DISTRIBUTION, STATUS, AND FEEDING ECOLOGY OF THE SUMATRAN RHINOCEROS IN MALAYSIA

BY

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Distribution, Status, and Feeding Ecology of the Sumatran Rhinoceros in Peninsular Malaysia. (186 pp.)

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The distribution, status, and feeding ecology of the Sumatran rhinoceros in Peninsular Malaysia was investigated from 1975 to 1981. Information on distribution and status country-wide was collected from field surveys, interviews with people living near rhino areas, and the literature. I confirmed that rhinos presently occur in 10 isolated areas scattered throughout the Malay Peninsula. The number of rhinos was estimated at 50 to 80 with the Endau-Rompin (20-25), Taman Negara (8-12), and Sungai Dusun (4-6) areas containing the largest contiguous populations. The Sumatran rhino is threatened with extinction in Peninsular Malaysia. Excessive killing of rhinos has greatly reduced numbers; habitat destruction from logging and land clearance for agricultural development have reduced the amount of available habitat and isolated small populations. The Endau-Rompin region was found to be the most suitable site to maintain a viable population of rhinos in Malaysia because it contains the largest number of animals, evidence of reproduction has been observed, a law enforcement program has been started, and a portion of the area (870 km^2)has been proposed for national park status. Feeding ecology of the Sumatran rhino was studied in the Endau-Rompin region, southern Peninsular Malaysia, to provide information on foods eaten and habitats selected. Feeding sites were located by following recent rhino tracks. Within primary hill forest, Sumatran rhinos selected feeding sites in stream bottom (59%) and lower slope (34%) physiographic types. Small forest gaps (35%) were used more than their availability (15%), but most of the feeding cases were in closed-canopy forest (63%). Sumatran rhinos were mostly browsers, feeding primarily on the mature leaves of woody understory plants. Large, fleshy fruits were eaten occassionally. The diet was diverse with 49 plant families, 102 genera, and between 156 to 181 species represented in 342 feeding cases. Prunus sp. (15.1%), Ficus sp. (6.4%), Pavetta sp. (6.1%), Medusanthera sp. (3.8%), and Eugenia sp. (3.0) contributed the greatest amounts to diet proportions. Chemical analyses of plant materials, collected from certain food plants and randomly selected non-food plants, indicated that Sumatran rhinos selected plants and plant parts high in minerals and crude protein but low in fiber. Phenolics and tannins were tolerated in the diet, but principal food plants contained less tannin.

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CHAPTER I

INTRODUCTION

This thesis contains 3 chapters dealing with the distribution, status, and feeding ecology of the Sumatran rhinoceros in Peninsular Malaysia. The chapters are written as discrete papers ready for publication, each with an abstract, introduction, text, acknowledgments, and references. The writing style of each chapter depends on the targeted journal.

Most of the information presented in Chapters II and III was collected during 1975 to 1978 while I was attached to the Malaysia Department of Wildlife and National Parks as a research officer. Additional information for Chapters II and III, and all the data for Chapter IV, was collected during January through May 1979, and July 1980 through August 1981 while I was on contract with World Wildlife Fund International. I designed and directed the projects, analyzed the data, and wrote the papers. Mr. Mohd. Tajuddin Abdullah, my Malaysian counter-part, assisted with the field work and will be a co-author in publication of Chapters II and III. Dr. Peter Waterman, University of Strathclyde, assayed the plant materials for secondary plant compounds and provided some interpretations of the plant chemistry data; he will be a co-author in publication of Chapter IV.

In Chapter II, information collected on the present distribution of Sumatran rhinos in Peninsular Malaysia is presented.

Locations of known rhino areas are shown, estimates of population sizes are given, and the status of rhinos in these areas is discussed. Also, recommendations are presented for the conservation of the Sumatran rhino in Peninsular Malaysia.

Chapter III reports the results of an intensive survey of Sumatran rhinos in the Endau-Rompin region. This area was found to contain the largest contiguous population of rhinos in the country. The number of rhinos occurring in the Endau-Rompin region is given based on a series of 4 census surveys. Conservation options for the Endau-Rompin area are presented.

In Chapter IV, the feeding ecology of Sumatran rhinos in the Selai River study site, located within the Endau-Rompin region, is described. Quantitative information is presented on the kinds and amounts of foods eaten, the types of habitats selected at feeding sites, and the chemical composition of certain food and non-food plants. Rhino food selection is discussed in terms of the availability of foods and habitat components, and the chemical composition of available plant material.

CHAPTER II

DISTRIBUTION AND STATUS OF THE SUMATRAN RHINOCEROS IN PENINSULAR MALAYSIA

ABSTRACT

Distribution and status of the Sumatran rhinoceros in Peninsular Malaysia were studied from 1975 to 1981. I compiled information collected from field surveys, interviews with people living near rhino areas, and the literature. Most potential rhino areas were surveyed on the ground to confirm the presence of animals, estimate numbers, and evaluate the status of the habitat. I confirmed that rhinos presently occur in 10 isolated areas scattered throughout the Malay Peninsula. The number of rhinos is estimated at 50 to 75 animals with the Endau-Rompin (20-25), Taman Negara (8-12), and Sungai Dusun (4-6) areas containing the largest contiguous populations. The Sumatran rhino appears threatened with immediate extinction in Peninsular Malaysia. Excessive killing of rhinos because of the high commercial value of their body parts has greatly reduced numbers. Habitat destruction from logging and forest clearance has separated and isolated already small populations. I recommend that conservation efforts for this species in Malaysia be concentrated in the Endau-Rompin region because this population has the best chances for survival.

INTRODUCTION

The Sumatran or two-horned Asiatic rhinoceros (Dicerorhinus sumatrensis Fisher 1814), one of the world's rarest large mammals, is threatened with extinction throughout its range (Simon, 1969). Once found across Southeast Asia, this rare, forest-dwelling rhino is now restricted to small isolated populations occurring in Burma, Thailand, the Malay peninsula, Sumatra, and Borneo (Van Strien, 1974; McNeely & Laurie, 1977; Borner, 1978; Schenkel & Schenkel, 1979; Payne, 1980; Flynn, 1981). Excessive hunting has greatly depleted rhino numbers and reduced their distribution (Van Strien, 1974). The high value of their body parts, especially the horn, continues to encourage illegal killing (Martin, 1979). In addition, extensive habitat destruction from logging and forest clearance for agricultural development has isolated already small populations and reduced the amount of suitable habitat.

In Malaysia, little information has been available on the distribution and status of the Sumatran rhino, the literature consisting mostly of old accounts by hunters and game wardens (e.g. Hubback, 1939; Foenander, 1952; Hislop, 1965). Difficult field conditions and elusive animals have discouraged extensive field surveys. After reviewing the status of rare Asian wildlife, Talbot (1960) emphasized the lack of information on the Sumatran rhino in Malaysia. A brief field survey by Milton (1963) provided information on the occurrence of a small rhino population near the Bernam River in the state of Selangor. In 1965, the 40 km Sungai Dusun Wildlife Reserve was established to

protect these rhinos. Strickland's (1967) short study of this rhino population provided the first ecological information on the species. About the same time, Stevens (1968) surveyed other existing wildlife reserves in Malaysia and proposed the establishment of additional sanctuaries where he had found rhino sign.

In 1974, the Malaysian Department of Wildlife and National Parks (DWNP) initiated a long-term study on the distribution and status of the Sumatran rhinoceros in Peninsular Malaysia. This paper presents the results of that study along with a review of historical reports collected from the literature and DWNP files. From 1975 through 1981, I compiled all rhino reports collected from DWNP field staff and interviews with people working or living in rhino habitat. Potential rhino areas were surveyed on foot to confirm the presence of animals. Confirmation of rhino reports by field surveys was necessary because most people confuse rhino tracks with those of Malayan tapir (Tapirus indicus). I found that many people believe tapirs are actually young rhinos; the base Malayan name (badak) is the same for both animals.

During the field surveys, I recorded all rhino sign, especially tracks and wallows, encountered while hiking through suspected rhino areas. Usually I walked along stream bottoms or ridges, where sign was most likely to be found. Sometimes a local guide would show me specific places where tracks or wallows had been observed previously. Recent rhino tracks were followed until at least 10 rear foot prints could be recorded. For each track, the maximum width between the lateral toes and the width of the middle toe was measured

(Flynn, 1978). The minimum number of individual animals in an area was estimated based on differences in median track size and the distance between track locations (Flynn and Abdullah, 1983). Also, the relative frequency of rhino sign encountered during a field survey was used as a rough index of rhino density.

I attempted to survey all potential rhino areas, but time availability and travel restrictions prevented me from visiting some places and adequately covering others, especially in the northern states of Perak, Kedah, and Kelantan. These states contain large, remote forested lands, and much of the border region is closed to non-military personnel. My research effort was concentrated in areas that showed the most promise for conservation of the species, especially the Endau-Rompin region in the southern portion of the Malay Peninsula.

Peninsular Malaysia, located at the southern tip of the Asiatic continent (1° to 7° N latitude and 100° to 103° E longitude), contains 131,700 km^2 of land divided politically into 11 states. Sarawak and Sabah, the Malaysian states in northern Borneo, were not included in this study. The topography of the Malay Peninsula is characterized by a prominent north-south granitic mountain range with several lesser ranges and small valleys. Broad plains lie along the east and west coasts. Several major river systems dissect the country into large basins which form the basis for most political subdivisions. Malaysia's climate is tropical ever-wet with little seasonal variation because of close proximity to the equator and warm oceans (Whitmore, 1975). The days are hot and humid, with the mean temperature near 27° C

in lowland areas and annual rainfall ranging from 2000 to 5000 mm (Dale, 1952). In the northern part of the peninsula, rainfall is more seasonal, influenced by the October-to-December monsoon season in the northeast, and the June-to-September monsoon in the northwest.

The natural vegetation of Peninsular Malaysia is tropical evergreen rain forest of the Indo-Malayan formation (Richards, 1952). These forests are exceedingly species-rich containing about 4000 species of woody plants, primarily trees and climbers (Whitmore, 1975). Forest structure is characterized by large (to 60 m) emergent trees, dominated by the family Dipterocarpaceae, which extend above a nearly closed main canopy at a height of 20 to 45 m. The dense understory consists of numerous small trees, palms, climbers, and herbaceous plants. Many problems exist in the classification of these forests (Poore, 1963), but the primary forest can be grouped into 15 general forest types (Wyatt-Smith, 1964; Whitmore, 1975). In this study, the following general forest types were encountered: (1) lowland dipterocarp forest (below 300 m); (2) hill dipterocarp forest (300 to 800 m); (3) upper dipterocarp forest (800 to 1200 m); and (4) montane forest (above 1200 m).

Almost 99% of Peninsular Malaysia was once covered with tropical rain forest (Lee, 1980). Recently, large tracts of forest have been cleared and planted to agricultural crops. Today, about 55% of the total land area is covered with forest (Forest Dept. Report, 1977) and about 22% of the land area is planted to agricultural crops, primarily rubber, oil palm, and rice. The balance of the land area is wasteland,

swamp, or urban development. Of the present forested lands, about 30% have been logged, including most of the lowland forest below 300 m. By 1990, most of the lowland areas will have been converted to agricultural crop lands, and most of the remaining commercial forest will have been logged (Lee, 1980).

DISTRIBUTION AND NUMBERS

Southern Region

Endau-Rompin area. The literature contains many reports of Sumatran rhinos occurring along the border of the states of Johor and Pahang, within the upper watersheds of the Endau and Rompin rivers (Fig. 1). Foenander (1961) conducted several brief surveys in Pekan District of Pahang and mapped the distribution of rhinos based on interviews with villagers. Milton (1963) collected a few reports of rhinos occurring in the upper Endau River basin and also near Tanah Abang and the Tersap River along the lower Endau. During a survey of the Endau-Kluang Wildlife Reserve, Stevens (1968) found rhino sign between the Endau, Emas, and Semberong rivers, and he recommended that this area be protected as a wildlife sanctuary. In 1970, members of the Malayan Nature Society (Ellis, 1971) made several trips into the upper Endau River area and reported evidence of rhinos in the upper Selai, Segamat, and Endau watersheds.

I surveyed the entire Endau-Rompin region, with an emphasis on

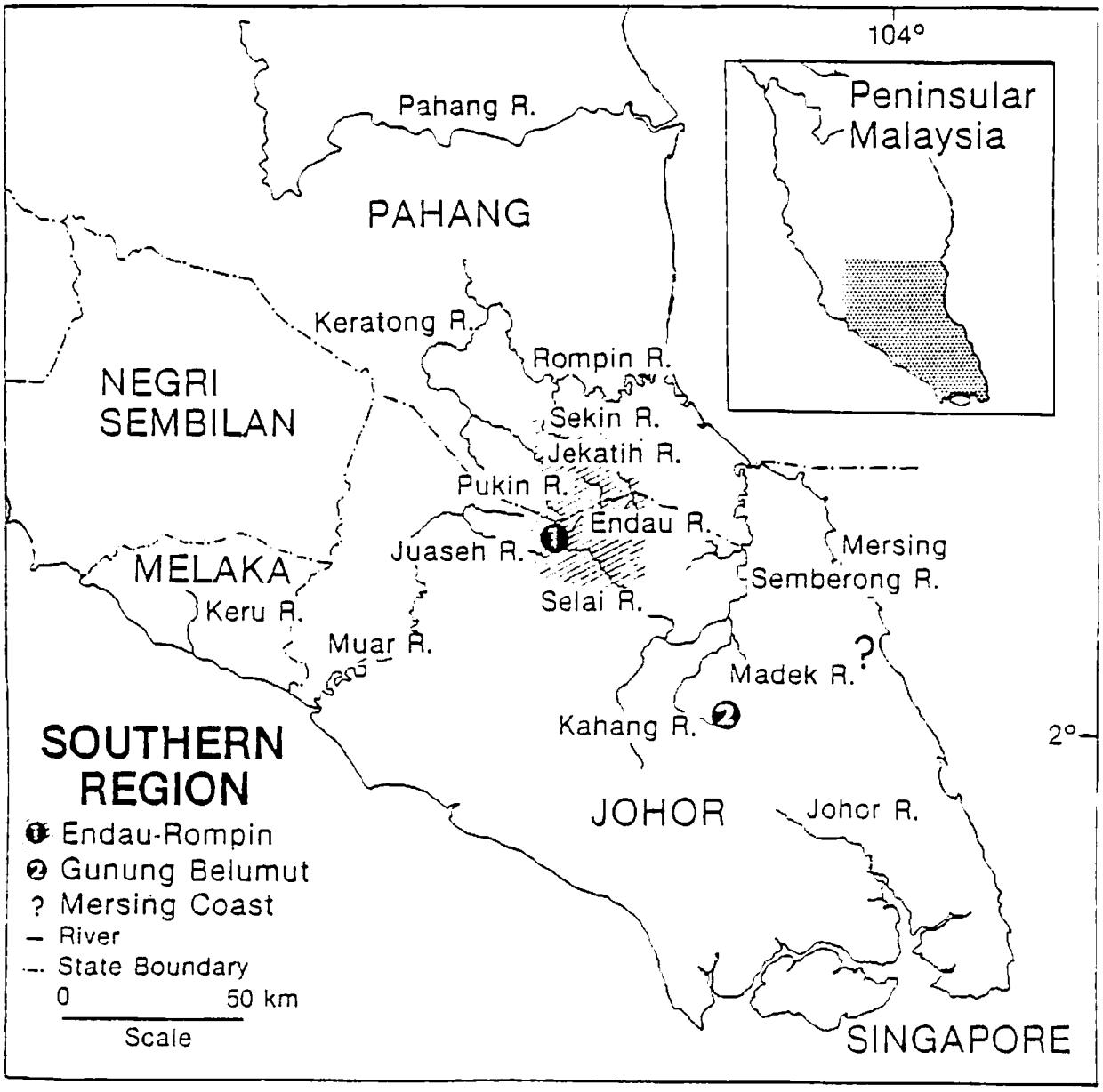

Fig. 1. Locations of Sumatran rhino track observations in the southern region of Peninsular Malaysia. Present rhino distribution in the Endau-Rompin area is marked by cross-hatching. An unconfirmed report is indicated by a question mark.

the remaining tract of contiguous unlogged forest (Flynn and Abdullah, 1983). Rhino sign was found throughout the region, especially within the contiguous primary forest, an area of about 1600 km^2. Rhino tracks and wallows were found consistently in the upper Endau, Selai, Kemidak, Juaseh, and Segamat watersheds in Johor; and the upper Pukin, Jekatih, Sekin, and Kemapan basins in Pahang (Fig. 1). I found no evidence of rhinos occurring in certain areas where they had been reported previously. Interviews with villagers living along the lower Endau River indicated that rhinos had not occurred in the Tanah Abang or Sungai Tersap areas for many years. Likewise, villagers living along the Semberong River stated that rhinos no longer occurred in that area, which had been proposed by Stevens (1968) as a rhino sanctuary. Much of the land between the Semberong and Endau rivers has been cleared for agriculture, and the Emas River area has been heavily logged. A survey along the eastern portion of the region near Gunung Lesong indicated that rhinos probably no longer occur east of the mountains, as reported previously by Foenander (1961).

The number of rhinos occurring in the Endau-Rompin region was calculated by multiplying estimated rhino densities by the amount of occupied habitat. Based on the frequency that rhino sign was encountered during the survey, the habitat was divided into high and low density areas. The high-density area was censused 4 times between 1977 and 1980 to estimate the minimum number of animals (Flynn and Abdullah, 1983). The 1980 census estimated that 10 animals occurred in the 400 km^2 census study area, a density of 1 animal per 40 km^2. In the rest of

the region, rhino density was much lower, probably less than half. Within the 1200 km^2 of low-densiy habitat, I estimated rhino density conservatively at 1 animal per 80-120 km^2 . Thus, a total of 20 to 25 rhinos occur in the entire 1600 km^2 of remaining habitat (Table 1).

During the study period, the tracks of at least 3 young rhinos were recorded. In 1975-1976, the tracks of a cow/calf pair were found often in the upper Selai and Endau river areas. During the 1977 census survey, Conry (DWNP, pers. comm.) recorded tracks of a cow/calf pair in the upper Juaseh-Kemidak area. Several reports of a cow/calf pair in the upper Kemidak basin were obtained in 1981. Beginning in February, villagers at Kampung Juaseh reported that they occasionally encountered tracks of a cow/calf pair in the upper basins of the Juaseh and Kemidak rivers. The presence of this pair was confirmed by track observations during March and June. All other track observations were of single animals, probably adults or independent sub-adults. This information indicates that the Endau-Rompin rhino population is still reproducing, but at an extremely low rate (0.5 young per year).

In 1933, 1014 km^2 of the upper Endau River area in Johor was established as the Endau-Kluang Wildlife Reserve by the state government. For many years, the remoteness of the region protected it from exploitation, but during the 1960's most of the land suitable for agriculture was excised, and several timber concessions were allotted, even within the wildlife reserve. In 1972, the federal government proposed that the Endau-Rompin area be established as a national park, with protection of the Sumatran rhino a major justification. This

Table 1. Number of Sumatran rhinoceros in Peninsular Malaysia.

Region	Number	Forest Type
Southern		
Endau-Rompin	20-25	Lowland & Hill
Gunung Belumut	2-3	Hill & Montane
Mersing Coast	0-1	Lowland
Northcentral		
Taman Negara	8-12	Lowland & Hill
Ulu Lepar	3-5	Lowland & Hill
Sungai Depak	3-5	Hill
Kuala Balah	3-4	Lowland & Hill
Bukit Gebok	1-2	Lowland & Hill
Krau Reserve	0-1	Lowland & Hill
West Coastal		
Sungai Dusun	4-6	Lowland
Northwest		
Ulu Selama	3-5	Lowland & Hill
Ulu Belum	3-5	Lowland & Hill
Kedah Border	0-1	Hill
Total	50-75	

national park would contain the upper Endau River basin and adjacent lands, including portions of Johor and Pahang.

In conjunction with the rhino surveys, the Endau-Rompin area was evaluated as a national park, and a management plan was prepared (Flynn, 1980). Briefly, this plan recommends that 870 km^2 of this region be classified as a national park, with special attention given to the most important rhino areas. High-use rhino areas would be zoned to exclude unnecessary disturbance and patrolled extensively by park wardens to prevent poaching. According to this plan, the proposed park would preserve about 65% of the remaining rhino habitat in the region. The balance of the rhino habitat, which includes most of the high-value commercial timber, has already been committed to timber concessions. Most of the area to be logged will remain covered by forest and managed by the Department of Forestry (DF) for timber production. Presently, the Malaysian government is considering the proposed management plan.

Gunung Belumut. Stevens (1968) reported finding rhino tracks near Gunung Belumut in central Johor (Fig. 1). During 1977, a rhino was observed swimming across the Kahang River near the northwest slope of the mountain (DF staff, pers. comm.). I made a brief visit to the Gunung Belumut area in 1978 and found tracks of at least 1 rhino in the upper Kahang River basin. Additional reports of rhinos occurring in the upper Kahang and Madek watersheds on the west and north slopes of Gunung Belumut were received in 1980 from villagers living along the lower Kahang River. Based on the limited information available, I estimate that 2 or 3 rhinos occur in the Belumut area.

Today only about 230 km^2 of steepland adjacent to Gunung Belumut remain under forest; the rest of the former 2300 km^2 Endau-Kota Tinggi Wildlife Reserve has been cleared for agricultural development. Stevens (1968) recommended that this area be protected as a wildlife reserve, but no action was ever taken on his proposal. Some of the steepland adjacent to Gunung Belumut will probably remain forested, but the long-term survival of rhinos is unlikely there.

Mersing Coast. Stevens (1968) found tracks of 1 or 2 rhinos along the east coastal plain within the Tenggaroh Forest Reserve, located about 40 km south of the district town of Mersing (Fig. 1). Unfortunately, I was unable to visit this area and no recent information is available. The presence of rhinos there is doubtful because much of the forested land has been logged or cleared for agricultural development.

Northcentral Region

Taman Negara. Rhinos have been reported consistently from northern Pahang, southern Kelantan, and western Trengganu (Fig. 2), especially within Taman Negara (National Park) (Foenander, 1952; Hislop, 1961; Khan, 1971). Rhinos were hunted extensively in northern Pahang by Hubback (1939), but he provided few details on the location of his hunting areas. After Taman Negara was established as a national park in 1937, DWNP staff began collecting information on rhino distribution in this remote area (Hislop, 1961; Khan, 1971).

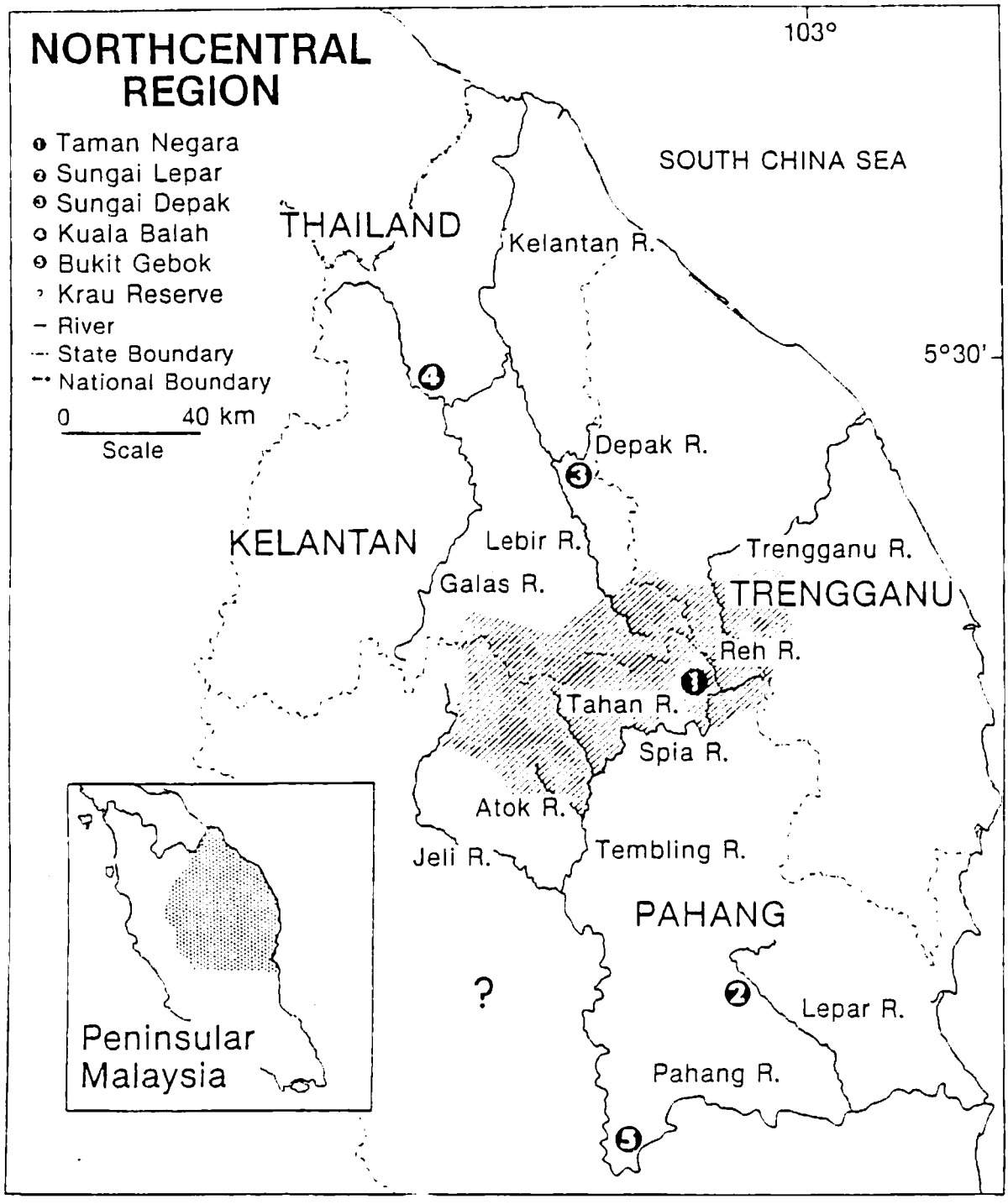

Fig. 2. Locations of Sumatran rhino track observations in the northcentral region of Peninsular Malaysia. An unconfirmed report is indicated by a question mark. The area occupied by Taman Negara (National Park) is shown by cross-hatching.

Rhino sign has been reported most frequently from the Spia River basin in the eastern section of the Park. Hislop (1961) hiked across much of the Park while he was a game warden and recorded rhino sign only from the Spia River north into the states of Trengganu and Kelantan. In 1976, Khan (DWNP director, pers. comm.) visited the Spia River area and found fresh tracks of 1 or 2 rhinos near the mouth of the Reh River. My survey of the Spia-Reh area in 1977 confirmed the presence of at least 2 animals in this region. Based on the locations of wallows, these animals appeared to range from the Spia River north to the Trengganu border. Information collected from my guide and other people living in the area indicated that these rhinos probably range farther north into southern Kelantan (Fig. 2). Recently, additional track observations have been recorded by DWNP staff in the Reh River area (Zaaba Abidin, DWNP park superintendent, pers. comm.). A brief survey of the upper Lebir River basin in the northeastern section of the Park during 1978 did not record any rhino sign.

In 1975, Olivier (pers. comm.) encountered tracks of an estimated 3 to 5 rhinos in the upper Atok River basin and adjacent areas in the southern portion of the park. Later in 1975, Nordin (DWNP park superintendent, pers. comm.) recorded rhino sign at the same location. My survey of the Atok River basin in mid-1976 confirmed the presence of at least 1 rhino, although little evidence of use was found. Another survey in 1980 did not record any rhino tracks in the lower Atok area. This information indicates that rhino density in the lower Atok Valley is low, and areas located farther to the west are used more frequently.

Only a few other reports of rhinos occurring within Taman Negara exist. In 1964, an adult rhino was observed near park headquarters at Kuala Tahan (DWNP ranger, pers. comm.). The tracks of this animal were followed along the Tahan River to a point near the Kelantan border (Khan, 1971). In 1977, another adult rhino was observed swimming across the Tembling River near Kuala Tahan. These animals may have come from the upper Tekai River area south of the Park, where Foenander (1952) suggested that rhinos occur. My surveys of the upper Tahan River in 1977 and 1981 did not locate any rhino sign, even at a previously used salt lick (Jenut Segantang). Rhino tracks were reported at Jenut Segantang in 1981 by a park ranger (Zaaba Abidin, pers. comm.). Olivier (pers. comm.) surveyed much of the Pahang portion of the Park for elephants during 1973 to 1975, but he found rhino sign only in the Atok area. Interviews with Orang Asli (aboriginals) who live and travel extensively within the Park indicated that rhino sign was rarely encountered. Other rhino reports have been collected from the western portion of the Park in the upper Tanum River watershed, but these reports were not confirmed.

I estimate that 8 to 12 rhinos presently occur in the Taman Negara region, with the upper Atok and Spia river areas being used most frequently. This estimate includes animals that range extensively into areas adjacent to the Park in the states of Pahang, Trengganu, and Kelantan. Additional survey work is needed to better document the distribution and number of rhinos in Taman Negara. However, my information indicates that rhino density in this region is quite low.

Also, tracks of young rhinos have never been recorded, indicating that recruitment is extremely low. Perhaps present population density is below a minimum needed for successful reproduction.

Sungai Depak. Hislop (1965) suggested that rhinos ranged from Taman Negara into southern Kelantan (Fig. 2). In 1976, Khan (director, DWNP; pers. comm.) found tracks of 2 rhinos along the Depak River in the upper Lebir River basin. Later in 1976, I confirmed the presence of at least 2 animals at the same location. At that time, a new logging road had been constructed along the Depak River. Rhino sign was found only near the end of this road where logging had not yet started. During 1977-1979, much of the Depak area was logged. No positive rhino reports have been received since the logging began. In 1979, Griffin (DF; pers. comm.) found no rhino sign while conducting a forest inventory of the upper Lebir River area. Based on available information, I estimate that 3 to 5 rhinos may occur in the upper Lebir River area. Animals found previously near the Depak River may have moved farther eastward or southward into more mountainous terrain, or they may have been eliminated during the logging operation by illegal hunting. During the next few years, most of the forested lands in southern Kelantan will be logged and the survival of rhinos outside Taman Negara is unlikely.

Kuala Balah. In 1976, I visited an area near Kuala Balah in the Pergau River basin, Kelantan (Fig. 2). Villagers in the area showed us recent tracks of 1 or 2 animals and a frequently used wallow located

near the edge of the primary forest. In 1977, a rhino was killed by poachers in the same area, about 50 km to the northeast. This animal's horn had been cut off with a chain saw. No other information is available on this rhino population. I estimate that 3 to 4 animals may occur in this section of central Kelantan based on track observations and reports from villagers living in the area. The chances of these animals surviving are low because most of the forest will be logged or cleared for agricultural development during the next few years.

Ulu Lepar. Foenander (1952) suggested that rhinos occurred in the upper Jengka Valley and the northwest portion of the Kuantan District of Pahang. In 1976, I investigated a report of rhinos occurring in the Lepar River Valley, located about 80 km west of the town of Kuantan (Fig. 2). A villager showed us a place on the east side of the Lepar River where he had observed a rhino during the previous week. I followed fresh rhino tracks from the point of his observation into nearby secondary forest. Suddenly, I encountered a large adult rhino running from a well-used wallow. The next day, older rhino sign was found 9 km upstream from the wallow near the primary forest fringe. From 1976-78, Conry (DWNP staff, pers. comm.) surveyed most of the lowland area within the Lepar Valley while studying the Malayan gaur (Bos gaurus). Occasionally, he encountered the tracks and wallows of at least 2 animals along the primary forest fringe west of the Lepar River. The only other rhino report from Kuantan District was received in 1979 from the geologist at the Sungai Lembing mine. Singh (pers. comm.) reported that a rhino was observed while a work crew was surveying the

mountainous area directly north of the mine.

I estimate that 3 to 5 rhinos occur within this section of the Kuantan District. These animals may range northward from the Lepar River to Taman Negara. Unfortunately, a thorough search of the hilly lands to the west and east of the Lepar Valley was not possible. Presently, this mountainous area is contiguous with a large forested region to the north. Large-scale agricultural development is planned for the upper Lepar River basin and the adjacent Tekam Valley, which will isolate the Lepar rhinos from those in the Taman Negara region. The long-term survival of the Lepar rhinos is uncertain because of the large amount of agricultural and forestry development in the region.

Bukit Gebok. In 1980, rhino sign was reported from the Bukit Gebok area (Fig. 2). A survey of this small isolated patch of forest confirmed the presence of at least 1 animal. I suspect that this isolated, solitary animal will not survive long because this patch of habitat is small and the threat of poaching is high.

Krau Wildlife Reserve. Hislop (1965) reported that rhinos occurred within the 500 km^2 Krau Wildlife Reserve in 1941, primarily on the western slopes of Gunung Benom (Fig. 2). Milton (1963) recorded the last confirmed rhino sign in this reserve. I was unable to survey the Krau Reserve because access was strictly controlled by the police. Information collected from villagers living near the Reserve indicated that rhinos probably no longer occur within the Krau.

West Coastal Region

Sungai Dusun Wildlife Reserve. The Sumatran rhino occurred sympatricly with the Javan rhino (Rhinoceros sondicus) along the west coastal plain (Fig. 3), especially in the states of Selangor and Perak (Foenander, 1952; Groves, 1967). The last known Javan rhino in Malaysia was shot in 1932 (Medway, 1969), and this species is now thought to be extinct in Malaysia. Because of the overlap in their historic distribution, species identification has been uncertain in this area (Strickland, 1967).

Wray (1906) reported that rhinos were formerly plentiful in the Dindings District of Perak. Sumatran rhinos in the Bernam Valley west of the railway line were first reported in 1949 by Hislop (1965). In 1957 and 1960, a solitary Sumatran rhino was observed in Lima Belas Estate, Perak, 15 km north of the Bernam River. Milton's (1963) 2-month survey recorded tracks of 2 to 3 rhinos in an area south of the Bernam River located between the Dusun and Tinggi rivers. In 1965, the Selangor state government established the 40 km^2 Sungai Dusun Wildlife Reserve to protect this small rhino population. Strickland (1967) conducted a 1-year study on the movements and ecology of these rhinos and concluded that at least 3 animals used the Reserve, primarily the more hilly lands in the eastern section. Since 1970, DWNP rangers have been stationed at a guard post built near the Dusun River within the Reserve to protect these rhinos.

Several visits were made to Sungai Dusun to collect rhino reports recorded by DWNP rangers, and to survey areas located to the

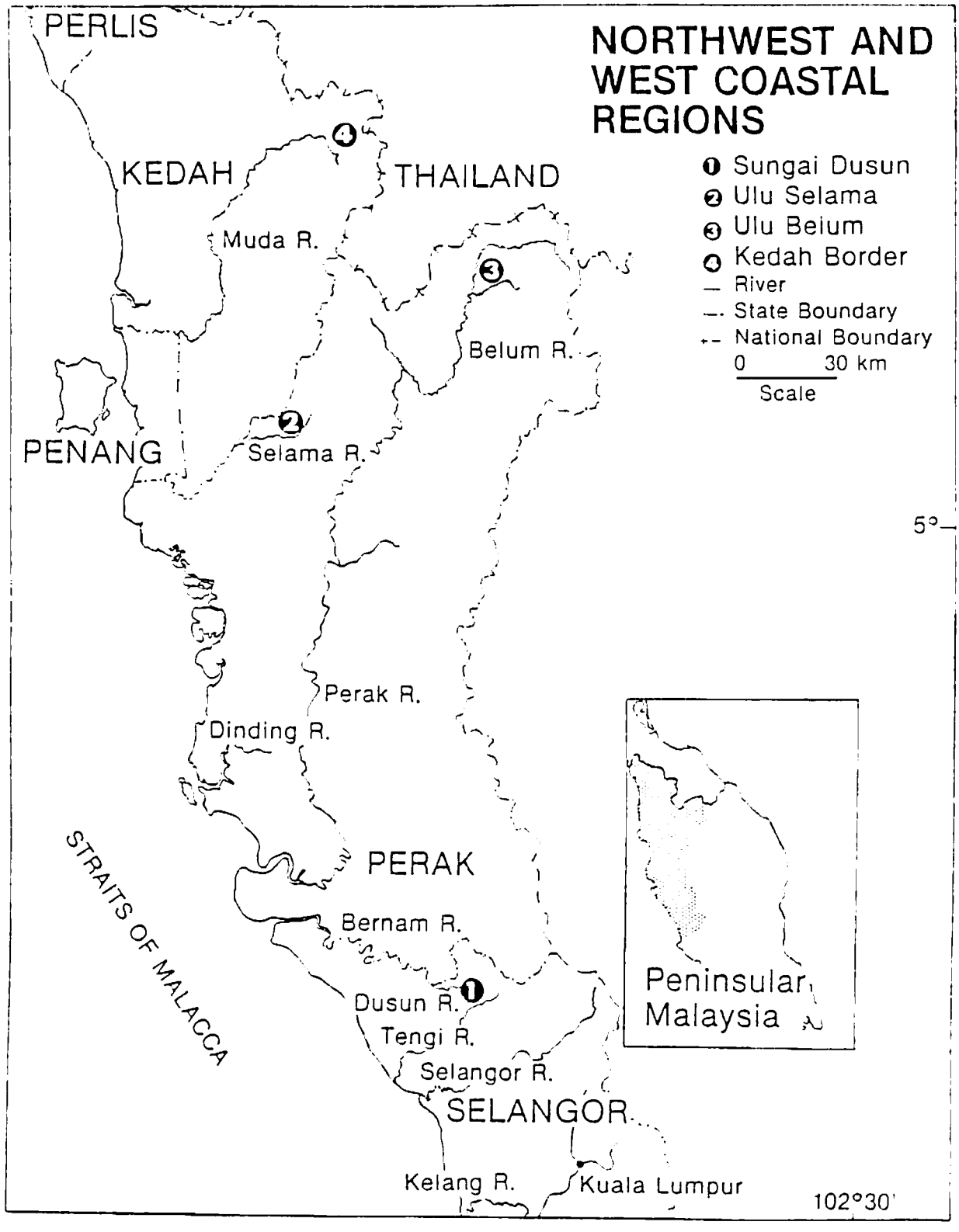

Fig. 3. Locations of Sumatran rhino track observations in the west coastal and northwest regions of Peninsular Malaysia.

north and east of the guard post. Frequently, the rangers observed rhinos at the guard post or their sign in the nearby forest. During 1976, solitary rhinos were observed at the guard post 6 times, and a cow/calf pair was observed once. During 1979-1981, rhinos were observed at the guard post 5 times and tracks were frequently encountered at a well-used wallow 2 km east of the guard post. Apparently, the rhinos came to the guard post to feed on ashes from campfires. In 1979, Marsh (pers. comm.) encountered a rhino 1.5 km north of the Reserve and found tracks to the west of the guard post. During 2 of my 5 visits, I found fresh tracks within 3 km of the guard post.

Based on an evaluation of the above observations, I estimate that 4 to 6 rhinos use areas within or adjacent to the Sungai Dusun Wildlife Reserve. Apparently, these rhinos use areas to the north and west more frequently than the habitat within the Reserve. This Reserve is too small to contain the complete home range of such a far-ranging species. Milton (1963) and Strickland (1967) were both naive to state that a 40 km^2 reserve would adequately contain the complete ranges of 3 animals. Unfortunately, rhino use of lands outside the Reserve, especially along the Bernam River, has not been adequately evaluated. The DWNP and the Selangor state government have proposed that 100 km^2 of adjacent land be added to this Reserve. The continued survival of this small rhino population will depend on expanding the size of this Reserve and protecting the animals within and outside the Reserve from poaching.

Northwest Region

Ulu Selama. Hislop (1965) stated that the largest number of rhinos in Malaysia occurred in the mountainous terrain within the Bintang Hijau Forest Reserve near the Selama River (Fig. 3). Milton (1963) visited the upper Selama River area and his party observed an adult rhino near a well-known salt lick (Jenut Sri Rimau). Strickland (1967) conducted a brief survey of the Selama basin and found tracks of at least 3 adult rhinos near the salt licks. During 1967, Stevens (1968) briefly visited the Selama area and recommended that a 220 km^2 wildlife reserve be established in the Selama basin to protect this rhino population.

I was unable to survey the Selama area because access to the forest was restricted by the police. The only recent information about rhinos in this area was collected by Thong (DWNP warden, pers. comm.). In 1977, he visited the salt licks and found fresh tracks of at least 2 rhinos. The present status of these animals is uncertain because this area receives no special protection. Based on previous track observations, I estimate that 3 to 5 rhinos occur in this region.

Ulu Belum. Hislop (1965) suggested that rhinos occurred in the upper Perak River watershed near the Thai border. Stevens (1968) recommended the establishment of a 2000 km^2 national park in this remote, mountainous region to protect the valuable wildlife resource. I was unable to survey the Belum River area because the border region has been the home of terrorists and bandits for many years. Thong

(pers. comm.) briefly surveyed the lower section of the Belum River in 1972 and found tracks of at least 2 rhinos. Thong's observations are the only confirmed rhino reports fron the area. Based on the above information, I estimate that 3 to 5 rhinos may occur in the Ulu Belum area.

Thai-Kedah border. Hislop (1965) reported finding rhino tracks in the mountainous land along the Thailand-Kedah border in 1941 (Fig. 3). This area was not surveyed because of police restrictions. Information collected by McNeely & Laurie (1977) on the Thai side of the border indicated that rhinos were no longer found there. A more thorough survey of the entire Thailand-Malaysia border region is needed to obtain adequate information on rhino occurrence there.

STATUS AND CONSERVATION

Today, the Sumatran rhinoceros appears threatened with immediate extinction in Peninsular Malaysia. Excessive hunting during the past few centuries has reduced this once widespread species to a few small scattered populations occurring in remote areas of the country. In addition, large-scale habitat destruction by logging and forest clearance for agricultural development has further isolated the already small populations and has reduced the amount of suitable habitat. The exploitation of the forests has also brought the surviving rhinos into

much closer contact with people, greatly increasing their susceptibility to poaching.

During the colonial period, Sumatran and Javan rhinos were given inconsistent protection in the Malay peninsula; their legal status varied among the states. With the approval of the 'Wild Animal and Bird Protection Ordinance' in 1955, the DWNP was centralized and both rhino species were classified as totally protected. The 'Wildlife Act of 1972' provided for better organization of the DWNP and stronger penalties for the killing or possession of totally protected species (maximum fine US$ 1200 and/or 2 years in jail). Since 1975, the DWNP has greatly increased the number of staff and the amount of funds available for conservation and law enforcement programs. With the proper deployment and coordination of funds and personnel, rhino poaching can be minimized.

The high price of rhino body products continues to provide a strong incentive for poaching. Martin (1979) found the average retail price of Asian rhino horn in 4 Asian countries to range from US$ 3000 to 11,000 per kg. The number of rhinos killed by poachers in Peninsular Malaysia is not known, but at least 2 animals have died since 1975. Even though the trading of Sumatran and Javan rhino body parts is prohibited under present law, African and Indian rhino products can be legally sold and are found in most Chinese medicine shops. At least 8 brands of a fever tonic made from rhino horn (known as ayer badak or rhino water) can be purchased in most retail stores for under US$ 0.50. The amount of rhino horn consumed or traded in Malaysia is not known.

Recently, Malaysia signed an international treaty controlling the trade in endangered species (Convention on the International Trade in Endangered Species of Wild Fauna and Flora). This treaty prohibits all trade in rhino body parts because the status of all species is precarious throughout the world. Hopefully, a program stopping the trade of all rhino products will soon be implemented in Malaysia.

Prospects for the long-term survival of the Sumatran rhino in Malaysia are poor. The loss of adult animals to poaching and the almost complete lack of reproductive success are the immediate problems. Evidence of young animals is seldom reported or encountered in the field. The only known recruitment of young rhinos has occurred in the Endau-Rompin and Sungai Dusun areas. Without any new births, a population is essentially dead and able to persist only because individuals of the species are long-lived. Sumatran rhinos have been kept in captivity for over 32 years (Van Strien, 1974). Little information is available on the reproductive biology of this rhino species, but all evidence suggests that their reproductive potential is quite low. Borner (1978) estimated reproductive parameters based on data from similar rhino species. He conjectured that under good environmental conditions female Sumatran rhinos become sexually mature at 3.5 to 6 years of age, then produce a calf only once in about 3 years. Several other factors probably contribute to the low reproductive rate observed in this species. Adults are solitary, far-ranging, and occur at low desities (Van Strien, 1974; Borner, 1978). No evidence of a breeding season has ever been observed. Thus, the

frequency of contact among sexually receptive animals would be low under optimal conditions and decrease rapidly with reduced population size. In areas with extremely low numbers, both reproductively active male and female individuals may not even be present in the population, or the density of individuals may be too low for successful mating.

The fragmentation of the rhino population into isolated habitat islands by logging and forest clearance has made the species more susceptable to extinction. The impact of demographic, environmental, and genetic stochastic factors increases in importance as population size decreases (Shaffer, 1981). An effective population size of at least 50 individuals has been proposed as the minimum necessary for maintaining short-term fitness in most species (Soule, 1980). In the long-term, genetic variability will be maintained only if population sizes are of an order of magnitude higher (Franklin, 1980). All rhino populations in Peninsular Malaysia are below the suggested minimum viable population size. Thus, only the largest rhino populations (Endau-Rompin, Taman Negara, and Sungai Dusun) have much chance for long-term survival and smaller groups have little chance for even short-term persistence.

A conservation program for this species needs to be developed which includes both short-term and long-term strategies. In the short-term, all animals must be protected from poaching and their habitat protected. All rhino areas should be regularly patrolled from guard posts located at main access points. The penalties for poaching and the trading in rhino body parts should be increased to facilitate

the protection program. Recent studies have shown that this rhino species avoids areas where their primary forest habitat has been modified by logging (Flynn, 1978). Thus, large tracts of preferred habitat need to be protected by establishing national parks or wildlife sanctuaries. Priority for habitat acquisition should be given to areas that contain the largest rhino populations. The exploitation of other rhino areas that can not be acquired should be delayed until a system of reserves has been established. Additional surveys of all rhino areas are needed to further document distribution and numbers. Known rhino groups should be carefully monitored to determine population trends, especially recruitment rates. Research into the habitat and food requirements of these animals should be continued until their ecology and habitat relationships are better understood. Experiments designed to increase food availability (Flynn, 1980) should be expanded and evaluated.

In order to prevent the extinction of this species in Malaysia, I suggest a long-term conservation strategy that would attempt to maintain viable rhino populations in a system of separated reserves. This program would require the translocation of animals from areas with extremely low numbers or insecure habitat to sanctuaries which contain viable breeding populations, suitable habitat, and good law enforcement systems. The threats of habitat destruction, parasites, disease, and natural catastrophes would be reduced by maintaining several isolated populations. An occasional movement of animals among the reserves would permit genetic mixing to minimize the negative impact of inbreeding

depression and other genetic factors (Franklin, 1980). However, capture and handling procedures would need to be developed before such a program could be implemented.

In Peninsular Malaysia, 3 areas exist that may be suitable for maintaining viable Sumatran rhino populations. The Endau-Rompin region appears to be the best place and conservation efforts should be concentrated there. This area contains the largest (20-25) and most dense (1 animal per 40 km^2) rhino population in the country (Flynn and Abdullah, 1983). Although some evidence of reproduction has been observed, the low recruitment rate indicates that this population may be near a minimum number required for reproduction to occur. A portion of the suitable rhino habitat in the Endau-Rompin region may be protected as a national park (Flynn, 1980). This national park would be surrounded by an additional 400 km^2 of forested lands managed for timber production. If approved as proposed, this national park will contain about 65% of the presently occupied rhino area, including most of the more heavily used habitats. Presently, DWNP rangers patrol portions of the rhino area, but this effort needs to be greatly increased. Guard posts should be built at the main access points to facilitate the protection program by discouraging human entry (Flynn, 1980).

Taman Negara is the next best area to maintain a rhino population in Peninsular Malaysia. This remote area contains the second largest number of rhinos in Malaysia (8-12), and the habitat within the park is reasonably secure because of legal protection as a national park. After Malaysia's agricultural lands have been cleared and the

commercial forests logged, Taman Negara will be the largest tract of primary forest remaining in the country. Presently, the density of rhinos there is extremely low; these animals may be too scattered to reproduce successfully. The Taman Negara area should be extensively surveyed to better document rhino distribution, numbers, and recruitment rates.

The Sungai Dusun area is the only other place in Peninsular Malaysia that has much potential for maintaining a viable population of Sumatran rhinos. A small number of rhinos have persisted there for many years, and evidence of young animals has been observed occasionally. The present reserve may be too small for the maintenance of a viable rhino population. Lands on the north and west side of the reserve should be added to create a more suitable sanctuary. The DWNP ranger patrol system needs to be strengthened and expanded to include areas used by the rhinos that are adjacent to the present reserve.

Other areas within Malaysia have little potential for maintaining viable populations of Sumatran rhinos. Still, all known rhino areas should be regularly patrolled to prevent poaching and determine numbers. A program should be developed to capture rhinos threatened by immediate habitat destruction or poaching for release in one of the more secure areas.

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REFERENCES

Borner, M. (1978). A field study of the Sumatran rhinoceros. Ph.D. thesis, Univ. Basel, Switzerland.

Dale, W. (1952). The rainfall of Malaya. J. Trop. Geogr., 13, 23-37.

Ellis, D. (1971). Rhinos in northern Johor, Malaysia. Singapore, The Malayan Nature Society. (Unpublished report).

Flynn, R. (1978). The Sumatran rhinoceros in the Endau-Rompin National Park of Peninsular Malaysia. Malay. Nat., 4, 5-12.

_____. (1980). Endau-Rompin National Park management plan. Kuala Lumpur, Malaysia, Department of Wildlife and National Parks.

_____. (1981). Sumatran rhinos in the Silabukan area, Sabah. Kuala Lumpur, Malaysia, World Wildlife Fund. (Unpublished Report).

_____. and M. Tajuddin Abdullah. (1983). The distribution and number of Sumatran rhinoceros in the Endau-Rompin region of Peninsular Malaysia. Malay. Nat. J., in press.

Foenander, E. C. (1952). Big game of Malaya. London, Batchworth Press.

_____. (1961). The occurrence of rhinoceros in Pekan District, Pahang. Kuala Lumpur, Department of Wildlife and National Parks. (Unpublished report).

Forest Department. (1977). Forest resources of Peninsular Malaysia. Kuala Lumpur, Department of Forestry.

Franklin, I. R. (1980). Evolutionary change in small populations. In Conservation biology: An evolutionary-ecological perspective, ed. by M. Soule and B. Wilcox, 135-150. Sunderland, Mass., Sinauer Assoc.

Groves, C. P. (1967). On the rhinoceros of Southeast Asia. Saugetierk. Mitt., 15, 221-237.

Hislop, J. (1961). The distribution of elephant, rhinoceros, seldang, and tapir in Malaya's National Park. Malay. Nat. J., 95-99.

_____. (1965). Rhinoceros and Seladang. Malaysia's vanishing species. IUCN Publ. N. S., 10, 278-283.

Hubback, T. (1939). The Asiatic two-horned rhinoceros. J. Mammal., 20, 1-20.

Khan, M. (1971). The distribution of large animals in Taman Negara. Malay. Nat. J., 24, 125-131.

Lee, D. (1980). The sinking ark. Kuala Lumpur, Heinemann Books.

Martin, E. B. (1979). The international trade in rhinoceros products. Gland, Switzerland, WWF/IUCN.

McNeely, J. & Laurie, A. (1977). Rhinos in Thailand. Oryx 13, 486-487.

Medway, L. (1969). THe wild mammals of Malaya. Kuala Lumpur, Oxford Press.

Milton, O. (1963). Field notes on wildlife conservation in Malaya. Spec. Publ. No. 16, American Committee for International Wildlife Protection.

Payne, J. (1980). Report on rhinoceros in the Silabukan Forest Reserve, Sabah. Sandakan, Sabah Forest Dept. (Unpublished report).

Poore, M. (1963). Problems in the classification of tropical rain forest. J. Trop. Geogr., 17, 12-19.

Richards, P. (1952). The tropical rain forest. Cambridge, Cambridge Univ. Press.

Schenkel, R. & Schenkel, L. (1979). Report from the SSC Asian rhino group meeting in Bangkok, Thailand. Gland, Switzerland, IUCN/WWF. (Unpublished report).

Shaffer, M. L. (1981). Minimum population sizes for species conservation. Bioscience 31, 131-134.

Simon, N. (ed.). (1969). Red data book, Mammalia. Gland, Switzerland, IUCN/WWF.

Soule, M. E. (1980). Thresholds for survival: maintaining fitness and evolutionary potential. In Conservation biology: An evolutionary-ecological perspective, ed. by M. Soule and B. Wilcox, 151-170. Sunderland, Mass., Sinauer Assoc.

Stevens, W. E. (1968). The conservation of wildlife in West Malaysia. Kuala Lumpur, Malaysia, Department of Wildlife and National Parks.

Strickland, D. (1967). Ecology of the rhinoceros in Malaya. Malay. Nat. J., 20, 1-17.

Talbot, L. (1960). A look at threatened species. Oryx 5, 153-293.

Van Strien, N. (1974). The Sumatran or two-horned Asiatic rhinoceros. A study of the literature. Meded. Landbouwhogeschool Wageningen 74-16.

Wray, L. (1906). Rhino trapping. J. Fed. Malay. States Mus. 1, 63-65.

Whitmore, T. C. (1975). Tropical rain forests of the Far East. Oxford, Claredon Press.

Wyatt-Smith, J. (1964). A preliminary vegetation map of Malaya with descriptions of the vegetation types. J. Trop. Geogr., 18, 200-213.

CHAPTER III

DISTRIBUTION AND NUMBER OF SUMATRAN RHINOCEROS IN THE ENDAU-ROMPIN REGION OF PENINSULAR MALAYSIA

ABSTRACT

Distribution of the Sumatran rhinoceros in the Endau-Rompin region of southern Peninsular Malaysia was studied from 1975 to 1981. I collected information from a general field survey and interviews with people living near rhino areas. I found that individual rhinos could be differentiated based on statistical differences in median track width, the distance between track observations of similar size, and recognizable cow/calf pairs. Rhinos were found to occur throughout the region in most of the remaining contiguous primary forest, occupying about 1600 km^2. The number of rhinos in 400 km^2 of the southern section was estimated from a series of 4 census surveys conducted from 1977 to 1981. I recorded the tracks of 8, 6, 8, and 8 unique rhinos on the study area during the censuses and estimated that 10 rhinos occurred there, a density of 1 animal/40 km^2. Rhino density in the remainder of the region appeared to be much lower, about 1 animal/80-120 km^2. I estimated that 20-25 Sumatran rhinos occur in the Endau-Rompin region. Young rhinos were found in the population in 1975, 1977, and 1981 for an annual total recruitment rate of 0.5 young/year. One case of adult mortality was documentated. The Endau-Rompin region is the best place in Malaysia to maintain a viable population of Sumatran rhinos because it contains the largest number of animals, evidence of recruitment has been observed, a law enforcement program has been started, and a portion of the region (870 km^2) has been proposed for national park status.

INTRODUCTION

The Sumatran or two-horned Asiatic rhinoceros (Dicerorhinus sumatrensis Fisher 1814), one of the world's rarest large mammals, is threatened with extinction throughout its range (Simon, 1969). This forest-dwelling rhino was once found across Southeast Asia, from the hills of eastern Assam in India through Burma, Thailand, Indochina, the Malay peninsula, and the Sunda islands of Sumatra and Borneo (Groves, 1967; Van Strien, 1974). Recent surveys have shown that the Sumatran rhino is now restricted to small scattered populations occurring in Burma (Schenkel and Schenkel, 1979), Thailand (McNeely and Laurie, 1977), the Malay peninsula (Flynn and Abdullah, 1983), Sumatra (Borner, 1978; Van Strien, pers. comm.), and Borneo (Schenkel and Schenkel, 1979; Payne, 1980; Flynn, 1981).

The historic hunting of rhinos for their body parts has greatly depleted numbers (Van Strien, 1974). Many Asiatic people believe that rhino body parts, especially the horn, have special medicinal properties. The increased use of rhino horn for knife handles in Yeman has caused the price of rhino horn to soar during the past few years (Martin, 1979). Recently, extensive habitat destruction from logging and forest clearance for agricultural development has further isolated rhino populations and reduced the amount of suitable habitat.

Little detailed information on the distribution and numbers of the Sumatran rhino in Peninsular Malaysia has been available, the literature consisting of old accounts by hunters and game wardens

(e.g. Hubback, 1939; Foenander, 1952; Hislop, 1965), or brief field surveys (Talbot, 1960; Foenander, 1961; Milton, 1963; Strickland, 1967; Stevens, 1968; Ellis, 1971). In 1975, the Malaysian Department of Wildlife and National Parks (DWNP) initiated a long-term study on the distribution, ecology, and conservation of the Sumatran rhino in Peninsular Malaysia (Flynn, 1978). Early in this study, I discovered that the Endau-Rompin region, located in the southern part of the Malay peninsula, contained the country's largest remaining rhino population (Flynn and Abdullah, 1983). In this paper, I present the results of a study into the distribution and number of Sumatran rhinos in the Endau-Rompin region.

Censusing a ground-dwelling mammal in tropical rain forest habitat is a difficult task. Dense vegetation, rough topography, heavy rainfall, and secretive animals prevent the use of standard methods (Bourliere, 1969). The Sumatran rhino presents a particularly difficult problem because the animals can not be easily observed or captured. Thus, all methods must be based on observations of indirect evidence of an animal's presence. The locations and size of tracks provide the only information that can be regularly collected in the field. This rhino species has feet with characteristic flat, circular soles and 3 large toenails, a half round toenail in front with more pointed toenails to the left and right of the sole (Van Strien, 1979). In firm soil, these animals leave clear foot prints that can be measured accurately (Flynn, 1978). A statistical analysis of the characteristics of rhino track measurements taken under field conditions indicated that individual

animals can be distinguished by differences in track sizes, the distance between track locations of similar size, and recognizable adult female/young pairs.

STUDY AREA

Endau-Rompin Region

The Endau-Rompin region is located in the southern portion of the Malay peninsula, about 225 km south of the capital city of Kuala Lumpur (Fig. 1). The study area straddles the Johor-Pahang state border and is bounded between 2° 15′ N and 2° 50′ N latitude and 103° 00′ E and 103° 30′ E longitude. The Endau and Rompin rivers drain the southern, eastern, and northern sections of the region, flowing eastward into the South China Sea. The Muar River drains the western section into the Straits of Malacca.

The region's topography is generally hilly, locally quite steep, with a central north-south trending mountain range that rises abruptly above the coastal plain. Elevations range from about 100 m near the coastal plain to over 1000 m at the tops of the highest mountain peaks. These mountains are composed of undifferentiated granitic rocks of Triassic age (Gobbett and Hutchison, 1973). To the east, Permian volcanic rocks of andesitic to rhyolitic composition are intruded by the granite. In the east and north, Jurassic-Cretaceous sandstones of the Tebak formation unconformably overlie the older granitic rocks, forming distinctive plateaus and escarpments (Burton,

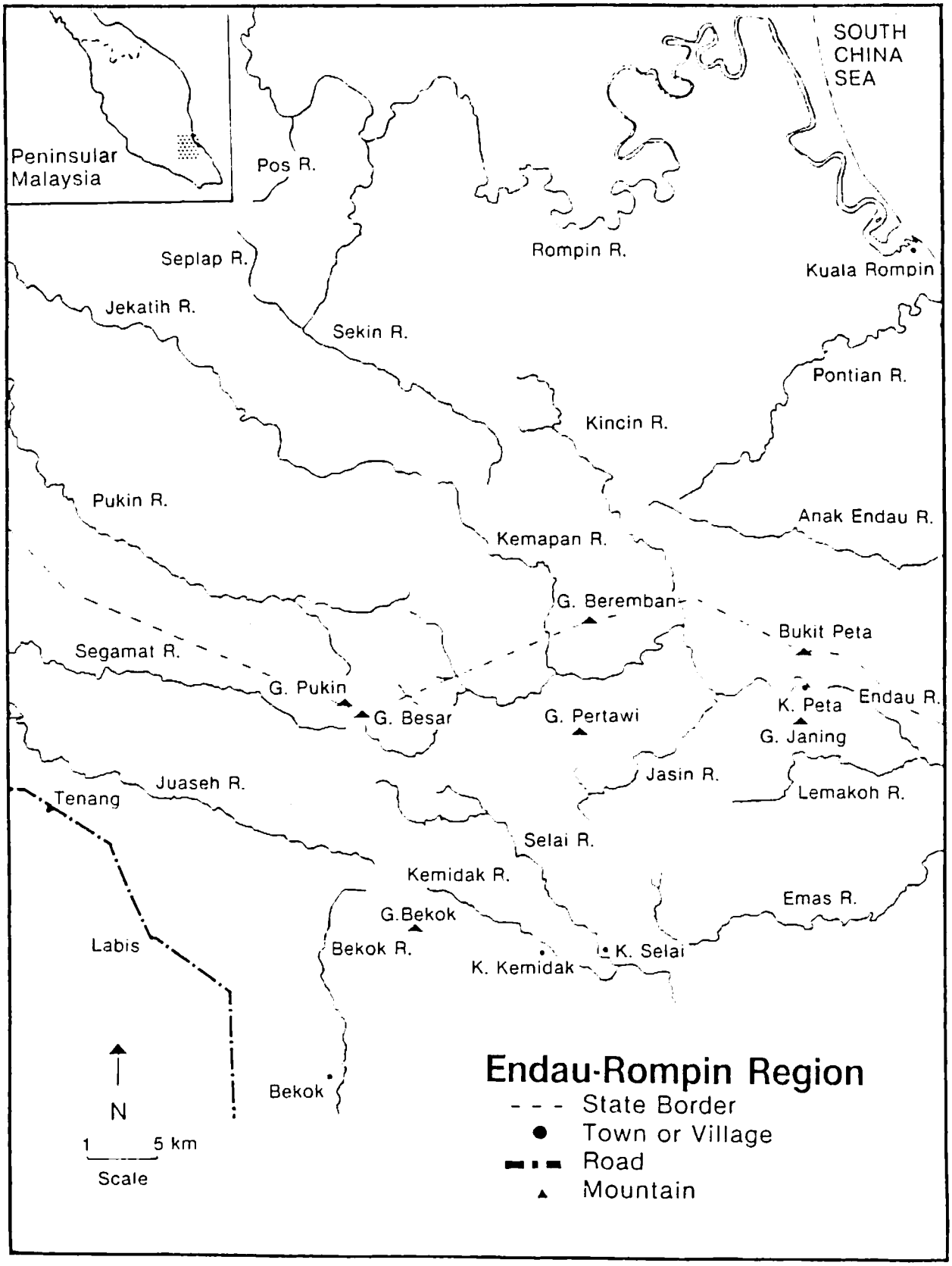

Fig. 1. Map of the Endau-Rompin region, located in southern Peninsular Malaysia, showing places mentioned in the text.

1973). The region's soils are quite variable depending on the underlying parent material, but are generally of poor quality (Smallwood, 1966). Red and yellow latosols and podzolic soils derived from acid igneous rocks cover most of the area. Latosols and podzolic soils derived from sedimentary rocks are found farther to the east (Smallwood, 1966).

The region has a tropical climate strongly influenced by close proximity to the equator and warm oceans. Atmospheric conditions are uniformly warm and humid throughout the region, with a mean annual temperature of 27° C and mean annual relative humidity of 85% in lowland areas (Dale, 1963). Rainfall is heavy throughout the year with little seasonal variation, except for slight increases during the June-to-August and October-to-December monsoon periods. Annual mean rainfall varies across the region depending on distance from the sea, ranging from a low of 2000 mm at the interior town of Segamat to a high of 3300 mm at the coastal town of Mersing (Dale, 1959).

The natural vegetation of the Endau-Rompin region is tropical evergreen rain forest of the Indo-Malayan formation (Richards, 1952). These forests are the most luxuriant of all plant communities and are characterized by numerous large evergreen, broad-leafed trees dominated by the family Dipterocarpaceae (Whitmore, 1975). Many problems exist in the classification of these forests (Poore, 1963), but they can be grouped into several general forests types (Wyatt-Smith, 1964; Forest Department, 1977). The majority of the Endau-Rompin region is covered with mixed lowland dipterocarp forest with hill dipterocarp forest on

the ridges and at elevations above 300 m. According to Gyekis (1966), a large portion of the western mountainous area contains forests of the meranti-keruing mixed hill type with seraya-keruing ridge forest predominating on the ridges and well drained sites. In the north and east, the forests are variable, composed primarily of edaphic hill forest, some seraya hill forest, and livestonea-kelat-kedendong forest (Lee, 1966).

Census Area

Preliminary study results indicated that rhino density in the Endau-Rompin region was quite variable, with density much higher in the southern section. A portion of this high-density area was selected for intensive census work. The census study area contained about 400 km^2 within the upper watersheds of the Juaseh, Kemidak, Tenang, Selai, Segamat, Endau, Pukin, and Jemai rivers (Fig. 2). The balance of the region will be refered to as the low-density area. The census area was mostly covered with primary tropical rain forest (90%) with small areas covered by logged forest (5%), mixed orchard (3%), and agricultural crops (2%).

METHODS AND PROCEDURES

Field Methods

General survey. The distribution of Sumatran rhinos in the

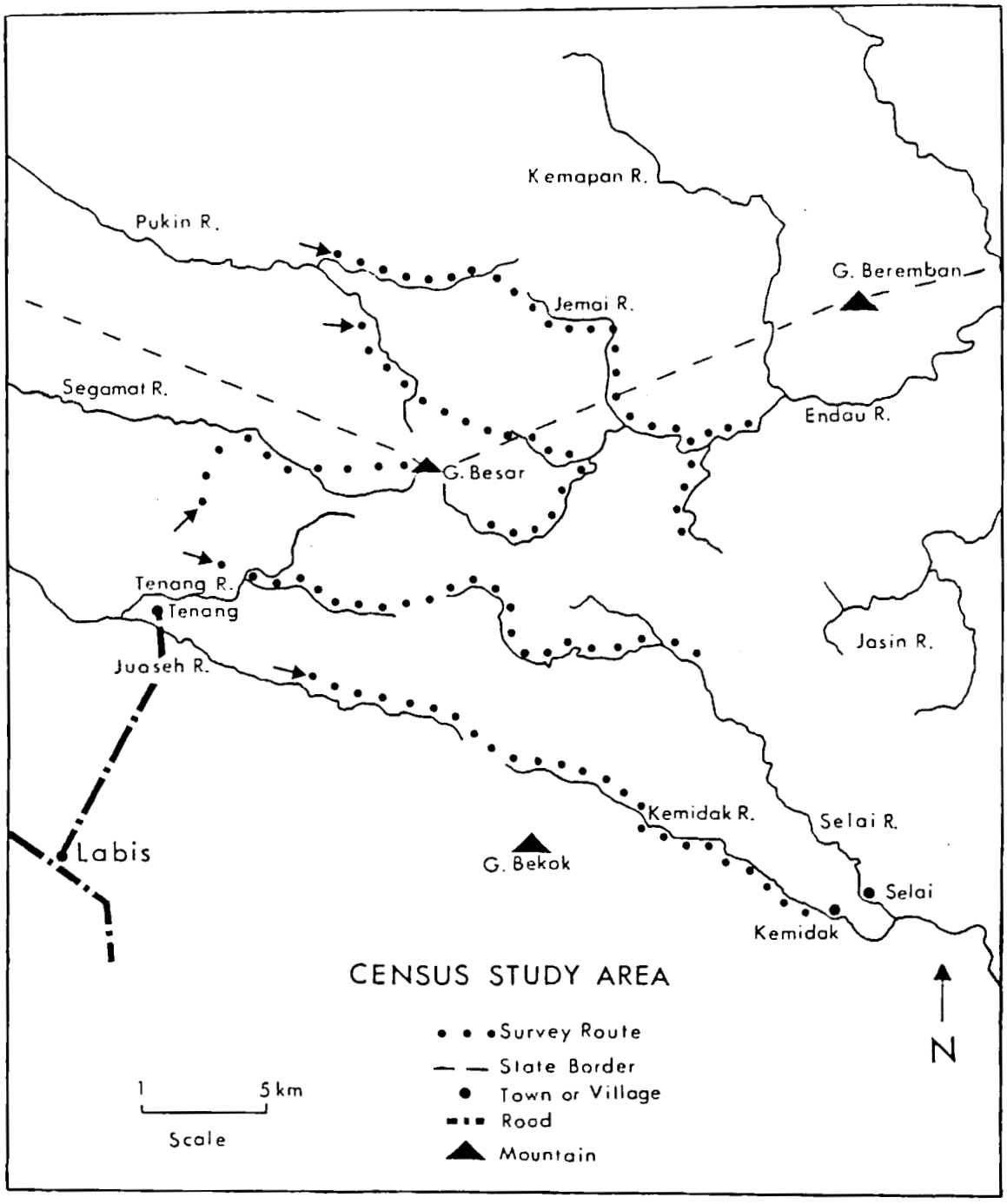

Fig. 2. Map of the census study area which is located in the Endau-Rompin region of southern Peninsular Malaysia. The census survey routes are indicated by dotted lines, with the starting points marked by arrows.

Endau-Rompin region was investigated by a general survey conducted during January 1975 to January 1978, January 1979 to June 1979, and July 1980 to May 1981. Initially, people living or working in the region, especially villagers at Kampung Juaseh, Kampung Tenang, Kampung Segamat, and Kampung Peta, were interviewed to gather information on places where rhino sign (tracks, wallows, or evidence of feeding) had been observed. These reports were evaluated for reliability and most were checked by field surveys, but a lack of time prevented me from verifying all reports. A survey team, consisting of DWNP rangers, local guides, and ourselves, searched potential rhino areas for sign. Each field survey lasted for about 10 days and 80 to 100 km were travelled on foot. Usually, survey routes followed small streams because rhino sign was easiest to observe there. The observation of sign confirmed the presence of rhinos in an area and provided a rough indication of population density.

I concentrated my survey efforts in areas where rhino sign had been reported frequently. Thus, the general rhino survey was started in the Juaseh-Segamat-Selai area. Adjacent watersheds were searched systematically until most sections of the region had been surveyed. The field surveys were time consuming, so all areas were not covered.

The locations of all rhino sign observed were plotted on topographic maps and recorded as map grid coordinates. At each track observation, the tracks were followed until several clear prints of the animal's hindfoot could be recorded. At each track, the maximum width between the lateral toenails and the width of the middle toenail were

measured to the nearest millimeter with a steel tape and calipers (Flynn 1978). The maximum width of the middle toenail was useful in differentiating between rhino and Malayan tapir (Tapirus indicus) tracks, with rhino tracks having a wider toenail. Usually, only tracks made by the hindfeet were recorded because the rhinos frequently placed their hindfeet on top of the forefoot prints. An attempt was made to follow a set of tracks until at least 10 clear prints made by the animal walking on flat, firm ground could be measured. The total number of tracks that were measured at each observation varied depending on weather conditions and time availability. Also, the topography and soil conditions were recorded at each track observation.

Census surveys. The number of rhinos occurring in the high-density census area was estimated using methods similar to those developed by Schenkel and Schenkel-Hulliger (1969) for censusing the Javan rhino (Rhinoceros sondicus) in Udjung Kulon Reserve, Indonesia. Rhinos occurring within the 400 km^2 study area were censused by 5 survey teams that walked simultaneously across the study area along permanent transect routes during a period of 4 to 5 days. A survey team usually consisted of a DWNP officer as team leader, 3 DWNP rangers, and local guides. Each survey team recorded the location, age, and size of all rhino tracks encountered along their route. After each census survey was completed, the information from each team was evaluated for accuracy and reliability. All incomplete or questionable data were eliminated from further analysis. Census surveys were conducted in March 1977, May 1977, March 1979, and September 1980.

The routes selected for the census surveys were established along small streams that flow roughly parallel east to west across the study area (Fig. 2). My initial surveys showed that rhino tracks were found most often along small streams because the animals use stream bottom habitat frequently (Flynn, in prep.) and their tracks were more noticeable in soft soil. Often, these streams provide the only available route for foot travel through the forest. Also, streams can be found at a latter date, so the same route can be repeated. Fortunately, most of the streams in the study area flow roughly parallel east or west from a central north-south mountain range. All routes began at the western edge of the study area at points accessible by road. The routes proceeded east along the streams to the top of the mountain ridge, then down the opposite drainage to the boundary of the study area. Each major tributary of the main stream was also surveyed to provide more complete coverage. The distance between adjacent routes ranged between 1 and 6 km and route lengths varied between 25 and 45 km ($\bar{x}$=34 km).

Statistical Procedures

Data collected during this study were analyzed on the DECSYSTEM-2050 computer system available at the University of Motana Computer Center. The Statistical Package for the Social Sciences (SPSS) (Nie *et al.* 1975) computer programs were used for all of the statistical analyses, unless noted otherwise. The statistical characteristics of a series of track measurements were investigated by computing descriptive statistics (mean, median, range, and skewness) and frequency histograms.

Skewed track frequency distributions were compared to a normal distribution by the Kolmogorov-Smirnov one-sample goodness-of-fit test using parameters estimated from the data. The sign test was used to examine whether a significant number of track distributions were skewed in a particular direction. A 95% confidence interval for the median was constructed for each track series (Campbell, 1967). Track measurement distributions made by the left and right feet of the same animal were compared using the Mann-Whitney two-sample rank sum test. This same test was used to compare 2 track series of the same animal made in soft and firm soil.

The track data collected during each census survey were analyzed to determine the minimum number of animals occurring on the study area during the census period. In this analysis, all track observations of the same age that were located farther than 8 km apart were considered different animals. The assumption was that rhinos usually do not travel more than 8 km in straight line distance during a 24-hour period, especially over a mountain ridge into another watershed. Other information, such as whether the animal had spent a large amount of time in a particular area, was used in the evaluation of the distance between tracks of the same size. Also, recognizable cow/calf pairs were used as criteria to identify individual rhinos. Previous work (Flynn, unpublished) indicated that a young rhino travels with its mother until the calf's median track width reaches about 17.0 cm. Thus, if a track series with a median width measurement of less than 17.0 was paired with a track with a median width size greater than 19.0 cm, a cow/calf pair

was presumed.

The remainder of the track series recorded during a census period were treated as independent observations. The Kruskal-Wallis (K-W) one-way analysis of variance (ANOVA) by ranks was used to test whether these observations all came from distributions with the same location. If this null hypothesis was rejected, simultaneous confidence intervals for the difference between medians were calculated according to a method by Campbell (1967). If the confidence intervals for the difference between the medians of a pair of observations did not include zero, then I concluded that the track distributions had been made by different animals. Other multiple comparison procedures were examined (Sokal and Rohlf, 1969; Gibbons, 1976), but these procedures proved to be less useful because of unequal sample sizes and the large number of groups.

The described census method yielded a minimum count of the number of rhinos within the study area during a given period. The detection of all rhinos within the study area by walking the 5 census routes was unlikely. The surveys were assumed to detect all rhinos within 2 km of the census routes. Thus, the survey routes adequately covered about 75% of the entire census study area. The total number of rhinos within the study area during the census period was estimated by increasing the minimum count by 25%.

The number of young rhinos in the population was determined using track size criteria. All animals with a median track width of less than 17.0 cm were considered dependent young, probably less than

2.5 years of age. All other animals were assumed to be either sub-adults or adults. Insufficient information existed to further separate animals into age categories based on foot width measurements.

RESULTS

Characteristics of Track Measurements.

The analyses presented in this paper are based on the observation of 110 sets of rhino tracks. The number of tracks measured for each observation varied from 1 to 30 ($\bar{x}$=11). Early in this study, only the median width of a track series was recorded because the utility of recording all of the track measurements of a series had not yet been realized. Thus, multiple samples were recorded for 73 of the track observations. For all track observations, the maximum width measurement between the lateral toes of the hindfeet varied from 15.0 to 22.5 cm, the width of the hindfoot front toe varied from 5.5 to 9.0 cm, the width of the forefoot varied from 18.5 to 23.0 cm, and the width of the front toe of the forefoot varied from 6.0 to 9.5 cm. The forefoot track was always wider than the hindfoot track for all animals with a mean difference of 1.5 cm. Because accurate measurements of the forefeet were difficult to obtain, only measurements of the width of the hindfeet were used in the rest of the analyses. The track distributions made by the right and left feet of the same animal were found to be similar for 3 sets of observations (Mann-Whitney rank sums test, $p>0.8$, 0.75, 0.9).

Thus, measurements of tracks made by both feet of an animal were pooled for each observation.

The range of individual track measurements of a series varied from 0 to 2.5 cm ($\bar{x}$=0.6 cm, n=73) with the variability of the terrain contributing the most to the magnitude of the range. Graphed histograms of track measurements indicated that several track series had skewed distributions. The skewness coefficients varied from -2.1 to 2.2, but the sample sizes were too small to test the skewness coefficients for significance (Ott, 1977). All track distributions with skewness coefficients greater than 1.0 were compared to a normal distribution using parameters estimated from the data. None of the distributions with high skewness coefficients were found to differ significantly from a normal distribution (Kolmogorov-Smirnov one-sample test, $0.075<p<0.9$). Also, an analysis of the signs of the skewness coefficients found that the track distributions were not significantly skewed in a particular direction (sign test, $p>0.45$) (Campbell, 1967). The skewness coefficients of track measurement distributions made by animals walking on flat terrain were consistently low. In track series of animals walking uphill, the track measurement distributions tended to be skewed to the right. Likewise, animals walking downhill tended to produce distributions skewed to the left. All track observations with sample sizes greater than 10 had low skewness coefficients ($\bar{x}$=0.50, n=44). The data indicated that track measurements of rhinos walking on flat ground with sample sizes greater than 10 were approximately normally distributed.

For 1 set of tracks, sufficient data were available to test the effect of soil type on track size. A rhino's tracks made in soft, muddy soil were found to be significantly larger than tracks made in firm ground (Mann-Whitney rank sums test, $p<0.05$). A 95% confidence for the difference in the medians was found to be $2< x_{0.6}<4$ mm. Thus, soft soil conditions may result in a shift to the right of the median by 2 to 4 mm.

Distribution

The tracks of Sumatran rhinos were observed 110 times in the Endau-Rompin region during 50 ground surveys. I spent over 300 days in the field and walked an estimated 2750 km through the forest. These surveys were centered in the census study area with the upper Tenang, Selai, Endau, Segamat, Juaseh, and Kemidak watersheds each surveyed 5 or more times. The lower Endau River area and the upper Kemapan, Jemai, Pukin, and Jekatih watersheds were each surveyed 2 to 4 times, and the upper Sekin, Kinchin, Emas, and Jasin watersheds were surveyed once. Additional information on the presence of rhinos along the lower Semberong, Emas, and Endau rivers was collected from villagers living there.

Rhino sign was found throughout the Endau-Rompin region, including most of the remaining contiguous primary forest habitat, about 1600 km^2 (Fig. 3). Habitat type, land-use patterns, and human disturbance were found to be the major factors restricting rhino distribution. The rhinos used most of the remaining contiguous primary

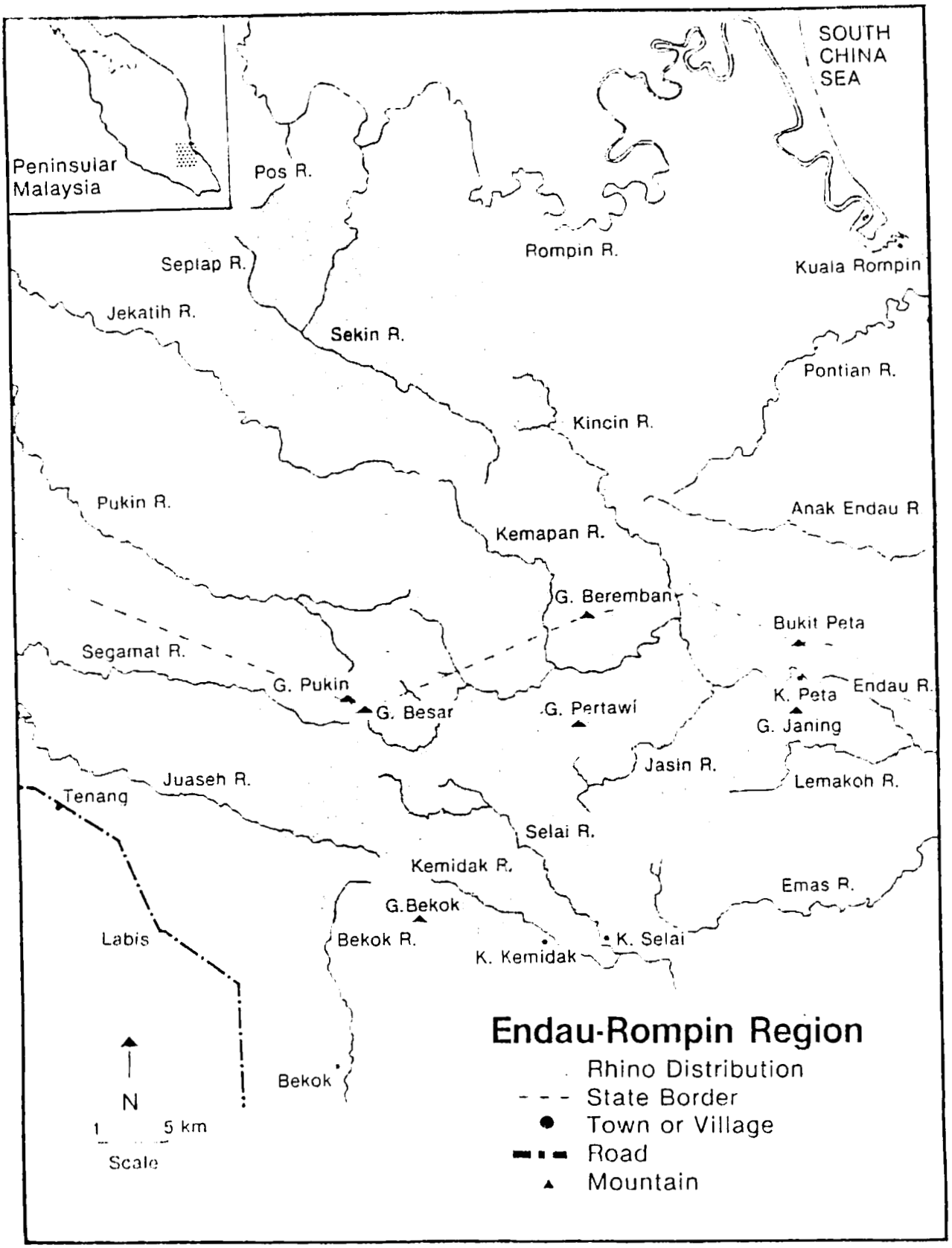

Fig. 3. Present distribution of Sumatran rhinos in the Endau-Rompin region of southern Peninsular Malaysia.

forest habitat, but they seldom moved into adjacent agricultural areas or logged forest. In general, rhino sign was not found more than 0.6 km from the primary forest fringe, and rhinos appeared to avoid areas of high human-use.

Rhino distribution was well documented in the southern and western portions of the region. Rhino sign was found during each trip into the upper watersheds of the Juaseh, Tenang, Segamat, Kemidak, and Selai rivers. Most observations of rhino sign were a considerable distance ($\bar{x}$=10 km, n=110) within the primary forest from the fringe, especially away from areas with high human use. Frequently, villagers from Kampung Juaseh and Tenang walked 4 to 6 km into the primary forest along the western boundary. This human disturbance appeared sufficient to reduce rhino use of the forest fringe. Also, hunting pressures probably have selected against animals using accessible areas. Rhino sign was seldom found in logged areas along the Endau River or in the Segamat, Pukin, Chapau, and Jemai watersheds. Repeated surveys of the Pukin-Jemai area documented changes in rhino distribution resulting from logging activity (Flynn, 1978). After logging began in 1977, rhino sign was no longer found where it had been observed previously. Surveys in 1979 and 1980 did not record rhino sign within logged areas, except within 0.6 km of the primary forest fringe.

A similar pattern of land development was observed in the southern sections. Logging has advanced rapidly along the Bekok, Selai, Emas, and Kemidak rivers from the south. In 1981, a new road was completed to Kampung Selai along the lower Selai River, greatly

improving human access to this important rhino area. All lands south of the proposed Endau-Rompin National Park boundaries have been committed to timber concessions.

Interviews with villagers living along the lower Semberong, Emas, and Endau rivers indicated that rhinos were no longer found there. Stevens (1968) reported finding rhino sign throughout this area. Now, most of the land south and east of the Emas River has been cleared for agricultural crops, and the Emas watershed has been logged extensively. Farther to the east along the Endau River near Tanah Abang, villagers reported that rhinos were no longer found anywhere along the lower Endau. Apparently, heavy poaching and logging during the 1960's eliminated these animals.

The present distribution of rhinos in the northern sections of the region was not well-documented because fewer surveys were conducted there and sign was encountered less frequently. However, my surveys recorded rhino sign in the upper Jekatih, Sekin, and Kinchin watersheds and established that rhinos occurred throughout that area. Villagers living along the Jekatih River reported that rhinos were once found throughout the entire region, but now they were restricted to the upper portions of unlogged watersheds. Much of the land within the lower Jekatih and Sekin basins has already been cleared for agricultural development; the remainder has been committed to timber concessions, primarily to Lesong Timber Products (50,000 ha). This land exploitation has resulted in a patched pattern of primary forest, logged forest, and agricultural lands. Many islands of primary forest within the logged

forest have been created, especially in hilly areas, and the amount of available habitat has been reduced. A few animals in the Seplap and Pos watersheds within the Lesong concession may have already been isolated from the main Endau-Rompin population.

In 1981, I made a brief survey of the upper Anak Endau and Pontian river basins near Gunung Lesong. A villager reported encountering rhino sign on the east slopes of this mountain during 1980. I found no evidence of rhinos occurring east of the Endau mountains. My discussions with several loggers indicated that they were not aware of any rhino reports from the region. Presently, the lowland forest is being logged by several timber companies. I doubt whether any rhinos now exist east of the Endau mountain ridge. If a few animals are presently found there, their chances for survival are poor because all of the habitat will soon be destroyed, and the threat of poaching is high.

A few reports of rhinos occurring farther to the north near the Rompin River were received from villagers living there, but I was unable to confirm these reports. Rhinos may still occur in the upper watersheds of small tributaries of the Rompin River (e.g. Aur, Keratong). However, these animals are isolated from the main Endau-Rompin population by logged forest and agricultural lands, and their chances for survival are poor.

Census Surveys

Census 1. The first census survey was conducted during 18-27 March 1977. The 4 survey teams recorded 8 sets of recent rhino tracks within the 400 km^2 study area (Fig. 4) (Table 1). Track observations 1 and 2, found within the upper Kemidak watershed, and observations 5 and 6, found in the upper Selai basin, were recognized as cow/calf pairs. Track observations 3, 4, 7, and 8 were considered to be different animals based on the distance between individual track observations (Table 2). Thus, at least 8 different rhinos were recorded on the study area during this census period. These animals consisted of 2 adult females (19.5 and 21.0 cm), 2 calves (15.0, 17.0 cm), and 4 independent sub-adults or adults (median track width = 17.5, 19.0, 19.2, 22.5 cm). Based on increasing the minimum count by 25%, the total number of animals in the study area was estimated at 10, or 1 rhino/40 km^2.

Census 2. The second census was conducted during 20-26 May 1977. The 5 survey teams recorded 7 sets of fresh rhino tracks on the study area during this census period (Fig. 5) (Table 3). Track observation 9 was considered as made by a unique animal based on the distance between track locations. The track width measurements of the remainder of the observations were not all from the same distribution (K-W ANOVA, $P<0.01$). A multiple comparison of 80% simultaneous confidence intervals for the difference in median track width indicated that track observations 9, 10, 11, 13, 14, and 15 were significantly different, but no difference was found between observations 11 and 12 (Table 4). Thus, the tracks of 6 different rhinos were found on the

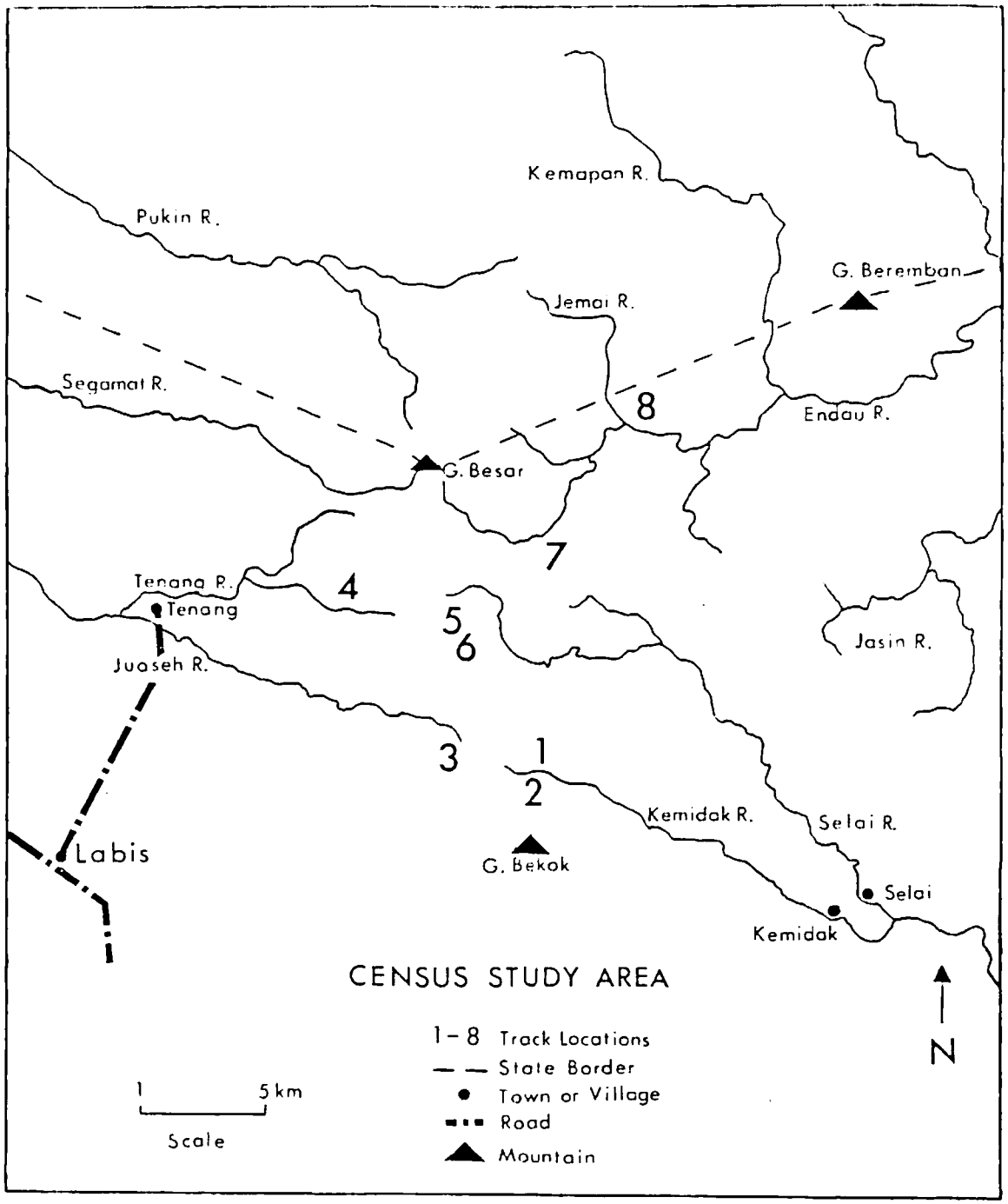

Fig. 4. Locations of Sumatran rhino track observations recorded on the census study area during Census I which was conducted from 18 to 27 March 1977.

Table 1. Sumatran rhino track observations recorded during Census I which was conducted from 18 to 27 March 1977.

Observation number	Sample size	Track width[a]	95% CI[b]
1	7	19.5	19.0-20.0
2	10	17.1	17.0-17.5
3	15	19.0	18.0-19.0
4	8	19.2	19.0-19.4
5	1	18.0	-
6	1	21.0	-
7	1	22.5	-
8	6	17.5	17.0-18.0

[a] Median track width.

[b] A 95% confidence interval for the median track width.

Table 2. Multiple comparison of track observations recorded during Census I.

Track observation	8	7	4
3	S	S	D
4	S	S	
7	S		

S = Track observation pair significantly different based on the comparison of simultaneous confidence intervals for the difference in median track width.

N = Median track width of the track observation pair not significantly different.

D = Track observation pair separated based on the linear distance between track observations (greater than 8 km).

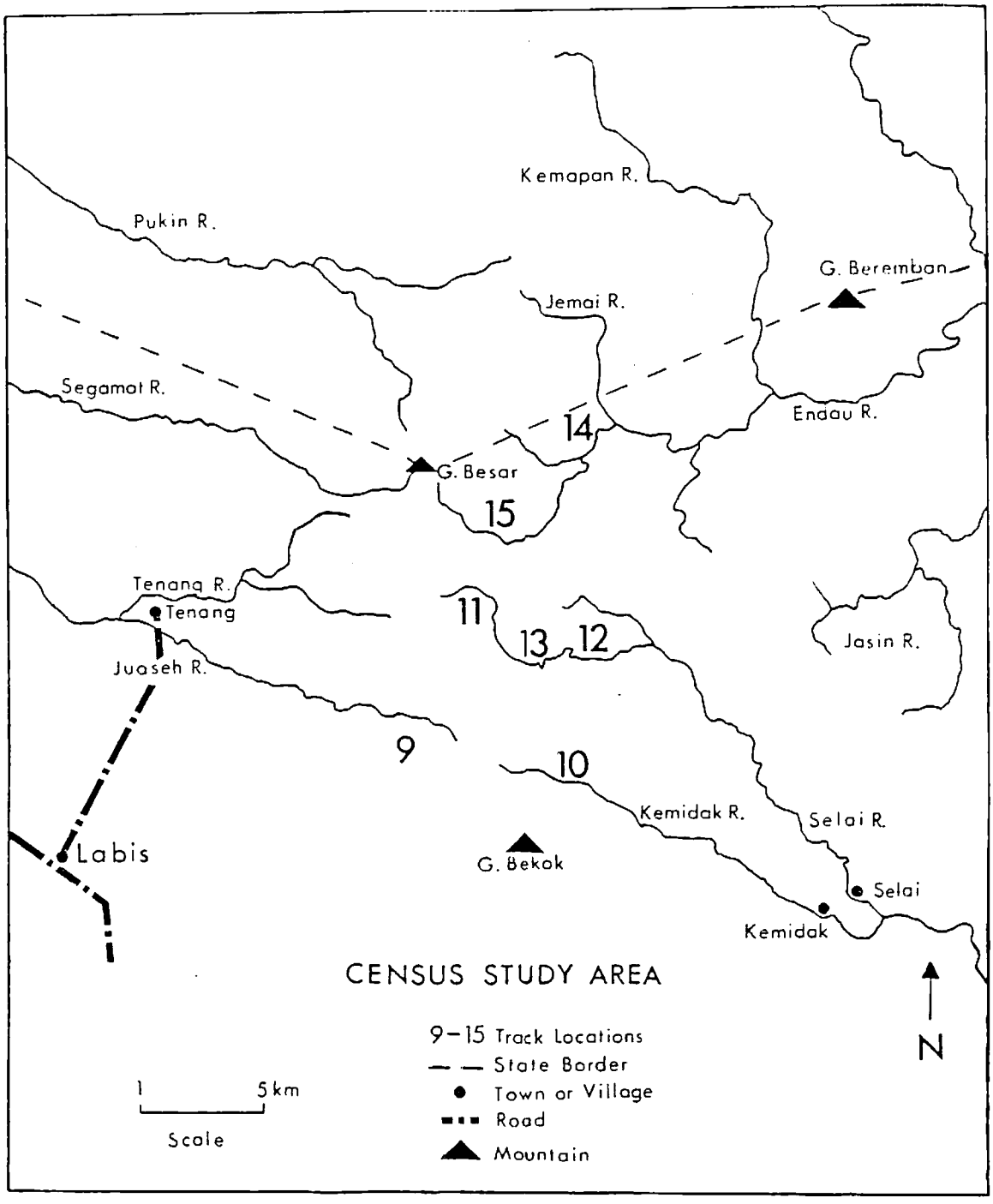

Fig. 5. Locations of Sumatran rhino track observations recorded on the census study area during Census II which was conducted from 20 to 26 May 1977.

Table 3. Sumatran rhino track observations recorded during Census II which was conducted from 20 to 26 May 1977.

Observation number	Sample size	Track width	95% CI
9	5	18.1	18.0-18.5
10	7	19.1	18.5-19.5
11	6	19.5	19.3-19.6
12	11	19.5	19.3-19.6
13	12	19.8	19.6-20.0
14	1	18.0	-
15	1	21.0	-

Key: see Table 1.

Table 4. Multiple comparison of Sumatran rhino track observations recorded during Census II.

Track observation	15	14	13	12	11	10
9	S	S	D	S	S	S
10	S	S	S	S	S	
11	S	S	S	N		
12	S	S	S			
13	S	S				
14	S					

Key: See Table 2.

study area during the census period. All of these animals were either sub-adults or adults (median track widths = 18.0, 18.1, 19.1, 19.5, 19.8, 21.0 cm). The total number of animals was estimated at 8, or 1 animal/50 km^2.

Census 3. The third census survey was conducted during 18-22 March 1979. During this census period, the 5 survey teams recorded 12 sets (Fig. 6) of recent rhino tracks (Table 5). Track observation 26 was considered as made by a unique animal based on the distance among track observations. The track width measurements of the remaining track observations were not all from the same distribution (K-W ANOVA, $P<0.01$). Significant differences were found among observations 16, 17, 18, 19, 21, 23, and 25, but no significant difference was found among observations 19, 20, and 22 or among observations 24, 25, and 27 (Table 6). Thus, the tracks of at least 8 sub-adult or adult rhinos (median track width = 18.0, 18.0, 18.4, 19.3, 19.4, 19.8, 20.4, 21.8 cm) were recorded on the study area during this census period. By increasing the minimum count by 25%, the total number of rhinos was estimated at 10, or 1 animal/40 km^2.

Census 4. The last rhino census was conducted during 10-13 September 1980. The 5 survey teams recorded 12 sets of fresh tracks on the study area during the census (Fig. 7) (Table 7). Track observations 28 and 38 were made by different animals, based on the distance between track locations. The track width measurements of the remainder of the observations did not all come from the same distribution (K-W ANOVA,

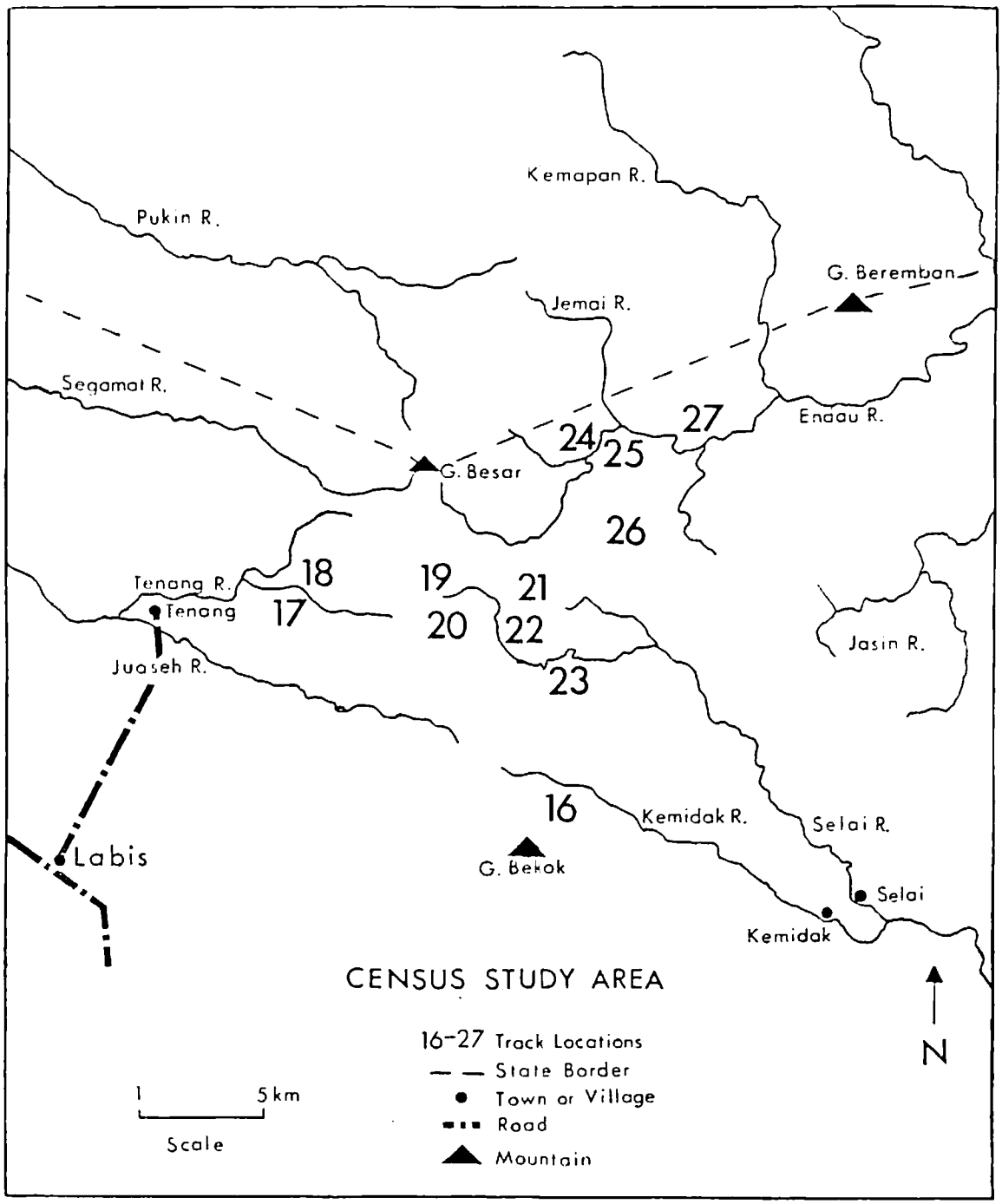

Fig. 6. Locations of Sumatran rhino track observations recorded on the census study area during Census III which was conducted from 18 to 22 March 1979.

Table 5. Sumatran rhino track observations recorded during Census III which was conducted from 18 to 22 March 1979.

Observation number	Sample size	Track width	95% CI
16	14	18.0	17.9-19.0
17	10	19.8	19.6-19.9
18	9	18.0	17.9-18.5
19	20	19.4	19.3-19.5
20	11	19.4	19.3-19.4
21	24	18.4	18.2-18.5
22	16	19.4	19.3-19.6
23	4	20.4	20.0-20.5
24	7	21.4	21.0-22.0
25	4	21.8	21.0-22.0
26	7	19.3	19.0-20.0
27	4	22.0	21.0-23.0

Key: see Table 1.

Table 6. Multiple comparison of Sumatran rhino track observations recorded during Census III.

Track observation	27	26	25	24	23	22	21	20	19	18	17
16	S	S	S	S	S	S	D	S	S	D	S
17	S	S	S	S	S	S	S	S	S	S	
18	S	S	S	S	S	S	S	S	S		
19	S	D	S	S	S	N	S	N			
20	S	D	S	S	S	N	S				
21	S	S	S	S	S	S					
22	S	D	S	S	S						
23	S	S	S	S							
24	S	S	N								
25	N	S									
26	S										

Key: See Table 2.

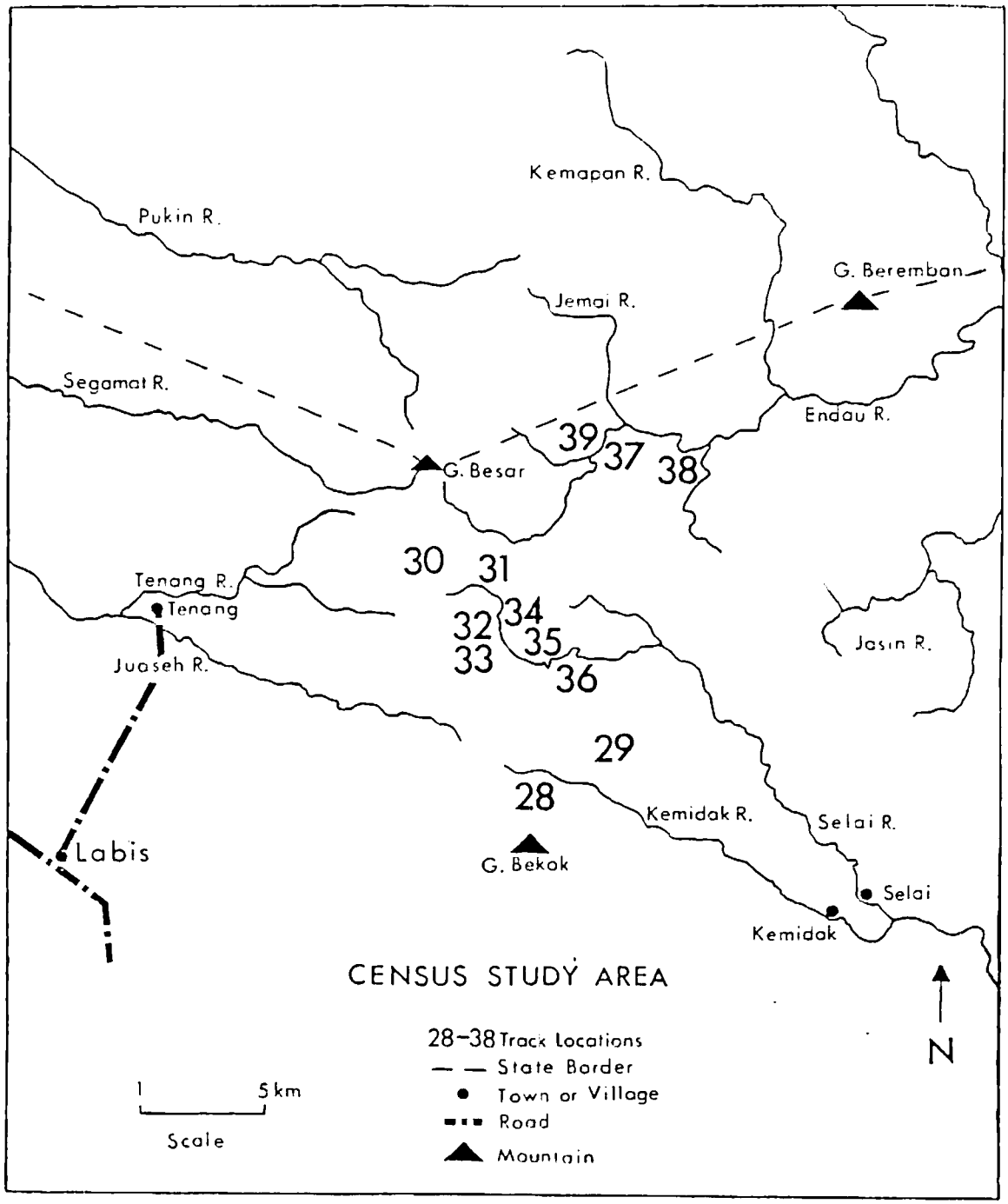

Fig. 7. Locations of Sumatran rhino track observations recorded on the census study area during Census IV which was conducted from 10 to 13 September 1980.

Table 7. Sumatran rhino track observations recorded during Census IV which was conducted from 10 to 13 September 1980.

Observation number	Sample size	Track width	95% CI
28	16	19.5	19.0-20.0
29	6	19.1	19.0-19.5
30	13	19.4	19.3-19.5
31	8	18.6	18.5-18.6
32	15	19.0	18.8-19.0
33	7	19.9	19.8-20.0
34	9	20.0	19.8-20.3
35	4	19.0	18.9-19.1
36	10	19.5	19.4-19.5
37	10	18.2	18.0-18.5
38	2	19.5	19.4-19.5
39	6	18.2	18.0-18.?

Key: See Table 1.

Table 8. Multiple comparison of Sumatran rhino track observations recorded during Census IV.

Track observation	39	38	37	36	35	34	33	32	31	30	29
28	S	D	S	D	N	S	S	S	S	D	N
29	S	D	S	S	D	S	S	D	S	D	
30	S	D	S	D	S	S	S	S	S		
31	D	S	D	S	S	S	S	S			
32	S	S	S	S	N	S	S				
33	S	S	S	S	S	N					
34	S	S	S	S	S						
35	S	S	S	S							
36	S	D	S								
37	N	S									
38	S										

Key: See Table 2.

$P<0.001$). Significant differences were found among observations 30, 31, 34, 38, and 39 (Table 8). No significant differences were found between track pairs 28 and 29; 33 and 34; or 37 and 39. Thus, the tracks of at least 8 sub-adult or adult rhinos (median track widths = 18.2, 18.6, 19.0, 19.4, 19.5, 19.5, 19.5, and 20.0 cm) were recorded. The total number of animals was estimated at 10, or 1 rhino/40 km^2.

Numbers

The number of rhinos occurring within the Endau-Rompin region was calculated by combining the number of animals estimated to occur in the high and low density areas. The number of rhinos within the 400km^2 high-density census area was estimated at 10, or 1 animal per 40 km^2. Rhino density was much lower outside of the census area, about half. I conservatively estimated rhino density within the 1200 km^2 of low-density habitat at 1 animal per 80-120 km^2. By multiplying the amount of available habitat (1200 km^2) by the estimated average density (1 animal per 80-120 km^2), the number of rhinos within the low-density area was estimated at 10 to 15. Combining these estimates yielded a total number of 20 to 25 rhinos occurring in the Endau-Rompin region.

Population Characteristics

During 1975-1981, the tracks of 3 young rhinos were recorded in the region for an annual total recruitment rate of 0.5 young per year. In September 1975, the tracks of a cow/calf pair were first observed in the upper Selai area. The tracks of this pair were encountered in the Selai-Endau area during the next 2.5 years. The

March 1977 census survey recorded the tracks of this pair and a second cow/calf pair in the upper Juaseh-Kemidak area. Beginning in February 1981, villagers reported a cow/calf pair in the upper Juaseh-Kemidak watershed. The presence of this pair was confirmed by track observations in March and June 1981.

All other track observations were of independent sub-adults or adults. Insufficient information existed to further separate animals into age classes based on track size. I suspected that the range in track size of adults was quite large. Track width measurements of known adult females varied from 19.5 to 21.0 cm. I found no evidence of sexual differences in track size; an adult female had one of the largest track widths (median = 21.0 cm).

One rhino death was recorded during this study. In September 1976, the skeleton of a rhino was found in the upper Selai watershed in a wallow. Apparently, this animal had died while near or in the wallow of undetermined causes. Skull wear patterns on the teeth indicated that this animal was quite old. No other deaths were recorded, but evidence of mortality was difficult to find.

DISCUSSION

Track Characteristics

I found that the locations and sizes of tracks were useful in documenting Sumatran rhino distribution and estimating numbers. These

animals have toenails that make clear impressions in the soil and the maximum width between the lateral toes of these tracks can be measured accurately. This measurement is useful in distinguishing individual animals. Only hindfoot tracks can be easily measured because these rhinos usually place their hindfoot on top of the forefoot print. Measurements from several tracks of a series were required for the use of statistical procedures in the data analysis.

Many of the frequency distributions of a set of track-width measurements appeared skewed even though statistical tests failed to detect any departures from normality. Sumatran rhinos have considerable flexibility in the movement of their toes. While ascending steep terrain, they tend to pull their toenails inward for a better grip on the hillside. Likewise, they spread their toes in a braking motion while decending. Tracks made in soft soil tend to be expanded, usually 2 to 5 mm. A large sample of track measurements provides a better estimate of location in a data set. Track measurement distributions of rhinos walking on firm soil in flat terrain with sample sizes greater than 10 were approximately normally distributed. Often this set of conditions cannot be met, and I concluded that nonparametric statistical procedures were appropriate for analyzing track data. The Kruskal-Wallis ANOVA in combination with simultaneous confidence intervals for the difference between medians was found to be a useful procedure for analyzing the data collected from census surveys.

Several problems were encountered with the census procedures developed for this study. The method required that several people with

experience in measuring rhino tracks were availble to lead the survey teams. Some of the data collected by inexperienced groups were difficult to interpert because of small sample sizes, confusion in species identification, or a mixture of measurements from fore and hind foot prints. Travel through the forest was often difficult, and groups often made slow progress or covered their routes inadequately. Weather conditions have a major effect on the ability to detect tracks because heavy rainfall completely washes out tracks. The census periods must occur during a relatively dry period, preferably during January to March. The small range in adult track size (5 cm) limits the number of individuals that can be identified based only on track-width measurements. If the adult rhino population exceeds about 10 individuals, the utility of the census method declines and alternative methods will need to be developed.

Distribution

Sumatran rhinos were once found throughout southern Peninsular Malaysia, although little historical information is available. During recent years, their distribution within the region has been greatly reduced by poaching and habitat destruction. Stevens (1968) reported that rhinos were found in the Endau-Rompin, Gunung Belumut, and Mersing Coast areas. A recent survey of the country (Flynn and Abdullah, 1983) confirmed the presence of rhinos in only the Endau-Rompin and Gunung Belumut areas, but the Mersing area was not searched.

My general survey of the Endau-Rompin region has documented that rhinos presently use about 1600 km^2 of primary forest habitat.

Since 1967, rhinos have disappeared from several areas. I found no evidence of rhinos along the lower Emas and Semberong rivers where Stevens (1968) proposed the creation of a rhino sanctuary. Also, rhinos were no longer reported from the Tersap and Tanah Abang areas along the lower Endau River. Land-use patterns and human disturbance appeared to restrict rhino distribution. Rhino sign was found most frequently in areas of low human use. Along the western boundary, rhino sign was seldom observed in places where villagers collect jungle products. A reduction in rhino distribution in the Pukin-Jekatih area was observed. As the forest was logged or clear-felled, the rhinos retreated farther into the primary forest. During a 1980 survey of the Jemai and Pukin watersheds, rhino sign was not found even though logging activity had stopped over 2 years ago.

Numbers

The Endau-Rompin region contains the largest contiguous Sumatran rhino population remaining in Malaysia. Based on the results of the survey and census work, I estimate that 20-25 animals occur there. The Taman Negara (8-12) and the Sungai Dusun (4-6) areas contain the next largest rhino populations remaining in the country (Flynn and Abdullah, 1983). Rhino density in the Endau-Rompin region was quite variable, depending on the section. The census study area contained the highest density of animals, about 1 animal per 40 km^2. In areas to the north and east, rhino sign was observed less frequently. The differences in density probably reflect habitat preference and the amount of human disturbance. The census study area contains mostly hill

forest above 300 m (Flynn, in prep.). The northern and eastern sections contain mostly lowland forest; much of this area has been subjected to high levels of human disturbance.

World wide, only the Gunung Leuser Reserve in northern Sumatra contains a larger number of Sumatran rhinos. Borner (1978) estimated that 20 to 40 rhinos occur in this vast mountainous region. After Endau-Rompin, the Silabukan area in Sabah, East Malaysia, probably contains the next largest group (8-10) of rhinos (Flynn, 1981). Insufficient data exist to accurately estimate the number of Sumatran rhinos remaining in the world, however present evidence (Van Strien, 1974; McNeely and Laurie, 1977; Borner, 1978; Schenkel and Schenkel, 1979; Payne, 1980; Van Strien, pers. comm.; Flynn, 1981; Flynn and Abdullah, 1983) suggests that the total number is less than 300. Thus, the Endau-Rompin region contains a significant proportion (5-10%) of the total individuals of this species.

Population Trends

The observation of cow/calf pairs in 1975, 1977, and 1981 indicated that reproduction was still occurring in the Endau-Rompin rhino population. The tracks of cow/calf pairs were observed only in the census study area, particularly within the Selai, Endau, Juaseh, and Kemidak watersheds. The average annual recruitment rate for the entire population was calculated at 0.5 young per year. This extremely low recruitment rate is probably insufficient to sustain a population.

In general, tracks of young rhinos have seldom been reported. Hubback (1939) found tracks of young animals only 3 times during many

years of tracking rhinos. The Sungai Dusun Wildlife Reserve was the only other area in Peninsular Malaysia where tracks of young animals were reported during the study period (Flynn and Abdullah, 1983). Borner (1978) reported finding the tracks of 5 different cow/calf pairs in the Gunung Leuser Reserve from 1972 to 1975 for an average annual recruitment rate of 1.6 young per year. The reproductive rate in the Gunung Leuser area is substantially higher than Endau-Rompin. Apparently, the higher reproductive rate in the Gunung Leuser area is reflective of the higher population numbers.

Only limited information was collected on rhino mortality. At least 1 animal died during the study period, but the cause of death was unconfirmed. No positive evidence of poaching was found, but information on poachers was difficult to obtain. In 1976, I found serveral foot-snares set for rhinos along the middle Endau River near the mouth of the Kemapan River. These snares were probably set by villagers living along the lower Endau River. The field surveys functioned as an effective patrol program and discouraged poaching activity. At each village visited, I emphasized that rhino hunting was illegal and entry into the rhino area was restricted.

Conservation

The Endau-Rompin region has the most potential for maintaining a viable population of Sumatran rhinos in Malaysia, and conservation efforts for the species should be concentrated there. My work has shown that Endau-Rompin contains the largest, and possibly the only reproductively viable, population of rhinos remaining in the country. A

large proportion of the region has been proposed for national park status which would protect the habitat from exploitation. Recent research has found numerous food plants available in the habitat (Flynn, in prep.).

A sound conservation program must contain short and long-term strategies. In the short-term, all remaining animals must be protected from poaching and their habitat protected. Habitat protection should be a primary priority of a conservation program. Unless a large tract of contiguous primary forest habitat is maintained, the survival of a viable rhino population is doubtful. The proposed Endau-Rompin National Park Management Plan (Flynn, 1980) recommends that 870 km^2 of the region be established as a national park. Within the park area, high-use rhino areas would be zoned to reduce the impact of human visitation. According to this plan, the proposed park would contain about 65% of the presently occupied rhino habitat. The balance of the rhino area, including most of the high-value commercial timber, has already been committed to timber concessions. Also, this plan recommends that a forested buffer zone, 15 to 20 km wide, be maintained around the Park to reduce the impact of agricultural development and human disturbance. The buffer zone would be managed by the Department of Forestry, in consultation with the DWNP, for sustained-yield timber production.

The exploitation of lands outside of the park area will conflict with rhino conservation. These lands will be logged or cleared for agricultural development. In the west, all lands containing primary forest within the state of Johor should be included within the proposed

park. The logging of this key rhino area will reduce the amount of habitat and greatly increase the impact of human disturbance. Lesong Timber Products has the timber rights to 500 km^2 of rhino habitat in the northwest portion of the region. This block of forest will be logged during the next 25 to 35 years. As this logging proceeds, the disturbance will have a negative impact on several animals. The rhino population will become fragmented as animals are isolated in patches of unlogged habitat. By logging the western sections of the concession area first, the negative impact on the rhinos may be reduced. Important rhino habitat adjacent to the proposed park boundary in the upper Sekin and Jekatih watersheds should be logged last. The maintenance of a system of corridors, composed of unlogged habitat, connecting patches of primary forest may reduce the fragmentation of the rhino population.

Development of the 200 km^2 Selanchar Complex oil palm plantation in the Pukin River basin will have a major impact on the rhinos. The early stages of this project by the Federal Land Development Authority (FELDA) has already destroyed critical rhino habitat. This plantation intrudes deeply into key rhino habitat along the Pukin River and threatens to further fragment this population. In addition, the project will attract an estimated 10,000 settlers or workers, exposing these rhinos to poaching and human disturbance. Presently, a hard-surfaced highway is being built along the Pukin River on land that was used by rhinos in 1977. I strongly recommend that the last stages (Schemes 7 and 8) of the Selanchar Project remain uncompleted, and all infrastructural development (town, roads, etc.) be

located at least 15 km from the Endau-Rompin National Park boundary.

All efforts must be made to prevent the killing of rhinos because population numbers are critically low. Presently, the Sumatran rhino is classified as a totally protected species under the 'Wildlife Act of 1972'. Penalties for the killing or possession of totally protected species are a maximum fine of US$1200 and/or 2 years in jail (Anonymous, 1972). However, these penalties are inadequate for the prevention of poaching and should be increased. The high price of rhino body parts, especially the horn, provides a strong incentive for rhino poaching. Martin (1979) found the average price of Asiatic rhino horn in 4 Asian countries to range in price from US$ 3000 to 11,000 per kg. In order to discourage poaching, the DWNP must regularly patrol the rhino areas. The ranger patrols should be concentrated along the forest fringe near the main access points. The construction of guard posts near the ends of access roads is needed to discourage human entry. A comprehensive protection program is outlined in the Endau-Rompin Management Plan (Flynn, 1980).

Presently, the number of rhinos may be below a minimum size required for maintenance of the population. Even within favorable habitat, small animal populations can be extinguished because of stochastic perturbations (Shaffer, 1981). The low recruitment rate indicates that this population is already near a minimum number necessary for reproduction. For improved reproductive success, the number of potential breeding individuals needs to be increased. This could be accomplished by capturing those animals in areas with extremely

low numbers or insecure habitat, and releasing them in the Endau-Rompin area. Also, an introduction of new animals into the population would increase genetic variability, reducing the negative impact of inbreeding depression (Franklin, 1980). An effective population size of at least 50 individuals has been proposed as the minimum population size necessary for maintaining short-term fitness in most species (Soule, 1980).

The rhino research program should be continued on a long-term basis. The census surveys should be conducted at regular intervals (annually) to monitor population trends. The monitoring of recruitment rates is probably more important than attempting to estimate total numbers. The survey work in the northern and eastern sections should be expanded to better document present rhino distribution. In particular, the Lesong concession should be closely studied to monitor the impact of logging on the rhinos. The long-term impact of habitat modification by logging on rhino habitat-use needs more study. The food and habitat requirements of this animal should be studied extensively to gather additional insights into its ecological relationships. Otherwise, this rare and unique species may disappear before we have learned much about it.

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REFERENCES

Anonymous. (1972). Protection of wildlife act, 1972. Laws of Malaysia, Act 76. Kuala Lumpur, Government Printing Office.

Borner, M. (1978). A field study of the Sumatran rhinoceros. Ph.D. thesis, Univ. Basel, Switzerland.

Bourliere, M. (1969). The estimation of higher vertebrate numbers in tropical forest environments. An. Acad. Brasil. Cienc., 41(Supp.), 23-28.

Burton, C. (1973). Mesozoic. In The geology of the Malay peninsula, ed. by D. Gorbett and C. Hutchison. New York, John Wiley and Sons.

Campbell, R. (1967). Statistics for biologists. Cambridge, Cambridge Univ. Press.

Dale, W. (1959). The rainfall of Malaya. J. Trop. Geogr., 13, 23-37.

_____. (1963). Surface temperatures in Malaya. J. Trop. Geogr., 17, 52-71.

Ellis, D. (1971). Rhinos in northern Johor, Malaysia. Singapore, The Malayan Nature Society. (Unpublished report).

Flynn, R. (1978). The Sumatran rhinoceros in the Endau-Rompin National Park of Peninsular Malaysia. Malay. Nat., 4, 5-12.

_____. (1980). Endau-Rompin National Park management plan. Kuala Lumpur, Malaysia, Department of Wildlife and National Parks.

_____. (1981). Sumatran rhinos in the Silabukan area of Sabah. Kuala Lumpur, World Wildlife Fund. (Unpublished).

_____. (in prep.). Feeding ecology of the Sumatran rhinoceros in southern Peninsular Malaysia.

_____. and M. Tajuddin Abdullah. (1983). The distribution and status of the Sumatran rhinoceros in Peninsular Malaysia. Biol. Conserv., in press.

Foenander, E. C. (1952). Big game of Malaya. London, Batchworth Press.

_____. (1961). The occurrence of rhinoceros in Pekan District, Pahang. Kuala Lumpur, Department of Wildlife and National Parks. (Unpublished report).

Forest Department. (1977). Forest resources of Peninsular Malaysia. Kuala Lumpur, Department of Forestry.

Franklin, I. R. (1980). Evolutionary change in small populations. In Conservation biology: An evolutionary-ecological perspective, ed. by M. Soule and B. Wilcox, 135-150. Sunderland, Mass., Sinauer Assoc.

Gibbons, J. (1976). Nonparametric methods for quantitative analysis. New York, Holt, Rinehart, and Winston.

Gobbett, D. and C. Hutchison. (1973). Eds. The geology of the Malay peninsula. New York, John Wiley and Sons.

Groves, C. P. (1967). On the rhinoceros of Southeast Asia. Saugetierk. Mitt., 15, 221-237.

Gyekis, K. (1966). Segamat District. Forest Reconnaissance Survey. For. Res. Inst. Rep. No. 7., Kepong, Selangor.

Hislop, J. (1965). Rhinoceros and Seladang. Malaysia's vanishing species. IUCN Publ. N. S., 10, 278-283.

Hubback, T. (1939). The Asiatic two-horned rhinoceros. J. Mammal., 20, 1-20.

Lee, P. C. (1966). A forest reconnisance of Rompin District, Pahang. For. Res. Inst. Rep. No. 3., Kepong, Selangor.

Martin, E. B. (1979). The international trade in rhinoceros products. Gland, Switzerland, WWF/IUCN.

McNeely, J. and A. Laurie. (1977). Rhinos in Thailand. Oryx 13, 486-489.

Milton, O. (1963). Field notes on wildlife conservation in Malaya. Spec. Pub. No. 16, American Committee for International Wildlife Protection.

Nie, J., Hull, J. Jenkins, K. Steinbrenner, and D. Bent. 1975. Statistical package for the social sciences. New York, McGraw-Hill.

Ott, L. 1977. An introduction to statistical methods and data analysis. North Scituate, Mass., Duxbury Press.

Payne, J. (1980). Report on rhinoceros in the Silabukan Forest Reserve, Sabah. Sandakan, Sabah Forest Dep. (Unpublished report).

Poore, M. (1963). Problems in the classification of tropical rain forest. J. Trop. Geogr., 17, 12-19.

Richards, P. (1952). The tropical rain forest. Cambridge, Cambridge Univ. Press.

Schenkel, R. and L. Schenkel-Hulliger. (1969). The Javan rhinoceros in Udjung Kulon Nature Reserve. Its ecology and behavior. Acta Trop. (Basel) 26, 97-135.

_____. and L. Schenkel (1979). Report from the SSC Asian rhino group meeting in Bangkok, Thailand. Gland, Switzerland, IUCN/WWF. (Unpublished report).

Shaffer, M. L. (1981). Minimum population sizes for species conservation. Bioscience 31, 131-134.

Simon, N. ed. (1969). Red data book, Mammalia. Gland, Switzerland, IUCN/WWF.

Smallwood, H. A. (1966). Schematic-reconnaissance soil survey of the Segamat-Gemas-Tangkak region of north Johor. Malay. Soil Survey Rep. Kuala Lumpur, Malaysia, Dep. Agric.

Sokal, R. and F. J. Rohlf. 1969. Biometry. San Fransico, W. H. Freeman and Co.

Soule, M. E. (1980). Thresholds for survival: maintaining fitness and evolutionary potential. In Conservation biology: An evolutionary-ecological perspective, ed. by M. Soule and B. Wilcox, 151-170. Sunderland, Mass., Sinauer Assoc.

Stevens, W. E. (1968). The conservation of wildlife in West Malaysia. Kuala Lumpur, Malaysia, Department of Wildlife and National Parks.

Strickland, D. (1967). Ecology of the rhinoceros in Malaya. Malay. Nat. J., 20, 1-17.

Talbot, L. (1960). A look at threatened species. Oryx 5, 153-293.

Van Strien, N. (1974). The Sumatran or two-horned Asiatic rhinoceros. A study of the literature. Meded. Landbouwhogeschool Wageningen, 74-16.

_____. (1979). On the difference in the footprints of the Javan and Sumatran rhinoceros. Tiger Paper, 7, 16-19.

Whitmore, T. C. (1975). Tropical rain forests of the Far East. Oxford, Claredon Press.

Wyatt-Smith, J. (1964). A preliminary vegetation map of Malaya with descriptions of the vegetation types. J. Trop. Geogr., 18, 200-213.