung piles/day. A mean survival time of 166.67 days per dung pile was calculated from a study by Wiles (1980) in a lowland bamboo forest in Salak Phra Wildlife Sanctuary, southwestern Thailand. This gives a dung decomposition rate of 0.0060 dung piles/day.

Albeit the difference in study areas, diet of *E. maximus*, and probably the amount and type of agents of decomposition, the difference in rates of dung decomposition between sites in the tropical rainforests of Southeast Asia was quite small. Thus, for estimating *E. maximus* densities in a tropical Southeast Asian rainforest based on dung density method (Dawson & Dekker, 1992), an average decomposition rate of 0.0065 could be used in studies that are too short to monitor the dung decomposition rates.

Densities of *E. maximus* obtained for the reserves where transect surveys were carried out were most likely over-estimates due to a bias influenced by the animals' preference for habitats close to roads and rivers (section 4.3.3). For management purposes, it is probably more realistic to use the minimum densities when extrapolating for the whole reserves. Thus, a density of 0.07 animals per km² was obtained for Tabin Wildlife Reserve and forested areas contiguous to it. In contrast, a density of 0.02 animals per km² was obtained for the reserves within and contiguous to the Sabah Foundation Concession Area. Based on these minimum density estimates, the 1220 km² Tabin Wildlife Reserve is estimated to have an *E. maximus* population size of 85 animals, and the 9,728.04 km² Sabah Foundation Concession Area is estimated to have a population of 195 animals.

The density estimate of 0.007 animals per km² for Tabin Wildlife Reserve obtained in this study is far lower than the mean density estimate of 0.3 animals per km² obtained by Dawson (1992 & 1993a). Surveys during different seasons might have resulted in a difference in density estimates. Dawson (1992 & 1993a) carried out her surveys during the dry season, whereas in this study, surveys in Tabin Wildlife Reserve were carried out during the wet season. Also, differences in density estimates could have partly resulted from a difference in dung decomposition rates used to estimate dung density. Major differences were most likely from distribution of transects. Dawson (1992 & 1993a) had her transects over a wider area, and covered several habitat types. Furthermore, this study had a much smaller sample size. Considering recent trends in habitat loss and fragmentation, population estimates obtained in this study for the Sabah Foundation Concession Area and Tabin Wildlife Reserve might not be far from the truth.

Evidence left behind by *E. maximus* found close to and along major rivers and tributaries strongly suggest the species' dependence on waterways and its associated riverine habitats. River systems and their associated habitats provide both large quantities of water and food important to *E. maximus* (McKay, 1973; Sukumar, 1989). The movement of the animals would therefore, be governed by the spatial distribution and temporal availability of water (McKay, 1973; Sukumar, 1989). Besides supplying the animal's needs for water and food, major river systems possibly serve as important points of reference or landmarks, particularly for wide-ranging species. In a tropical rainforest, where visibility is limited, major waterways are most likely the most readily recognizable landmarks. This was further evidenced by an observation in the Kuamut Forest Reserve and Malubuk Virgin Jungle Reserve where tracks and dung of a group of *E. maximus* were found for several kilometers, along a shallow tributary of Malubuk River. Thus, historically, their range would include habitats associated with river systems.

Similarly, there is a preference for *E. maximus* to travel along or very close to roads in forested areas. Most likely, this is due to the greater food availability by roads and the relative ease by which animals can travel.

More evidence of *E. maximus* (section 4.3.4), hence probably a higher density, observed in secondary forests was most likely due to a higher food availability in the former (Olivier, 1978; Sukumar, 1989; Dawson, 1993b). This, however, does not necessarily imply that secondary forests have a higher carrying capacity and are more important for the species' survival. An earlier survey in Tabin Wildlife Reserve yielded a higher density of *E. maximus* in primary forests (Dawson, 1993a).

Higher densities of *E. maximus* in secondary forests in current times might actually be that these forests were once prime habitats for the species in former times. Thus, with forest regeneration and reduced disturbance, *E. maximus* could highly likely have returned to their former ranges.

In southern India, Sukumar (1989) observed that some high density *E. maximus* habitats were formerly sites of human settlement, and that such habitats are usually prime habitats with abundant water supply, fertile soil and high potential productivity. *E. maximus*, therefore would be attracted to those habitats even prior to human occupation, and might be reasserting their former ranges after humans abandoned those sites (Sukumar, 1989).

Regular visits by the species to mineral sources clearly indicate the importance of these sources to *E. maximus*. Hence, the species distribution and movement might be governed by the distribution of these mineral sources (Davies & Payne, 1982; Sukumar, 1989). This might also account for the species occasional presence in the mangrove forests in the lower Segama region, particularly where there is a transition between riverine and mangrove forests. Brackish water in this region might provide an alternate source of minerals. In Tennaserim, the movements of *E. maximus* to the coast to drink salt or brackish water were observed to be almost migratory (Peacock, 1933).

Observations (section 4.3.4) showed that *E. maximus* groups using several contiguous reserves within and adjoining the Sabah Foundation Concession Area. Thus, it is imperative that these reserves be maintained as a single protected area to ensure the long-term survival of *E. maximus*. Also, of equal importance is the need to maintain the forested area between Tabin and Kulamba Wildlife Reserves as a land corridor, allowing movement between the two reserves, and effectively increasing the area available for the protection of the species.

Table 4.1 A summary of transect surveys for *Elephas maximus*

Location	No. of transects	Total transect length (km)	Transect width (m)	Total no. of dung piles observed	Dung density (per km²)	Elephant density (per km²)	N e i. k
1. Danum Valley PFR	5	9.372	-	0	-	-	-
2. Gunung Rara FR	7	1.444	4	2	15.55	0.01	n
3. Malua FR	8	1.878	12	60	1610.78	0.79	n
4. Kuamut FR & Malubuk VJR	9	4.69	14	50	2161.14	1.06	0
5. Kalabakan FR	4	1.04	-	0	-	-	-
6. Sungai Pinangah FR & Sungai Imbak VJR	7	1.625	-	1	-	-	-
7. Ulu Segama FR	38	20	14	129	531.62	0.26	0
8. Tangkulap FR	5	0.836	12	37	4851.69	2.38	n
9. Sapulut FR	4	0.86	-	0	-	-	-
10. Tabin WR	36	19.152	15	70	522.98	0.26	0
11. Sabah Foundation Concession Area	82	41.46	14	242	516.6	0.25	0
12. All excl. Tabin WR	91	43.17	14	279	596.53	0.29	0
13. All incl. Tabin WR	127	62	15	349	589.79	0.29	0

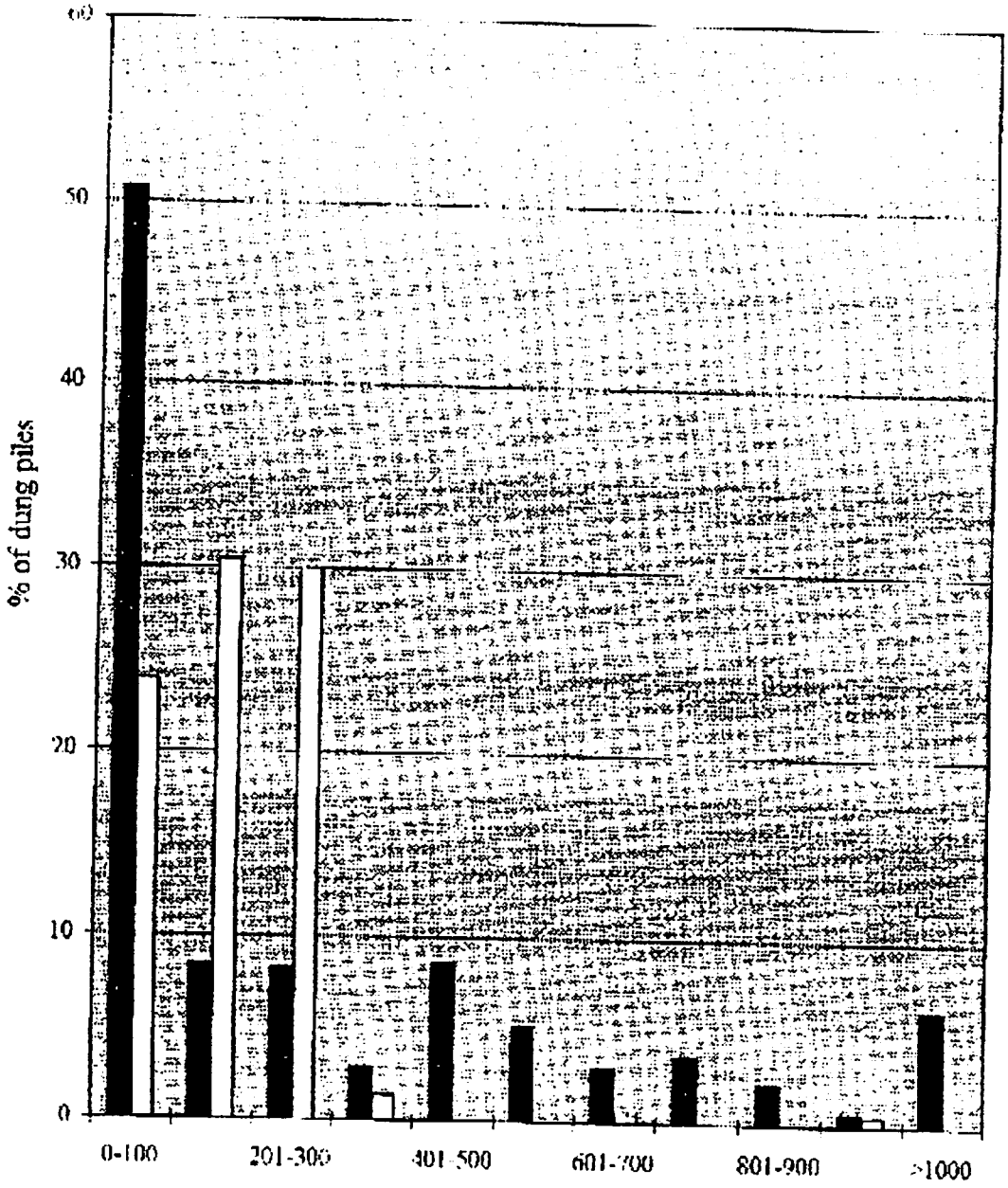
PFR: Permanent Forest Reserve; FR: Forest Reserve; VJR: Virgin Jungle Reserve; WR: Wildlife Reserve

Note:

1. See figure 2.2 for locations of reserves;
2. Caution should be observed with respect to the results presented here, and these results should not be taken out of context.

n.d. - calculations not possible as there are no data within 100 m or > 500 m

Figure 4.1 Distances of dung piles along transects, from rivers and roads (weighted data)



5. BANTENG

5.1 The Study Animal

The study animal *Bos javanicus* d'Alton, 1823, belongs to the family Bovidae, which includes cattle, buffaloes, antelope, goats and sheep (Lekagul & McNeely, 1977; Payne, *et al.*, 1985). The family Bovidae is characterized by horns that continue to grow as the animals grow older, and these horns are never shed (Peacock, 1933; Lekagul & McNeely, 1977; Payne, *et al.*, 1985). Three subspecies of *B. javanicus*, a cattle, are recognized, namely *B.j. javanicus*, *B.j. lowi* and *B.j. birmanicus* (Anon., 1983). *B.j. lowi* is the Bornean form and an endemic.

5.1.1 Description

Adult bulls measure 120 to 170 cm at shoulder height (Lekagul & McNeely, 1977; Anon., 1983; Payne, *et al.*, 1985), and weigh between 600 and 800 kg (Peacock, 1933; Lekagul & McNeely, 1977; Anon., 1983), although bulls as large as 190 cm at shoulder height and 825 kg have been recorded (Anon., 1983). Cows are smaller, averaging 140 cm at shoulder height and weighing 400 kg (Anon., 1983).

There is much variation in the coloration of bulls. Adult bulls are mostly blackish-brown and bluish-black. Cows and young bulls are bright red or chestnut. Both sexes have a distinctive white patch on their rumps and white 'stockings' on the lower part of their legs (Peacock, 1933; Lekagul & McNeely, 1977; Anon., 1983; Payne *et al.*, 1985). A young bull's head may grow white and the points on his coat dark brown. With age, his head grows dirty gray with dark markings, and his coat either fades to a yellowish-khaki hue or else darkens to a chocolate-brown color. In khaki-colored bulls, usually found in central and upper Myanmar, the coat is bluish gray on the withers and flanks, and the head becomes dark gray with a hairless frontal ridge. In dark-colored bulls, found from southernmost Myanmar, Indochina, Thailand, Peninsular Malaysia, Borneo, Jaya and Bali, old bulls grow almost black in color, with dark gray faces and white-rimmed eyes. Also it is common to find bulls that retain a bright chestnut coloration to an advanced age, but the withers and loins still showing a gray discoloration and the points dark (Peacock, 1933).

The horns of bulls are angular, turning out and then up, with inward-pointing tips and reaching a spread of 60-75 cm. The horns of cows are short, thin, smooth and crescent shaped. A patch of thick, naked skin between the horns is present in both sexes (Lekagul & McNeely, 1977; Anon., 1983). In old bulls, the horns are often worn and rubbed down, frequently flaking off near the tips, becoming ragged, blunted ends. The girth of the horn increases with age and the corrugations may extend for three-quarters of the horn. The horn color is usually dark brown or greenish brown (Peacock, 1933).

5.1.2 Distribution

Bos javanicus is found in restricted localities ranging from the northeastern edge of India, through Myanmar, Thailand, northern peninsular Malaysia, central and southern Indochina, Borneo, Java and Bali (Lekagul & McNeely, 1977; Djuwantoko, 1982; Anon., 1983; Payne *et al.*, 1985). The Bornean form, *B.j. lowi*, occurs along the Sugut, Kinabatangan, Segama, Kretam, Tabin and upper Padas Rivers in Sabah; in Kutai and possibly other scattered localities in Kalimantan (Davies & Payne, 1982). There are considered extirpated in Brunei (Payne *et al.*, 1985), and in Sarawak (Medway, 1977).

5.1.3 Social Organization and Ecology

B. javanicus usually occur in small groups from two to ten, but occasionally herds of 25-40 are encountered, and the presence of solitary males are not uncommon (Peacock, 1933; Lekagul & McNeely, 1977; Payne *et al.*, 1985). The species is mainly nocturnal, and frequently graze in open grassy areas (Peacock, 1933; Lekagul & McNeely, 1977; Payne *et al.*, 1985).

5.1.4 Legal Status

The Bornean subspecies *B.j. lowi* is currently listed as 'Endangered' in the IUCN's Red Data Book (IUCN, 1996) but not listed in the CITES (Byers *et al.*, 1995). In Sabah, *B.j. lowi* was initially classified as a 'Game Animal' under the Fauna Conservation Ordinance of 1963, but subsequently reclassified in 1982 as a 'Protected Animal' in an Amendment of First Schedule to the ordinance (Jabatan Hidupan Liar, 1988). Thus, hunting, killing or capturing it is illegal, unless with a special license issued only by the Director of the Sabah Wildlife Department, but no such licenses have yet been issued.

5.2 Methods

Originally it was planned that an adaptation of the indirect method for estimating *E. maximus* density from dung density (Dawson & Dekker, 1992; section 4.2) will be used in estimating densities of *B. javanicus*. This was not possible because the encounter rates were extremely low, therefore impossible to estimate densities. Instead, only index counts based on tracks were possible.

Tracks of *B. javanicus*, when encountered along transects were carefully observed, and the number of animals was estimated based on differences in sets of tracks. Index counts were calculated as tracks per kilometer walked along the transects for each area surveyed.

5.3 Results

5.3.1 Population Estimates

A total distance of 62 km was covered in 127 straight-line transects (table 5.1). Only a single dung sample was encountered while carrying out transect surveys for *B. javanicus*. It was along a transect placed on the western part of Tabin Wildlife Reserve. Although the same distance was covered as that of the surveys for *E. maximus*, very little evidence of its presence was observed. Evidently signs of *B. javanicus* was as rare as that of *D. sumatrensis*. Dung was occasionally encountered in other areas while carrying out river and road surveys, and patrol surveys.

Dung, tracks and other signs of *B. javanicus* were observed in the Ulu Segama, Malua, Kuamut and Sungai Pinangah Forest Reserves, Danum Valley Protection Forest Reserve, Malubuk Virgin Jungle Reserve, and the Lower Segama region which include both Tabin and Kulamba Wildlife Reserves. Signs of the species were also observed in the Lower Kinabatangan during a different study (Boonratana, 1993).

As it was not possible to calculate animal density from dung sighting, due to the rarity of dung along transects, index counts were instead calculated based on tracks encountered along the transects. Malua Forest Reserve apparently has the highest index count of *B. javanicus* at

1.60 tracks/km, followed by Kuamut Forest Reserve and Malubuk Virgin Jungle Forest Reserve combined, at 0.85 tracks/km (table 5.1). An index count of 0.32 tracks/km was obtained when all the transects in reserves within the Sabah Foundation Concession Area and contiguous to it were pooled. This value is close to the value obtained for Tabin Wildlife Reserve (0.34 tracks/km).

Signs of *B. javanicus* were mainly found along rivers and logging roads, or very close to them, especially when there were new grasses. Beside grasses, feeding signs of *B. javanicus* were often observed on the barks and young leaves of *Neonauclea* sp. (Rubiaceae). Once in the lower Segama region, fresh tracks of the same animal were found on opposite banks of the Segama River.

5.3.2 Current Threats

In Sabah, *B. javanicus* are currently threatened by loss of habitat to forest fragmentation, logging, shifting and permanent agriculture, and conversion of large forested areas to oil palm plantations; but mainly hunting for trophies and meat (Andau & Ambu, 1989). During this study, there was evidence that meat of *B. javanicus* were frequently sold at Pinangah, a village in Upper Kinabatangan, for US$1.60 per kilogram. Villagers from Tundunbuangin in the Lower Kinabatangan reportedly hunt *B. javanicus* in the Kulamba Wildlife Sanctuary, and sell the meat in the nearby Unico Plantation for US$2.40 a kilogram (Unico workers, pers. comm.). Serious poaching for *B. javanicus* occurs in the eastern part of Tabin Wildlife Reserve adjoining a FELDA scheme (Federal Land Development Agency), mainly by the scheme's residents. Meat are usually sold within the scheme, at US$2.00 a kilogram (Jupin b. Noor, pers. comm.). Hunting of general wildlife for sport reportedly occurs in this area, by hunters from towns, as far as Kota Kinabalu. *B. javanicus* meat from the Lower Kinabatangan area are occasionally sold at Sukau, a village by the Kinabatangan River, for US$3.20 a kilogram.

5.4 Discussion

The extremely low rate of encounter of dung and tracks of *B. javanicus* along the transects strongly suggests that this species exists at extremely low densities, probably in the low hundreds (< 300). Compared with the first faunal survey carried out in Sabah (Davies & Payne, 1982), the situation for *B. javanicus* has evidently deteriorated. Apparently, *B. javanicus* population are presently rare in areas that were previously reported as common by Davies and Payne (1982).

A recent study on the effects of hunting of wildlife found that *B. javanicus* is still subject to heavy hunting in the few areas in Sabah where they occur (E.L. Bennett, pers. comm.). From this study, information gathered showed that *B. javanicus* were hunted for meat in the Lower and Upper Kinabatangan, and Lower Segama regions (section 5.4). Thus, based on evidence gathered, the species is highly endangered in Sabah. It is already extirpated in Sarawak and Brunei, and probably rare in Kalimantan. This dire situation is apparently common throughout the species' known range (Salter, 1993; Srikosamatara & Suteethorn, 1995), and is endangered on a global scale (Byers *et al.*, 1995), therefore the Sabah populations are of global importance.

Whatever evidence of *B. javanicus* observed, showed that it was more common along abandoned logging roads. Roads probably allow the animals an easier route of travel. Alternatively, grasses being a major dietary item for *B. javanicus*, are commonly found along

roads. More likely, it is a combination of both, and that these roads are usually close to waterways, another important resource. Also, there is evidence that rivers are not barriers to the species' movement.

Table 5.1.--A summary of transect surveys for *Bos javanicus*

Location	No. of transects	Total transect length (km)	Total no. tracks observed	Index count (tracks/km)
1. Danum Valley PFR*	5	9.372	2	0.21
2. Gunung Rara FR	7	1.444	0	-
3. Malua FR*	8	1.878	3	1.60
4. Kuamut FR & Malubuk VJR*	9	4.69	4	0.85
5. Kalabakan FR	4	1.04	0	-
6. Sungai Pinangah FR & Sungai Imbak VJR*	7	1.625	-	-
7. Ulu Segama FR*	38	20	5	0.25
8. Tangkulap FR	5	0.836	0	-
9. Sapulut FR	4	0.86	0	-
10. Tabin WR*	36	19.152	6	0.31
11. Sabah Foundation Concession Area*	82	41.46	14	0.34
12. All excl. Tabin WR*	91	43.17	14	0.32
13. All incl. Tabin WR*	127	62	20	0.32

PFR: Permanent Forest Reserve; FR: Forest Reserve; VJR: Virgin Jungle Reserve; WR: Wildlife Reserve

Note:

1. See figure 2.2 for locations of reserves;

* Signs of *B. javanicus* seen

6. CONCLUDING DISCUSSION AND RECOMMENDATIONS

6.1 Introduction

The primary aims of this study were to provide a reliable population figure for the critically endangered *D. sumatrensis* in Sabah, and density estimates of *E. maximus* and *B. javanicus* in major forested areas in the state. These included identifying areas having possibly viable populations for proposed new protected areas, and providing input into species management plans for Sabah. Survey results have provided baseline information that will enable the Sabah Wildlife Department to monitor the abundance and distribution of these large herbivores in key areas. Furthermore, basic ecological and behavioral information on the three large herbivores will provide guidelines to assist their management.

6.2 Synopsis

Results of the surveys of this project in Sabah show that the future prospects of Sabah's three mega-herbivores appear quite bleak. The situation with *D. sumatrensis* has not changed much, although at least now we know that the minimum number of animals present in the state. Survey results showed that there are at least 11 *D. sumatrensis*, and possibly between 23 and 33 animals present in Sabah. The two main *D. sumatrensis* populations are concentrated in the Danum Valley Protection Forest Reserve and the surrounding reserves within the Sabah Foundation Concession Area, and Tabin Wildlife Reserve and some adjoining forested areas within the Lower Segama region. Based on evidence gathered, *D. sumatrensis* is beyond doubt critically endangered within both the national and global context. It is threatened by loss and fragmentation of habitats, and hunting for trade.

Density estimates obtained for *E. maximus* were probably over-estimates resulting from a bias as to where the transects were located. Minimum densities obtained for the same transects were probably more realistic in terms of actual densities and for species management purposes. These minimum densities for the different areas surveyed show that the *E. maximus* population in Sabah may very likely be in the low hundreds. This is cause for immediate concern considering that their habitats are shrinking and fragmenting at an alarming rate. Breaking populations up into smaller sub-populations will in the long term make them vulnerable to extirpation as a result of demographic, environmental, and genetic stochasticity (Gilpin and Soulé, 1986). Also, *E. maximus* frequently come into conflict with humans, often requiring measures to resolve the conflict.

Most surprising and quite alarming, however, is the situation with *B. javanicus*. Their numbers are shockingly low, estimated to be less than 300 for the whole state. This most probably is a direct result of poaching. Viable populations might still persist in the western part of Tabin Wildlife Reserve, and along the Upper Segama River within the Sabah Foundation Concession Area.

Surveys also confirmed the importance of natural waterways and their associated habitats, and mineral sources to the three mega-herbivores. The implication of this is that if such habitats are destroyed or reduced, then the carrying capacity of the habitat for the species that depend on these habitats will be drastically reduced even if non-riverine habitats are protected. Thus, it is important to include the protection of natural waterways and their associated riverine habitats, when preparing species or protected area management plans, and also plans for the management of timber license areas.

The usual guideline of a 40 m wide riverine reserve along large rivers (J. Payne, pers. comm.) is inadequate for mega-herbivores. This distance is equivalent to only a few trees, which do not provide sufficient shelter or food for these and other large mammals, including river-dependent species. Based on a density of *E. maximus* dung near river banks (section 4.3.3), it is suggested that a riverine reserve of at least 500 m is needed to retain adequate forest habitat to serve the needs of this mega herbivore and riverine habitat dwelling species (Boonratana, 1996).

Survey results and failure of *D. sumatrensis* captive breeding program strongly indicate that conservation efforts and available resources should be concentrated on protection and management of those wild populations in totally protected areas and other areas that are large enough to be viable in the long-term. The latter also imply that serious efforts should go towards securing a totally protected area status for those areas with populations that might possibly be viable in the long-term as in the case of *D. sumatrensis*, and areas that are now known to contain viable populations, as with *E. maximus*.

It is extremely difficult to reintroduce captive-bred animals into the wild (Caldecott & Kavanagh, 1983; Rabinowitz, 1993; 1994; Wildlife Conservation Society & Sarawak Forest Department, 1996). This is especially true with forest-dwelling species, whose behavioral and ecological needs are specific. Although there have been some success with captive breeding and reintroduction, it is imperative that *in situ* conservation must be the main focus. Bearing in mind the restraints of monetary funds and manpower, the most cost-effective way is *in situ* conservation. In its final context, all conservation is aimed at preserving species in their natural habitat It is quite clear then, that conservation of wildlife should be in their natural habitats. Furthermore, it often costs less than captive breeding (Harcourt, 1986; Stanley-Price, 1989; Rabinowitz, 1993; 1994; Wildlife Conservation Society & Sarawak Forest Department, 1996), and definitely much better for the animals themselves.

Effective protection and management, however, will directly contribute towards the conservation of these large herbivores by conserving the geographical extent and the quality of wildlife habitats of their ranges.

6.3 Conservation Recommendations

6.3.1 *Dicerorhinus sumatrensis*

i. Based on the greater home range reported for *D. sumatrensis* (c. 30 km^2), a minimum area of 1500 km^2 with suitable habitat must be made available for a minimum viable breeding population of 50 animals. Thus, it is recommended that extensions be made to the Danum Valley Protection Forest Reserve to include the Ulu Segama, Malua, Kuamut, Gunung Rara Forest Reserves and the Maliau Basin Conservation Area. A study is, however, needed as to the where exactly the areas of extension should be. It is important that these extensions should include main waterways and mountain ridges that traverse between reserves. Similarly, a land corridor joining Tabin and Kulamba Wildlife Reserves must be established to achieve this minimum area needed to maintain the Lower Segama population.
ii. Major surveys for the critically endangered in the Danum Valley Protection Forest Reserve and Tabin Wildlife should be conducted biennially, using standardized measurements and data collection sheets. Plaster casts of tracks should be labeled and maintained at the Danum Valley Field Center and the headquarters of Tabin Wildlife

Reserve for their respective areas. Thus, from the information gathered over time, population trends and distribution patterns can be correctly assessed.

iii. Carry out at least one major survey for *D. sumatrensis* in the Maliau Basin Conservation Area and the adjoining areas within the Gunung Rara Forest Reserve, to determine the true status of the species in these areas. If there is a potentially viable population, surveys should be repeated biennially.

iv. It is very important to maintain the quality of surveyors of major surveys that employ several teams. Team leaders and coordinators should have more than just a basic knowledge of wildlife ecology and field research techniques. Each team should have at least two persons with knowledge of 'forest craft.' To maintain quality of surveys, non-professional individuals who have shown aptitude during previous surveys, should be maintained for future surveys. University students from the related sciences should participate in these major surveys, as these exercises provide an excellent opportunity for training in wildlife conservation research. Care, however, must be taken to limit the number of students, so as not to digress from research to pure training.

v. Maintain two fully-trained permanent survey and enforcement teams of four to seven persons, one team for each reserve. Their aims would be: (a) to carry out regular enforcement patrols and surveys for *D. sumatrensis* in the Danum Valley Protection Forest Reserve and Tabin Wildlife Reserve; (b) to carry out opportunistic enforcement patrols and surveys in other reserves where the species were recorded. To conserve *D. sumatrensis*, active enforcement is needed due to the high costs of the animal's horns and its other body parts. The team for Danum Valley Protection Forest Reserve should comprise personnel from the Sabah Wildlife Department and Sabah Foundation, and the team for Tabin Wildlife Reserve should comprise personnel from the Sabah Wildlife Department. For opportunistic patrols and surveys in other forest reserves, the team can comprise personnel from the Sabah Wildlife Department, Sabah Forest Department, and Sabah Foundation. It is also recommended that personnel from the Police Field Force accompany enforcement teams, so that teams can be armed.

vi. Enforcement teams should carry out their patrolling activities both inside and along the boundaries of the reserves. Patrols should be regular and frequent, but carried out at random so as to make their schedule unpredictable to the would-be poachers. To protect *Panthera tigris*, a valuable species, the Nagarahole National Park (640km^2) in India has a staff of about 250, most of whom are engaged in patrols and law enforcement (U. Karranth, pers. comm. in Wildlife Conservation Society and Sarawak Forest Department, 1996). This is not feasible for Sabah, but the number of staff, and time spent patrolling needs to be increased very greatly from current levels.

vii. The personnel from the Sabah Wildlife Department must receive much more training in techniques of patrols, and also on apprehension and arrest of offenders. Assistance can be requested from the Police trainers for the latter.

viii. No further attempts should be made to capture more animals for the state wildlife department's captive breeding program. Rather, the current captive breeding program should focused on the animals already in captivity, and efforts at capturing more animals should be channeled towards anti-poaching activities. There is not much point investing funds and resources in a venture that is very expensive and has little chance of success. Furthermore, if copulations of captive animals do not lead to successful pregnancies, then captive animals should be marked and released with radio-collars attached, into well-protected and well-managed areas. Also, a small team led by a qualified researcher must be available to follow and study the released animals.

ix. If translocation of isolated or threatened animals becomes necessary, then a functioning radio-collar should be attached to each animal prior to its release to a new environment.

Of equal importance is to have a qualified researcher available to follow the radio-collared animal. Information on how the animal adapts to its new environment, its activity patterns, its patterns of habitat use, etc., will be of immense value towards managing the species. Also critical to ensure animal doesn't immediately die.

x. A major education campaign must be carried out at all levels on the dire status of *D. sumatrensis*. This campaign should also be carried out at the top Government levels in order to mobilize their support.

6.3.2 *Elephas maximus*

i. Monitoring of the species should be carried out biennially. Some of the transects prepared for this study and earlier studies should be maintained for monitoring purposes. Using the same transects repeatedly will make data highly comparable. Also, it will effectively reduce the costs, time and manpower needed for such an exercise. Maintenance of transects could be combined with patrolling activities, otherwise it will probably keep access to the forests open to poachers.

ii. The forest cover of Dermakot, Tangkulap, Ulu Segama, Malua, and Kuamut Forest Reserves should be maintained to provide a safe haven for the species. There should be a consideration to close forest blocks with mineral sources to logging. Furthermore, several other totally protected species (*D. sumatrensis*, *Neofelis nebulosa*, *Helarctos malayanus*, and *Pongo pygmaeus*) occur in these reserves. Preferably, however, the reserves should be established as a single contiguous totally protected area, as this will reduce the chances of the animal being extirpated. As an initial step, all riverine forests within forest reserves, a 500m wide each side of rivers should be protected.

iii. There should be no longer any delay in gazetting the proposed Lower Kinabatangan Wildlife Reserve. The proposed reserve not only have viable populations of *E. maximus*, but also many other species including *Nasalis larvatus* and *Pongo pygmaeus*.

iv. With decreasing forested areas, the problem of 'pest' elephants will get worse, not better. These 'pest' elephants could be translocated into areas with viable habitat, possibly re-stocking declining original population. Care should, however, be taken in selecting sites where animals are to be translocated. Also, members of the same family should be translocated to the same area.

6.3.3 *Bos javanicus*

i. All efforts should be made to eliminate any poaching of these species from Tabin Wildlife Reserve. The guard post at the eastern sector of Tabin Wildlife Reserve should have a permanent staff of at least seven including a senior ranger stationed there. Also, the guard post should be equipped with a radio. A team of three to four persons should regularly patrol the eastern part of the reserve, including all its access routes. An officer or a senior ranger should occasionally accompany the anti-poaching patrols to ensure its purpose is achieved and maintain the morale of the patrolling teams. Patrol teams should be accompanied by personnel from the Police Field Force so as to be armed.

ii. Similar efforts to eliminate poaching from Kulamba Wildlife Reserve must also be carried out. A guard post with at least three personnel from the Sabah Wildlife Department should be established in Tundunbuangin, as most of the poaching of *B. javanicus* in Kulamba Wildlife Reserve are by hunters from this village.

iii. Law enforcement and patrolling activities should be carried out in other reserves where *B. javanicus* are known to occur, and at all markets. Traders involved in the sale of *B. javanicus* meat should be warned on their first offense, but prosecuted on their second.

iv. There should be a state-wide conservation education and public awareness campaign to alert people at all levels on plight of the species; from rural hunters to senior law enforcement officers.

6.3.4 General

i. Laws pertaining to wildlife must strictly be enforced, and anti-poaching patrols must be carried out continuously. There should be a permanent anti-poaching unit for each division of the state, comprising at least six personnel to a unit. The unit should seek cooperation from the Police Department, possibly the Police Field Force, in carrying out their activities. If this is not possible, then there should be at least two larger units for the whole state. These units should be equipped with radios, and have a 4-wheel drive vehicle, off-road motorcycles and mountain bicycles at their disposal. Off-road motorcycles and mountain bicycles will greatly increase the units anti-poaching efforts, particularly along abandoned logging roads.
ii. Anti-poaching patrols should concentrate their activities at mineral sources, access routes to major reserves, and along logging roads. Anti-poaching activities, however, should be unobtrusive enough so as not to disturb the animals. Also, these units must frequently but randomly make surprise checks at fresh markets where wildlife products are sold.
iii. The Sabah Wildlife Department should seek cooperation from other government agencies to eradicate illegal hunting among personnel of the various agencies. Understanding and cooperation at the top level will prevent resentment among the various departments, should it become necessary to take actions against the offenders. Also, illegal hunting by civil servants would possibly reduce if such offenses were to put a blemish on the offenders' service records. In the case of logging companies, a criteria of no hunting can be placed as a condition of their license.
iv. Consider establishing an intelligence network in communities living in towns, villages, plantations and logging camps. As added incentive, attractive monetary rewards be offered for information leading to the punishment of offenders. Anonymity of informers must be protected for the system to be effective.
v. The Sungai Pin abandoned logging road is the main 'illegal' access route into the Danum Valley Protection Forest Reserve. This and other abandoned logging roads that allow access to poachers into the reserve should be permanently seal off at several locations along those roads. A simple solution to this is to bulldoze trenches across several locations along the road, and destroying key bridges. Frequent checks along these routes should be carried out to see if there are signs of human intrusion. Similarly, such precautions can be carried out in all other forest reserves.
vi. Protection must be secured for the land corridor between Tabin and Kulamba Wildlife Reserves, thereby allowing unhindered movement of large mammals between the two reserves. The forest within this land corridor is still viable, and joining this two reserves will effectively increase the size of the area available to wide-ranging large mammals.
vii. Redefine the term riverine reserve (under the Land Ordinance 1930 and its subsequent amendments), to include all forest cover up to at 500 m on either side of rivers in all forested areas, therefore providing legal protection against destruction of habitats crucial not only to these three large herbivores but many other wildlife.
viii. Conduct a thorough review of the status of existing forest reserves with the idea of increasing the numbers and size of totally protected areas. This should be done as a joint study between Forestry and Wildlife Departments.
ix. If lack of manpower is an obstacle to anti-poaching patrols reserves, then a request for additional manpower could be made from the paramilitary and/or armed forces stationed

in the state. This will also allow an excellent exercise for those forces besides allowing them to become familiar with the country. Also, it will greatly contribute to the forces' peacetime efforts. Care should, however, be taken to make the patrol teams small, and be accompanied by a senior ranger or officer, lest the patrol teams engage in poaching themselves. Also, a major liaison is needed with senior-most officers, to ensure that they are supportive of 'no hunting', and will make it clear to their field operatives.

6.4 Conclusions

In Sabah, *D. sumatrensis*, *E. maximus* and *B. javanicus* suffer from poaching and loss of prime habitats to logging, habitat fragmentation and. Both *D. sumatrensis* and *E. maximus* need large areas and use a wide range of habitats, therefore are 'umbrella' species. Due to their size, value, and long association with man, they are also 'flagship' species, able to raise funds and support for conservation. Thus, their conservation need not totally be a single-species focus, but integrated into the overall biological diversity.

Also, while trying to secure legal protection for viable forested areas, strict law enforcement and round-the-clock anti-poaching activities should take the utmost priority, as this is the most critical conservation measure.

APPENDIX I: The second major survey for the Sumatran rhinoceros in the Danum Valley Protection Forest Reserve

INTRODUCTION

Danum Valley Protection Forest Reserve is currently one of the only two protected areas in Sabah known to contain populations of *Dicerorhinus sumatrensis* that might be viable in the long term. The other is Tabin Wildlife Reserve (Payne, 1990a; Sabah Wildlife Department, 1993). Before 1992, faunal surveys and some studies (Davis & Payne, 1982; Ahmad, 1987; Payne 1990a & b; Abd. Hamid, 1991), have provided some information on the distribution of *D. sumatrensis* in the 438 km² Danum Valley Protection Forest Reserve. Density estimates, however, were available for only a limited area within the reserve (Ahmad, 1987; Abd. Hamid, 1991).

Thus, in 1992 a major survey, the first of its kind, was carried out to determine the status of *D. sumatrensis* in the 1108 km² Greater Danum Valley Conservation Area (Rabinowitz, 1992). The Greater Danum Valley Conservation Area is an informally termed area that comprises the recently gazetted 438 km² Danum Valley Protection Forest Reserve (section 2.1.1) and the contiguous 670 km² proposed Danum Valley Wildlife Forest Reserve (Marsh, 1995). The Danum Valley Protection Forest Reserve is mainly primary forest, whereas the forest in the proposed Danum Valley Wildlife Forest Reserve has been selectively logged. Besides investigating the presence, relative abundance and distribution of *D. sumatrensis*, the survey also aimed to help standardize methods for future major surveys and to initiate a long term monitoring program for the species in the Greater Danum Valley Protection Forest Reserve.

In the first major survey for *D. sumatrensis*, Rabinowitz (1992) adapted and intensified methods employed by Borner (1979) and van Strien (1986). This involved a total of seven teams of approximately seven persons per team, with each team covering an area about 30 km² to 50 km², over a period of ten field days. From this survey it was estimated that there were between 13 and 23 *D. sumatrensis* in the Greater Danum Valley Conservation Area (Rabinowitz, 1992). Also, the exercise proved that the method employed by Borner (1979) and van Strien (1992) is ideal for surveying elusive species in dense tropical rainforests, particularly for those species that exist in low numbers and have a patchy distribution.

Thus, a second major survey for *D. sumatrensis*, similar to the first, was carried out from 8th to 22nd May 1995. The second major survey was sponsored by the Sabah Wildlife Department of the Ministry of Tourism and Environmental Development, Innoprise Corporation Pte. Ltd., of the Sabah Foundation, and Wildlife Conservation Society. Participants on the survey were from the Sabah Wildlife Department, Innoprise Corporation Pte. Ltd., Sabah Parks, Sabah Museum, National University of Malaysia (Sabah), University of Malaysia - Sarawak, Sabah Nature Club, World Wide Fund for Nature (Malaysia), Wildlife Conservation Society, resident scientists from the Danum Valley Field Center, and a few volunteers.

The Sabah Wildlife Department is currently preparing a report on the survey, compiled from unpublished teams' reports. As it is also an important component of a state-wide survey for mega-herbivores in Sabah, it is also included in this report. In this appendix, the survey is briefly described, and relevant additional information not covered in the Wildlife Department's report are presented and discussed.

METHODS

Survey techniques employed were the same as those used in the first major survey (Rabinowitz, 1992; section 3.2). Briefly, the exercise took a total of 14 days and had 53 participants. Participants were divided into seven teams with seven or eight persons to a team; each team had between 2-3 sub-teams. The first two days were spent at the Danum Valley Field Center. Participants were briefed, and trained in survey techniques and emergency medical procedures. The next ten days were spent in the field collecting data. Teams assigned to remote areas were taken in by helicopter, while the rest hiked or traveled some distance by 4-wheel drive vehicles and hiked the remaining distance. Participants returned to the field center on the 13th day and were debriefed, and departed from the center on the 14th day.

During the briefing, teams planned their daily survey routes for their assigned areas. Training in survey and data collection techniques included track identification, measurements and cast-preparation using plaster of Paris. Imprints of *D. sumatrensis* tracks were made on different substrates, so everyone became familiar with them, and of possible differences in size and appearance of prints due to the different substrates. Also, an imprint of a young *Elephas maximus* was made, as it was commonly mistaken for *D. sumatrensis* under field conditions. For arriving at a density estimate only fresh and very recent tracks were analyzed. Age and distance between similar-sized tracks were also taken into consideration. Plaster casts were made of *D. sumatrensis* tracks encountered during the survey. These plaster casts are maintained at the Danum Valley Field Center.

Besides the measurements (appendix III) used in the first major survey and the current study, an additional measurement, W-max was also included. W-max is the maximum track width, measured between the outermost points of the first and third toes, popularly used in many studies on *D. sumatrensis* in Malaysia. Both measurements, W-max and W1-W2 (appendix III) were taken as no consensus could be reached to use either one.

As opposed to the first major survey which had only four contiguous sites (Rabinowitz, 1992), all the seven sites in the second major survey were contiguous. This was done to concentrate the surveys within the Danum Valley Protection Forest Reserve (figure I.1). Furthermore, this allowed some areas not surveyed in the first major survey to be covered in the second. Natural barriers such as mountain ridges and rivers were the basis for division of areas to be surveyed by various teams.

The presence of wildlife other than *D. sumatrensis* was recorded based on sighting, vocalization, spoor, tracks and other evidence. Mineral licks and signs of human intrusion were also recorded.

RESULTS

Dicerorhinus sumatrensis

The seven teams surveyed a combined contiguous area of approximately 339 km^2. Tracks of *D. sumatrensis* were found by teams 1, 4, 5 and 7 in their respective areas (Table I.1). Exact location of evidence is withheld to prevent possible poaching of the animals (section 3.3). For purpose of analysis, only fresh and recent tracks (within a week to the onset of the survey) were considered, because it is extremely difficult to age and distinguish old tracks. Based on the measurements, distance and age between similar-sized and tracks, there were at least five individuals and possibly ten in the total area surveyed.

Mineral Sources

Only team 6 reported finding a mineral source. The team described it as "natural springs with clear bubbly water, salty to taste, coming out from the ground close to streams that led to the Segama River." Its location is approximately 117°44'E and 45°52.8'N and measured 25 m by 25 m. Signs of animals in and around the springs were *E. maximus, S. barbatus, C. unicolor* and *Muntiacus* spp. This is an important find as there is no previous record of this mineral source.

Human Intrusion

All teams except team 4 reported signs of human intrusion. Most human signs and camps were old and some were probably made by groups of surveyors from the Departments of Geology or Forestry. Signs of human intrusion in team 6's area, however, strongly suggested the presence of poachers, based on the small cuttings observed along the trails. Furthermore, these human signs were following a set of older signs made by *D. sumatrensis*. By contrast, surveyors leave many telltale human signs, such as bending and cutting of saplings, and slash-marks on trees along routes taken. Team 7 found two spent cartridges, in their area; one of the cartridges was near skeletal remains of a *C. unicolor* and a *S. barbatus*.

DISCUSSION

Dicerorhinus sumatrensis

The combined areas of teams 1, 4 and 5, where fresh and recent tracks of *D. sumatrensis* were found, covered a total area of approximately 127 km². The absence of fresh and recent tracks and other signs of *D. sumatrensis* in the remaining areas surveyed implied the absence of the animal in those areas at the time of the survey. Based on this assumption, there are at least five and possibly ten animals in the combined contiguous areas of all teams, that is 339 km². It is possible the actual number of animals might be more than the evidence showed. This was because there was a long dry spell before the survey, and it rained almost daily during the survey. The rains and flash floods could easily have obliterated all faint signs made during the long dry spell.

Extrapolating findings of the second survey, the 438 km² Danum Valley Protection Forest Reserve is estimated to have a *D. sumatrensis* population of six to 13 individuals, and possibly 16 to 32 individuals in the 1,108 km² Greater Danum Valley Conservation Area. In the first major survey, it was estimated that there were 13 to 23 *D. sumatrensis* in the Greater Danum Valley Conservation Area, based on evidence suggesting the presence of four to seven individuals in the 300 km² covered by the survey teams (Rabinowitz, 1992). The difference in estimates for the Greater Danum Valley Conservation Area between the first and second major surveys is mainly due to the extrapolation process. Rabinowitz's (1992) estimate were extrapolated to a 1,000 km² area as opposed to the supposed 1,108 km² area of the Greater Danum Valley Conservation Area. If Rabinowitz's data were extrapolated to the latter area, an estimate of 15 to 26 *D. sumatrensis* would therefore be expected. This new estimate from the first major survey is very close to that of the second major survey. This slight difference in estimations should *not* be taken as an increase in population size. The two sets of results overlap, so are *not* significantly different.

Measurements of tracks taken during the second survey could not be compared with the ones taken during the first for several reasons. First, there was a long gap between the two surveys, therefore younger individuals could have matured during that time. Secondly, tracks were measured on varying substrate and under different climatic conditions. There is evidence that measurements of the same track varied greatly even after a few days of rain. Team 5 found

that measurements of the middle toe w1-w2, and W-max of the same track increased by 1.5 cm and 1.2 cm respectively by the third day, and after heavy rains (C.W. Marsh, pers. comm.). Thirdly, only a few of the recommended track measurements were taken. This was partly because some of those measurements were not visible, and partly because of the observers' reluctance to attempt to measure the different parameters. Fourthly, plaster casts of tracks found during the first survey were not maintained, therefore could not be compared with plaster casts made during the second survey. Plaster casts of tracks along with complete measurements are essential in identifying individuals (van Strien, 1986).

Measurement of different tracks from the same series showed that the middle toe measurement was consistent, from 0.5 to 1 cm. Van Strien (1986) concluded from his study that the middle toe measurement is the most consistent of all measurements. This is further supported by findings from both the major surveys in DanumValley, and a state-wide survey for *D. sumatrensis* (this study). The maximum track width, W-max, showed too much variation, probably because of substrate type and slope. The splaying of feet in a deep and soft substrate can result in imprints with concave sides. Furthermore, possible double imprints can lead to incorrect measurement of W-max. The measurement W1-W2, however, showed little variation. Similar findings were reported by team 5 during the second major survey (C.W. Marsh, pers. comm.). Thus, it is highly recommended that W-max should not be included in future track measurements, and measurements of tracks should follow that prescribed in appendix III.

Dicerorhinus sumatrensis defecates often (van Strien, 1986), therefore dung is expected in areas where fresh tracks are found. Furthermore, dung is usually deposited along main routes of travel (Borner, 1979). The rarity of *D. sumatrensis* dung in the second survey and its absence during the first has several implications. Dung of *D. sumatrensis* is sought for its medicinal value (Borner, 1979), and is a possible explanation for its rarity (Rabinowitz, 1992). Alternatively, the species tended to defecate in streams (van Strien, 1974; 1986; Borner, 1979). Captive individuals in the Malacca Zoo, in Peninsular Malaysia, and the Sepilok Rhino Breeding Center, in eastern Sabah, have been observed to defecate into pools of water. Captive animals at the Malacca Zoo are sprayed with water at their rear feet to initiate defecation before the animals are released to the larger enclosure for public viewing. Van Strien (1986) suggested that this is a purely physical response. Conversely, this physiological reaction might possibly be an adaptive behavior towards a long history of poaching, therefore explaining why *D. sumatrensis* dung was rarely encountered. A long history of poaching might also explain why other indicative signs of the animal such as twisted saplings were rarely encountered.

Human Intrusion

Surveys such as this provide an opportunity for important conservation areas to be patrolled, as a deterrent to illegal human intrusions. For example, a team during the first major survey came across an active poachers' camp (Rabinowitz, 1992). Arrests were not successful as the poachers escaped into the forest before the helicopter transporting the survey team could land. Although the second major survey did not find any active poachers' activity, the surveyors nevertheless found evidence of poachers' activity in the recent past. Sometimes, observing signs of recent illegal intrusions is difficult, as these poachers make temporary camps by the sandy banks of rivers, whose evidence inevitably gets washed away during floods. Flash floods are a common occurrence in many parts of Sabah.

Most poachers entering Danum Valley Protection Forest Reserve Area are edible birds' nests harvesters and gold prospectors. They nevertheless hunt and trap wildlife for food while in the forest, and might hunt *D. sumatrensis* should an opportunity arise. No one can deny the possible existence of professional *D. sumatrensis* poachers in Sabah, particularly from the evidence found by team 6 during the second major survey and based on other reports (Andau, 1987). This supports Rabinowitz's (1992) conclusion that there is no area safe from poachers when there exists a potentially large monetary gain.

CONCLUSIONS

At least five *D. sumatrensis* and possibly ten to thirteen individuals were in the Danum Valley Protection Forest Reserve at the time of the survey. Although the survey suggested that only a small number of *D. sumatrensis* reside in the reserve, it nevertheless gave a number and not a 'guesstimate', by which wildlife managers could plan species conservation management strategies that might assist in arresting the decline of this critically endangered species. Major surveys such as this should be repeated biennially to allow the long term monitoring of the species, and also patrolling the area for illegal activities, greatly adding to the conservation efforts in the Danum Valley Protection Forest Reserve.

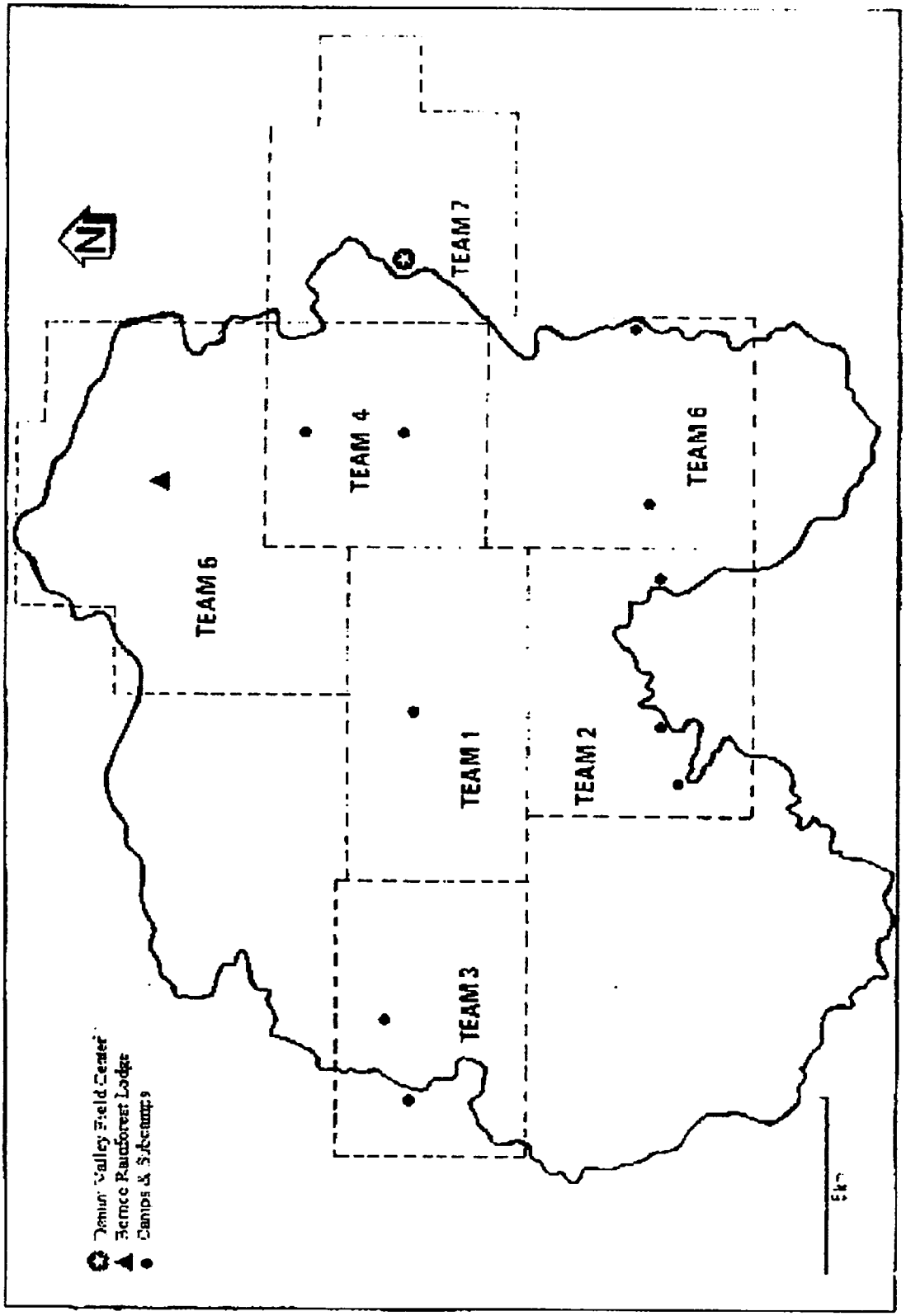
Table I.1.—Track measurements (in cm) of *D. sumatrensis* found during the second major survey at the Danum Valley Protection Forest Reserve

Note:
1. Measurements are either average or from best prints as recommended by team leaders.
2. Definitions of measurements are given in appendix III

* not included in analysis because the prints were old
# not included in analysis because print was dismissed as that made by an elephant
^ not included in analysis because no measurements were taken

Track ID	L1-L2	l1-l2	W1-W2	W-max	S1-S2	w1-w2	Foot	n
T1/01	-	-	-	19.3	-	8	?	2
T1/02^	-	-	-	-	-	-	?	-
T1/03	-	-	-	21	-	-	?	3
T1/04	-	-	-	23	-	10	?	6
T1/05	-	-	-	21.2	-	8.7	?	3
T1/06	-	-	-	22.3	-	8.5	?	2
T1/07	-	-	-	21.4	-	8.1	?	4
T1/08	-	-	-	21.9	-	8.6	?	5
T1/09	-	-	-	22.1	-	8.9	?	7
T4/01	-	-	-	20	-	8.5	?	1
T4/02	-	-	-	22.2	-	8.0	?	7
T4/03	-	-	-	21	-	8.0	?	3
T4/04	-	-	-	22.5	-	9	?	1
T501	20.5	-	18	21.3	15	8	Left	4
T5/02*	-	-	24	-	-	8.5	rear	1
T5/03	-	-	17.5	22.5	-	8	?	5
T5/04	21.8	16.8	19.5	-	15.8	8	Rear	3
T5/05*	-	-	-	22.5	-	7	?	1
T5/06	24	15.5	18.3	-	-	8.5	?	2
T7/01#	-	-	-	23.8	-	12.1	?	4
T7/02*	-	-	16.5	22	-	8	? ?	3

Figure I.1 Map of Danum Valley Protection Forest Reserve showing division of survey areas



APPENDIX II: List of wild fauna recorded in the Danum Valley Protection Forest Reserve during the second major survey for the Sumatran rhinoceros

Note:
1. presence of wildlife based on sighting, vocalization, tracks, nests, feces, etc.
2. mode of detecting wildlife presence could not be included here as some of the teams' reports did not mention how they recorded wildlife presence.

* new record for Danum Valley Protection Forest Reserve

SPECIES/TEAMS		1	2	3	4	5	6	7
MAMMALS								
Moonrat	*Ehinosorex gymnurus*			x				
Common Treeshrew	*Tupaia glis*					x		
Giant Squirrel	*Ratufa affinis*						x	x
Prevost's Squirrel	*Callosciurus prevosti*	x		x				x
Horse-tailed Squirrel	*Sundasciurus hippurus*		x					
Plain Pygmy Squirrel	*Exilisciurus exilis*			x				
Tufted Ground Squirrel	*Reithrosciurus macrotis*						x	
Porcupine spp.			x	x				
Common Porcupine	*Hystrix brachyura*		x					
Long-tailed Porcupine	*Trichys fasciculata*		x					
Thick-spined Porcupine	*Thecurus crassipinis*		x					
Western Tarsier	*Tarsius bancanus*						x	
Red Leaf Monkey	*Presbytis rubicunda*	x	x	x	x	x	x	x
Grey Leaf Monkey	*Presbytis hosei*		x				x	
Proboscis Monkey	*Nasalis larvatus*					x		
Long-tailed Macaque	*Macaca fascicularis*		x	x		x	x	
Pig-tailed Macaque	*Macaca nemestrina*			x	x		x	x
Bornean Gibbon	*Hylobates muelleri*	x	x	x	x	x	x	x
Orangutan	*Pongo pygmaeus*	x	x	x	x	x	x	x
Malayan Sun Bear	*Helarctos malayanus*	x		x	x	x	x	x
Otter spp.		x		x		x		
Smooth Otter	*Lutra perspicillata*		x					
Oriental Small-clawed Otter	*Aonyx cinerea*						x	x
Yellow-throated Marten	*Martes flavigula*		x	x				x
Malay Badger	*Mydaus javanensis*				x		x	
Malay Civet	*Viverra tangalunga*	x		x			x	x
Common Palm Civet	*Paradoxurus hermaphroditus*						x	x
Binturong	*Arctictis binturong*							x
Short-tailed Mongoose	*Herpestes brachyurus*	x			x			
Clouded Leopard	*Neofelis nebulosa*				x			x
Marbled Cat	*Felis marmorata*							x
Asian Elephant	*Elephas maximus*	x	x	x	x	x	x	x
Sumatran Rhinoceros	*Dicerorhinus sumatrensis*	x			x	x	x	x
Bearded Pig	*Sus barbatus*	x	x	x	x	x	x	x
Mousedeer spp.		x	x	x	x	x	x	x
Lesser Mousedeer	*Tragulus javanicus*		x	x	x		x	x
Greater Mousedeer	*Tragulus napu*			x	x		x	x
Bornean Yellow Muntjac	*Muntiacus atherodes*						x	
Bornean Red Muntjac	*Muntiacus muntjac*	x	x	x	x	x	x	x

Sambar Deer	*Cervus unicolor*	x	x	x	x	x	x	x
Banteng	*Bos javanicus*		x					
SPECIES/TEAMS		1	2	3	4	5	6	7
BIRDS								
Oriental Darter	*Anhinga melanogaster*			x		x	x	
Crested Serpent Eagle	*Spilornis cheela*					x		x
Brahminy Kite	*Haliastur indus*						x	
Ferruginous Wood-partridge	*Caloperdix ignita**						x	
Black Wood-partridge	*Melanoperdix nigra**	x						
Crested Wood-partridge	*Rollulus rouloul*						x	
Crestless Fireback	*Lophura erthropthalma*						x	
Crested Fireback	*Lophura ignita*					x	x	x
Bulwer's Pheasant (?)	*Lophura bulweri*			x				
Great Argus	*Argusianus argus*	x	x	x	x	x	x	x
Green Imperial Pigeon	*Ducula aenea*						x	
Emerald Dove	*Chalcophaps indica*							x
Malay Lorikeet	*Loriculus galgulus*						x	
Raffle's Malkoha	*Phaenicophaeus chlorophaeus*			x			x	
Chestnut-breasted Malkoha	*Phaenicophaeus curvirostris*						x	
Greater Coucal	*Centropus sinensis*							x
Buffy Fish-owl	*Ketupa ketupu*			x			x	x
Nightjar sp.								x
White-bellied Swiftlet	*Collocalia esculenta*			x			x	
Diard's Trogon	*Harpactes diardii*						x	
Scarlet-rumped Trogon	*Harpactes duvaucelli*						x	
Red-naped Trogon	*Harpactes kasumba*						x	
Orange-breasted Trogon	*Harpactes oreskios*						x	
Common Kingfisher	*Alcedo atthis*				x		x	
Blue-eared Kingfisher	*Alcedo meninting*						x	
Blue-banded Kingfisher	*Alcedo euryzoma*			x				
Stork-billed Kingfisher	*Pelargopsis capensis*						x	
Red-bearded Bee-eater	*Nyctyornis amictus*			x			x	
Broad-billed Roller	*Euristomus orientalis*						x	
Pied Hornbill	*Anthracoceros coronatus*							x
White-crowned Hornbill	*Berenicornis comatus*						x	
Bushy-crested Hornbill	*Anorrhinus galeritus*			x			x	x
Wreathed Hornbill	*Rhyticeros undulatus*			x				
Black Hornbill	*Anthracoceros malayanus*			x			x	x
Rhinoceros Hornbill	*Buceros rhinoceros*	x		x	x	x	x	x
Helmeted Hornbill	*Rhinoplax vigil*	x		x	x		x	x
Gold-whiskered Barbet	*Megalaima chrysopogon*						x	
Yellow-crowned Barbet	*Megalaima henricii*						x	
Gaudy Barbet	*Megalaima mystacophanos*						x	
Little Barbet	*Megalaima australis*			x			x	
Many Coloured Barbet	*Megalaima afflesii*						x	
White-bellied Woodpecker	*Dryocopus javensis*				x			
Grey-capped Woodpecker	*Piciodes canicapillus*						x	
Crimson-winged Woodpecker	*Picus puniceus*	x						
Rufous Woodpecker	*Micropternus brachyurus*						x	

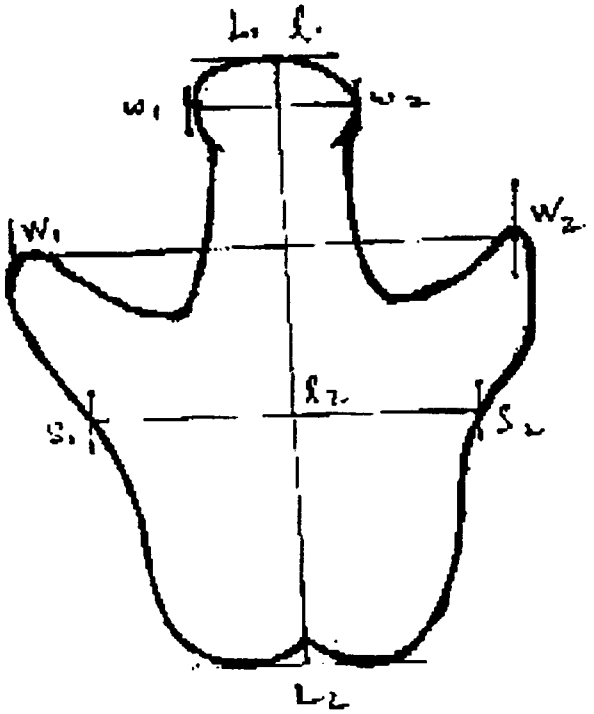
Orange-backed Woodpecker	*Chrysocolaptes validus*			x			x	
Black and Yellow Broadbill	*Eurylaimus ochromalus*					x		
Pitta sp.								x
Garnet Pitta	*Pitta granatia*						x	
Blue-headed Pitta	*Pitta baudi*	x			x			
Blue-winged Pitta	*Pitta moluccensis**	x					x	
Straw-headed Bulbul	*Pycnonotus zeylanicus*						x	
Yellow-vented Bulbul	*Pycnonotus goiavier*						x	
Grey-cheeked Bulbul	*Criniger bres*						x	
Red-eyed Bulbul	*Pycnonotus brunneus*						x	
Greater Racket-tailed Drongo	*Dicrurus paradiseus*			x	x		x	
Bronzed Drongo	*Dicrurus aeneus*					x	x	x
Crow-billed Drongo	*Dicrurus annectans*						x	
Crested Jay	*Platylophus galericulatus*	x					x	
Slender-billed Crow	*Corvus enca*						x	
Black-capped Babbler	*Pellorneum capistratum*						x	
Short-tailed Babbler	*Trichastoma malaccense*						x	
Chestnut-backed Scimitar Babbler	*Pomatorhinus montanus*						x	
Plain Babbler	*Malacopteron affine*						x	
Fluffy-backed Tit Babbler	*Macronous ptilosus*						x	
Striped Tit Babbler	*Macronous gularis*						x	
Ferruginous Babbler	*Trichastoma bicolor*						x	
Rufous-tailed Shama	*Copsychus pyrrhopyga*				x		x	
White-rumped Shama	*Copsychus malabaricus*			x	x		x	
White-crowned Forktail	*Enicurus leschenaulti*	x						
Chestnut-naped Forktail	*Enicurus ruficapillus*				x		x	
Yellow-bellied Warbler	*Abroscopus supercilliaris*	x						
Rufous-chested Flycatcher	*Ficedula dumetoria*						x	
Asian Paradise Flycatcher	*Terpsiphone paradisi*	x			x		x	x
Black-naped Monarch	*Hypothymis azurea*			x			x	
Hill Myna	*Gracula religiosa*						x	
Plain Sunbird	*Anthreptes simplex*						x	
Crimson Sunbird	*Aethopyga siparaja*						x	
Little Spiderhunter	*Arachnothera longirostra*						x	
Yellow-rumped Flowerpecker	*Prionochilus xanthopygius*						x	
Dusky Munia	*Lonchura fuscans*						x	

SPECIES/TEAMS		1	2	3	4	5	6	7
REPTILES								
	*Draco volans**					x		
Green Fence Lizard	*Bronchocoela cristatella*				x			
Orange-sided Skink	*Mabuya multifasciata*						x	
Water Monitor Lizard	*Varanus salvator*		x	x	x	x	x	
Rough-naped Monitor Lizard	*Varanus rudicollis*						x	
Yellow-ringed Cat Snake	*Boiga dendrophila*			x	x			
Oriental Whip Snake	*Ahaetulla prasina*						x	
Wagler's Pit Viper	*Trimeresurus wagleri*			x				
Cobra sp.								x
Forest Soft-shelled Turtle	*Dogania subplana*						x	
Burmese Brown Tortoise	*Geochelone emys*			x	x		x	

Forest Tortoise	*Tetsudo emys**			x				
SPECIES/TEAMS		1	2	3	4	5	6	7
AMPHIBIANS								
Long-fingered Slender Toad	*Ansonia longidigita*						x	
Brown slender Toad	*Ansonia leptopus*						x	
Yellow-legged Torrent Frog	*Amolops jerboa*						x	
Slender Litter Frog	*Leptolalax gracilis*			x	x			
Bornean Horned Frog	*Megophyrs nasuta*				x		x	
Poisonous Rock Frog	*Rana hosei*			x				
Giant River Toad	*Bufo juxtasper*			x		x		
Green Tree Toad	*Pedostibes rugosus*						x	
Brown Tree Toad	*Pedostibes hosei*				x			
Kuhl's Creek Frog	*Rana kuhli*				x		x	
Yellow-bellied Puddle Frog	*Occidozyga laevis*						x	
Rough Guardian Frog	*Rana finchi*						x	
Blyth's Frog	*Rana blyth*				x		x	
Abbott's Litter Frog	*Leptobrachium abbotti*						x	
Spotted Stream Frog	*Rana signata*				x		x	
White-lipped Frog	*Rana chalconota*				x			
Tree Hole Frog	*Metaphrynella sundana*						x	
Four-lined Tee Frog	*Polypedates leucomystax*						x	
Black-spotted Rock Frog	*Staurois natator*				x		x	
Rock Skipper	*Staurois latopalmatus*			x		x		

APPENDIX III: Data recording sheet for *Dicerorhinus sumatrensis*

DATE:_____TIME:_____WEATHER:_____SEASON_____
LOCATION:_____PERSONNEL:_____
[CIRCLE APPROPRIATE CATEGORY/CATEGORIES]
FOREST TYPE: VIRGIN/NEW LOGGED/OLD LOGGED/OTHER:_____
SUBSTRATE: DRY SOIL/ MUD/SAND/OTHER:_____
SIGN OBSERVED: TRACK/ WALLOW/DUNG/SCRAPES/URINE/TWISTED SAPLING/FEEDING/OTHER:_____
LOCATION OF SIGN: ALONG TRAIL/CROSSING TRAIL/AT SALT LICK/IN FOREST/ON SLOPE/ON RIDGETOP/ALONG WATERWAY/OTHER:_____



IF TRACK
1. SLOPE: UP SLOPE/DOWN SLOPE
2. DIRECTION OF SLOPE:_____
NOTES:_____

TRACK ID # _____ TRACK MEASUREMENTS (cm):
LEFT FOOT/RIGHT FOOT/UNKNOWN & FRONT FOOT/REAR FOOT/UNKNOWN
TRACK LENGTH (L1-L2): _____ TRACK LENGTH (l1-l2):_____
TRACK WIDTH (W1-W2):_____TRACK SPAN (S1-S2):_____
FRONT TOE WIDTH (w1-w2):_____CAST OF FRONT TOE TAKEN: YES / NO
NOTE: DESCRIBE AND DRAW DISTINCTIVE MARKS ON TRACK

APPENDIX IVa: Dung density data recording sheet for *Elephas maximus*

DATE_____LOCATION_____SEASON_____ WEATHER_____TOPOGRAPHY_____FOREST TYPE_____ TRANSECT NO._____TRANSECT LENGTH_____ BEARING_____ START TIME_____ END TIME_____ PERSONNEL			
DISTANCE ALONG TRANSECT (m)	PERPENDICULAR DISTANCE TO DUNG PILE (m)	STAGE OF DECAY*	REMARKS

* A = All boli intact, fresh, moist, with odour; B = All boli intact, but dry, no odour; C1 = More than 50% of all boli intact; C2 = Less than 50% of all boli intact; D = All boli broken up or in a flat mass.

APPENDIX IVb: Defecation rates data recording sheet for *Elephas maximus*

DATE:_____LOCATION:_____SEASON:_____					
Age/Sex_____ Time Block_____		Age/Sex_____ Time Block_____		Age/Sex_____ Time Block	
Time	No. of boli	Time	No. of boli	Time	No. of boli
Total defecation_____		Total defecation_____		Total defecation_____	

APPENDIX IVc: Dung decay rate data recording sheet for *Elephas maximus*

DATE BEGIN:_____DATE
END:_____SEASON:_____
LOCATION:_____HABITAT
TYPE:

SAMPLE NO.	DATE	NO. OF BOLI	PROGRESSIVE DECAY STAGE BY DAYS *												
			1	3	5	7	14	21	28	35	42	49	56	63	70
Total dung piles surviving															

* A = All boli intact, fresh, moist, with odour; B = All boli intact, but dry, no odour; C1 = More than 50% of all boli intact; C2 = Less than 50% of all boli intact; D = All boli broken up or in a flat mass; E = No dung visible (fully decayed).

APPENDIX Va: Dung density data recording sheet for *Bos javanicus*

DATE_____LOCATION_____SEASON_____
WEATHER_____TOPOGRAPHY_____FOREST TYPE_____
TRANSECT NO._____TRANSECT LENGTH_____COMPASS BEARING_____
START TIME_____END TIME_____PERSONNEL_____

DISTANCE ALONG TRANSECT (m)	PERPENDICULAR DISTANCE TO DUNG (m)	STAGE OF DECAY*	REMARKS

* A = Dung intact, fresh, moist, with odour; B = Dung intact, but dry, no odour; C = More or less 50% of dung intact and still recognizable; D = Dung broken up and barely recognizable.

APPENDIX Vb: Defecation rates data recording sheet for *Bos javanicus*

DATE:_____ LOCATION:_____ SEASON:_____					
Age/Sex_____ Time Block_____		Age/Sex_____ Time Block_____		Age/Sex_____ Time Block_____	
Time	No. of dung	Time	No. of dung	Time	No. of dung
Total defecation_____		Total defecation_____		Total defecation_____	

APPENDIX Vc: Dung decay rate data recording sheet for *Bos javanicus*

DATE BEGIN:_____ DATE END:_____ SEASON:_____ LOCATION:_____ HABITAT TYPE:_____														
SAMPLE NO.	DATE	NO. OF DUNG	PROGRESSIVE DECAY STAGE BY DAYS *											
			1	3	5	7	14	21	28	35	42	49	56	63	70
Total dung surviving															

A = Dung intact, fresh, moist, with odour; B = Dung intact, but dry, no odour; C = More or less 50% of dung intact and still recognizable; D = Dung broken up and barely recognizable; E = No dung visible (fully decayed).

APPENDIX VI List of wild fauna recorded in the various areas surveyed

Mode of detection: a=visual; b=vocalize; c=tracks; d=dung; e=nests; f=wallows; g=scrapes, claw marks, rub marks, feeding signs, twisted saplings, etc.
Sites: 1=Ulu Segama Forest Reserve; 2=Malua Forest Reserve; 3=Kuamut Forest Reserve & Malubuk Virgin Jungle Reserve; 4=Sungai Pinangah Forest Reserve & Sungai Imbak Virgin Jungle Reserve; 5=Tangkulap Forest Reserve; 6=Gunung Rara Forest Reserve; 7=Maliau Basin Conservation Area; 8=Sapulut Forest Reserve; 9=Kalabakan Forest Reserve; 10=Lower Segama Region (incl. Tabin & Kulamba Wildlife Reserves); 11=Danum Valley Protection Forest Reserve (see appendix II)

SPECIES/SITES		1	2	3	4	5	6	7
MAMMALS								
Echinosorex gymnurus	Moonrat		a					
Tupaia glis	Common treeshrew							
Pteropus vampyrus	Large flying fox							
Manis javanica	Pangolin				a			
Tarsius bancanus	Western tarsier		a				a	
Presbytis hosei	Hose's leaf monkey							ab
Presbytis rubicunda	Red leaf monkey			ab	a		a	a
Trachypithecus cristatus	Silvered langur							
Nasalis larvatus	Proboscis monkey	ab						
Macaca fascicularis	Long-tailed macaque	a				a		
Macaca nemestrina	Pig-tailed macaque		a			a	a	a
Hylobates muelleri	Bornean gibbon	ab	ab	b	b		ab	ab
Pongo pygmaeus	Orangutan	e	a	abg			e	
Ratufa affinis	Giant squirrel						ab	
Callosciurus prevostii	Prevost's squirrel							
Callosciurus notatus	Plaintain squirrel							
Exilisciurus exilis	Plain pigmy squirrel	a						
Rheithrosciurus macrotis	Tufted Ground Squirrel							a
Petaurista petaurista	Red giant flying squirrel			a				
Aeromys thomasi	Thomas's flying squirrel			a				
Rattus rattus	House rat							
Hystrix brachyura	Common porcupine	a	g					
Helarctos malayanus	Sun bear	g		g			acg	ac
Mydaus javanensis	Teludu			a	g			
Martes flavigula	Yellow-throated marten				a			
Otter sp.		acg	acg	acg				
Aonyx cinerea	Oriental small-clawed otter							
Lutra perspicillata	Smooth otter	ac						
Civet spp.		c	c	c	c	c	c	c
Viverra tangalunga	Malay civet	a		a	a	a	a	
Cynogale bennettii	Otter-civet	a						
Hemigalus derbyanus	Banded palm civet			a				
Arctogalidia trivirgata	Small-toothed palm civet			a				
Herpestes semitorquatus	Collared mongoose							
Herpestes brachyurus	Short-tailed mongoose		a					
Neofelis nebulosa	Clouded leopard		a	a			a	

Felis planiceps	Flat-headed cat							
Felis bengalensis	Leopard cat	a	a	a			a	
Elephas maximus	Asian elephant		abcdg	abcdg	abcdg	cd	cd	cc
Dicerorhinus sumatrensis	Sumatran rhinoceros		cfg	g	fg	f	fg	g
Sus barbatus	Bearded pig		cef	acef	acefg	acg	cg	ac
Tragulus javanicus	Lesser mousedeer			a	c			
Tragulus napu	Larger mousedeer		a	a	ac	c		cg
Muntiacus sp.	Barking deer		c	ac	a	c	c	ac
Cervus unicolor	Sambar deer		acd	acd	c	ac	c	ac
Bos javanicus	Banteng		cd	cd				
REPTILES								
Crocodylus porosus	Estuarine crocodile		c					
Varanus salvator	Water monitor lizard		a					
Varanus rudicollis	Rough-naped monitor lizard		a					
Najah sumatrana	Black cobra		a					
Dogonia subplana	Forest soft-shelled turtle		a					
Geochelone emys	Burmese brown tortoise		a					
BIRDS								
Anhinga melanogaster	Oriental darter		a					
Ardea sumatrana	Dusky-grey heron		a					
Ciconia stormi	Storm's stork							
Egretta intermedia	Intermediate egret							
Egretta alba	Great egret							
Egretta eulophetes	Chinese egret							
Butorides striatus	Little green heron		a					
Haliastur indus	Brahminy kite		a					
Haliaeetus leucogaster	White-bellied sea eagle		a					
Ichthyophaga ichthyaetus	Grey-headed fish eagle							
Spilornis cheela	Crested serpent eagle			a	a			
Aborophila charltoni	Scaly-breasted partridge				ab			
Lophura ignita	Crested fireback		a					
Lophura bulweri	Bulwer's pheasant		a					
Argusianus argus	Great argus		b	b	b			
Numenius phaeopus	Whimberel							
Treron olax	Little green pigeon							
Ptilinopus jambu	Jambu fruit dove							
Ducula aenea	Green imperial pigeon		a					
Psittacula longicauda	Long-tailed parakeet							
Loriculus galgulus	Blue-crowned hanging parrot							
Merops viridis	Blue-throated bee-eater		a					
Eurystomus orientalis	Broad-billed roller							
Phaenicophaeus chlorophaeus	Raffle's malkoha							
Phaenicophaeus curvirostris	Chestnut-breasted malkoha							
Centropus sinensis	Greater coucal		a			ab		
Centropus bengalensis	Lesser coucal							
Hirundo tahitica	Pacific swallow		a					
Alcedo meninting	Blue-eared kingfisher		a					
Pelargopsis capensis	Stork-billed kingfisher		a					

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