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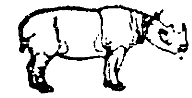

Dicerorhinus Sumatrensis

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Distribution and number of Sumatran rhinoceros in the Endau-Rompin region of Peninsular Malaysia

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Abstract. Distribution of the Sumatran rhinoceros in the Endau-Rompin region of southern Peninsular Malaysia was studied from 1975 to 1981. We collected information from a general field survey and interviews with people living near rhino areas. We 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. We 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. We 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

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through Bu... ...insula, and the Sunda islands of Suma... , Van Strien 1974). Recent surveys have shown that ... ...natran ...ino is now restricted to small scattered populations occurring in Burma (Schenkel & Schenkel 1979), Thailand (McNeely & Laurie 1977), Peninsular Malaysia (Flynn & Abdullah, unpubl. data), Sumatra (Bomer 1978; Van Strien, pers. comm.), and Borneo (Schenkel & 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, we discovered that the Endau-Rompin region, located in the southern part of Mainland Peninsular Malaysia, contained the country's largest remaining rhino population (Flynn & Abdullah, unpubl. data). In this paper, we 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 cannot 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 mainland Peninsular Malaysia, 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 & 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 1973). The region's soils are quite variable depending on the underlying parent material, but are generally of poor quality. 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 forest types (Wyatt-Smith 1964; Forest Department 1977). The majority of the Endau-Rompin region is covered with mixed lowland dip-

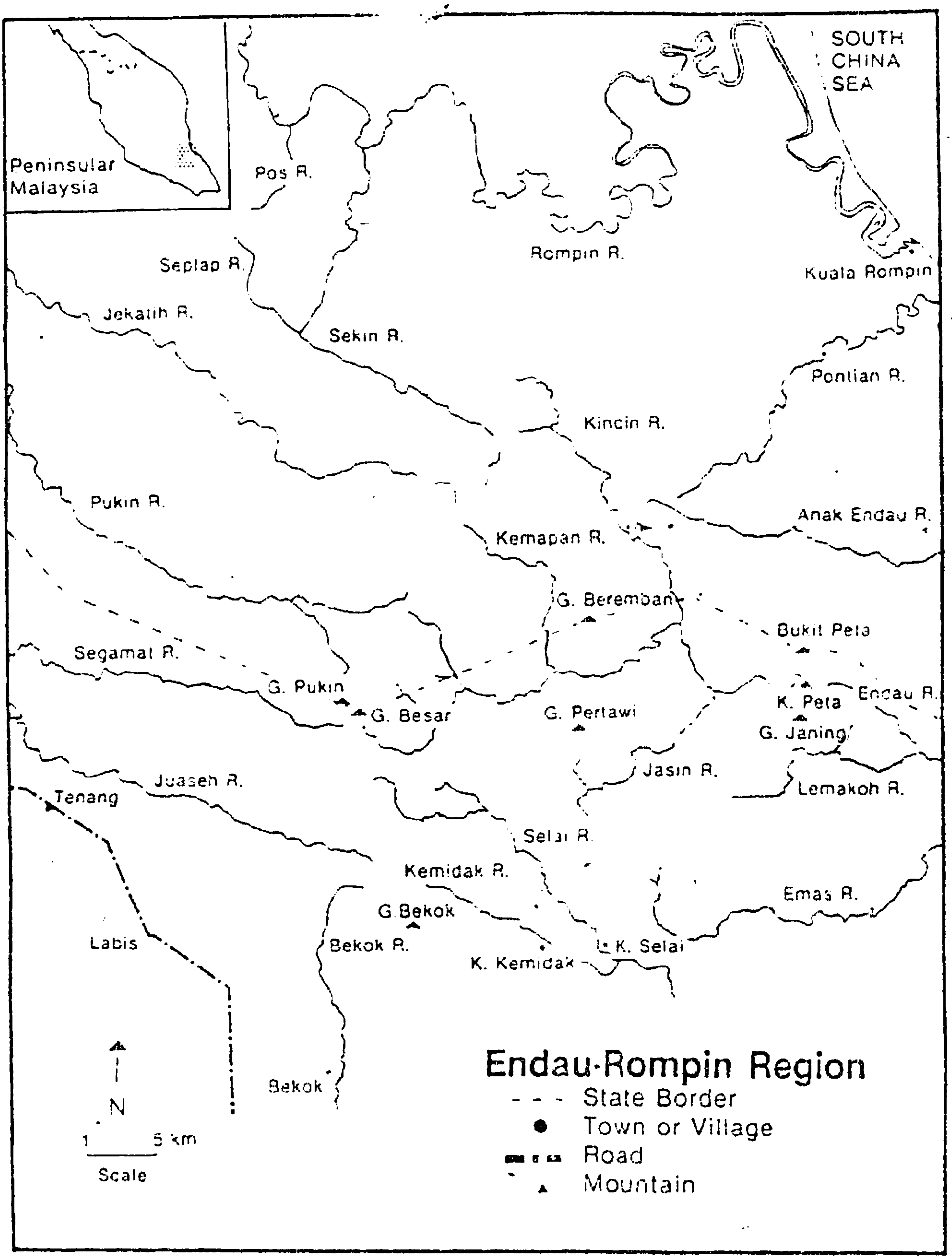

Figure 1. Map of the Endau-Rompin region, located in southern Peninsular Malaysia, showing places mentioned in the text.

terocarp 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 Juasch, Kemidak, Tenang, Selai, Segamat, Endau, Pukin, and Jemai rivers (Fig. 2). The remainder 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 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 Juasch, 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 us 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.

We concentrated our survey efforts in areas where rhino sign had been reported frequently. Thus, the general rhino survey was started in the Juasch-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.

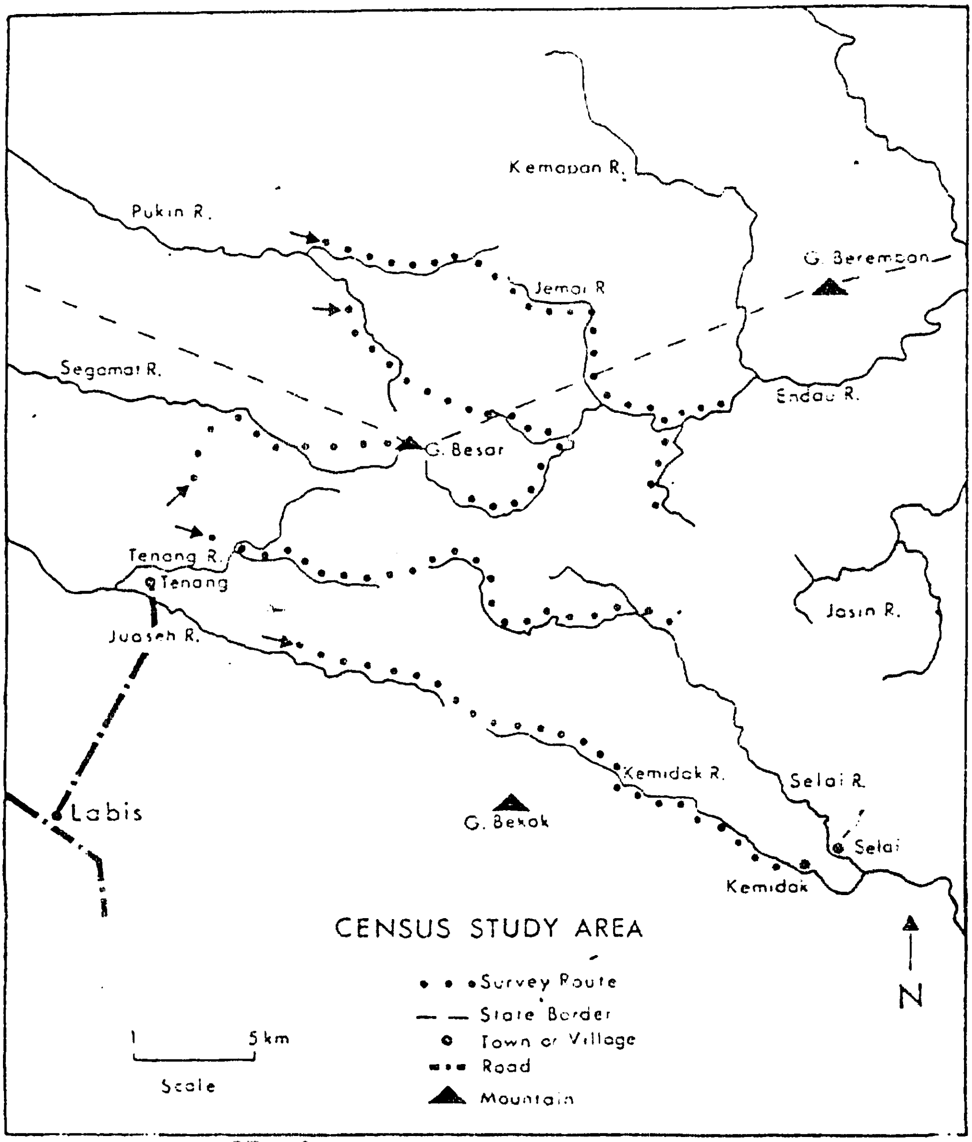

Figure 2. Map of the census study area which is located in the Endau-Rompin region of southern Peninsular Malaysia. The census survey routes are indicated by dotted lines, with the starting points marked by arrows.

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 millimetre 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 occuring in the high-density census area was estimated using methods similar to those developed by Schenkel & Schenkel-Hulliger (1969) for censusing the Javan rhino *(Rhinoceros sondaicus)* 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). Our initial surveys showed that rhino tracks were found most often along small streams because the animals use stream bottom habitat frequently (Flynn, unpubl. data) 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 (average 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 asumption 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 we concluded that the track distributions had been made by different animals. Other multiple comparison procedures were examined (Sokal & 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 $2 < X_{0.5} < 4$ 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. We 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 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

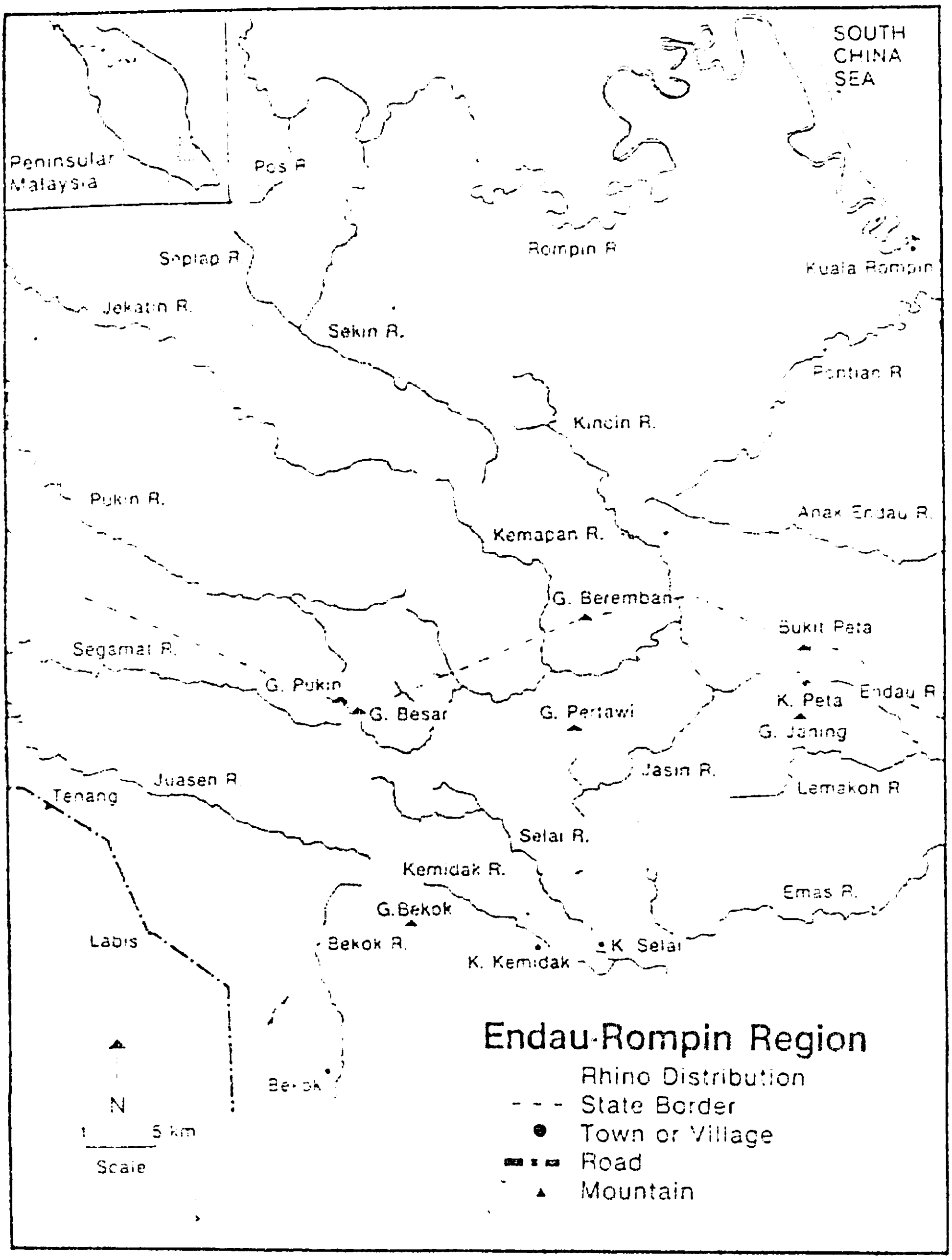

Figure 3. Present distribution of Sumatran rhinos in the Endau-Rompin region of southern Peninsular Malaysia.

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 had 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, our 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, we 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. We found no evidence of rhinos occurring east of the Endau mountains. Our 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. We 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 we were 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 (median track width 19.5 and 21.0 cm), 2 calves (median track width 15.0 and 17.0 cm), and 4 independent sub-adults or adults (median track width 17.5, 19.0, 19.2 and 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 study area during the census period. All of these animals were either sub-adults or adults (median track width 18.0, 18.1, 19.1, 19.5, 19.8 and 21.0 cm). The total number of animals was estimated at 8, or 1 animal/50 km^2.

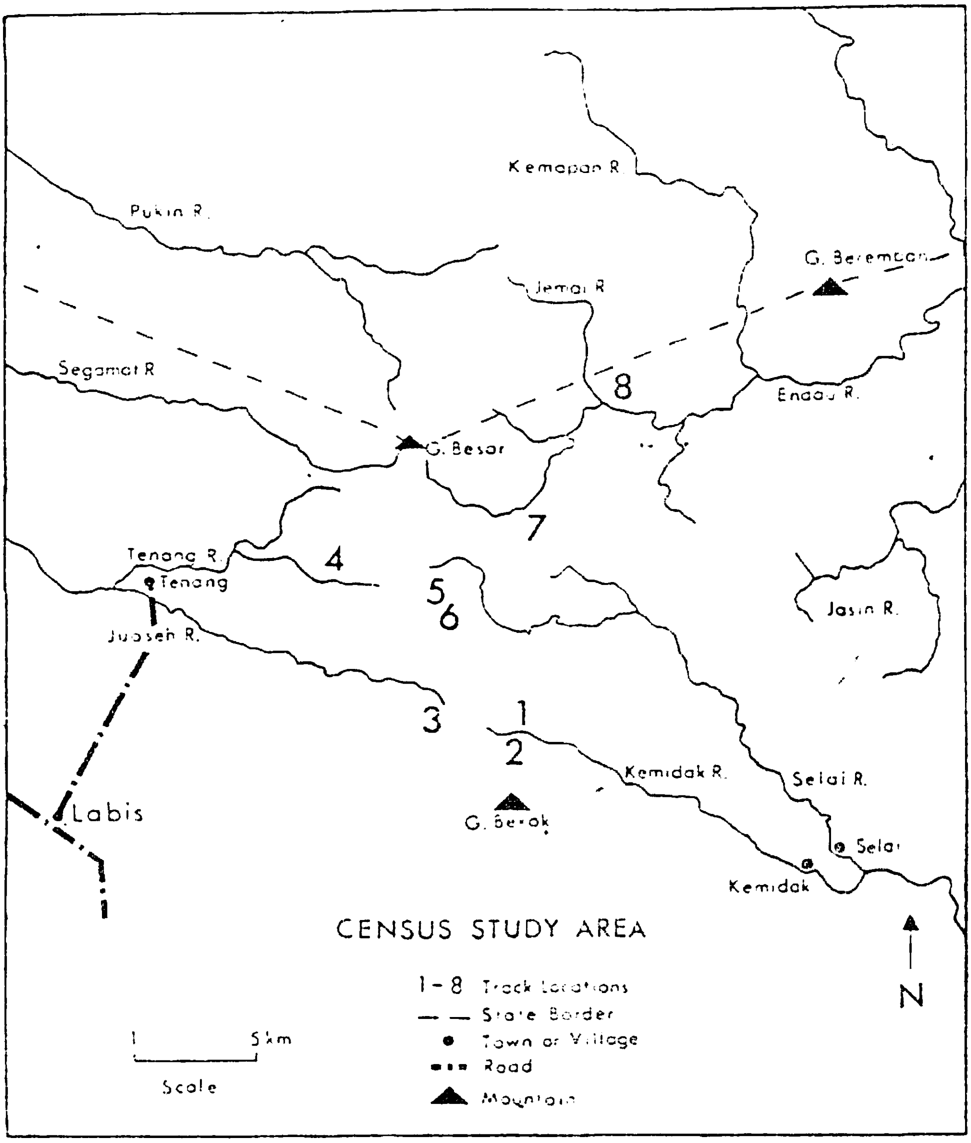

Figure 4. Locations of Sumatran rhino track observations recorded on the census study area during Census I which was conducted from 18 – 27 March 1977.

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

Observation number	Sample size	Track width[1]	95% CI[2]
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

[1] Median track witdh.

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

Table 2. *Multiple comparison of track observations recorded during Census 1.*

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).

Table 3. *Sumatran rhino track observations recorded during Census 2 which was conducted from 20 – 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.

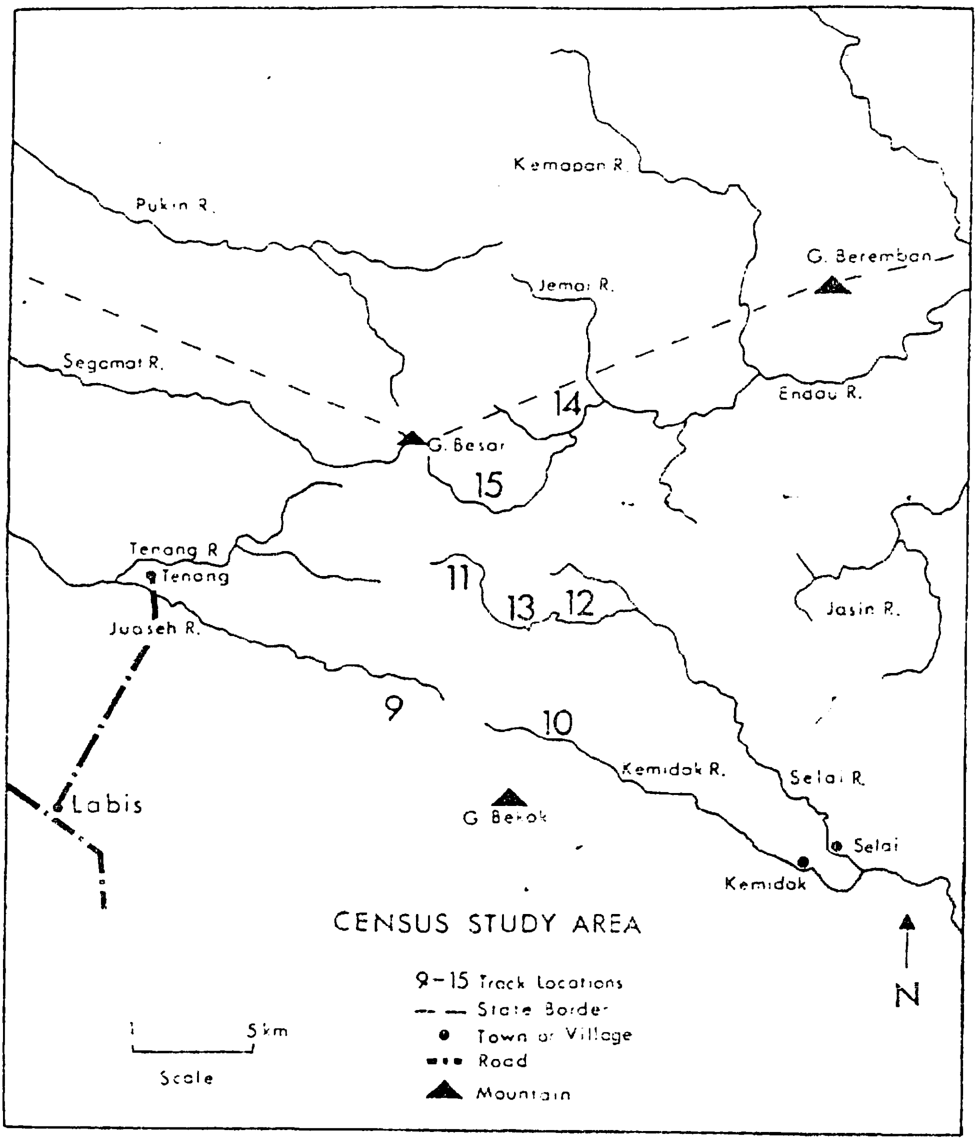

Figure 5. Locations of Sumatran rhino track observations recorded on the census study area during Census 2 which was conduced from 20 – 26 May 1977.

Table 4. *Multiple comparison of Sumatran rhino track observations recorded during Census 2.*

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.

Census 3. The third census survey was conducted during 18 – 22 March 1979. During this census period, the 5 survey teams recorded 12 sets of recent rhino tracks (Fig. 6; 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 and 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, $P < 0.001$). 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 width 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.

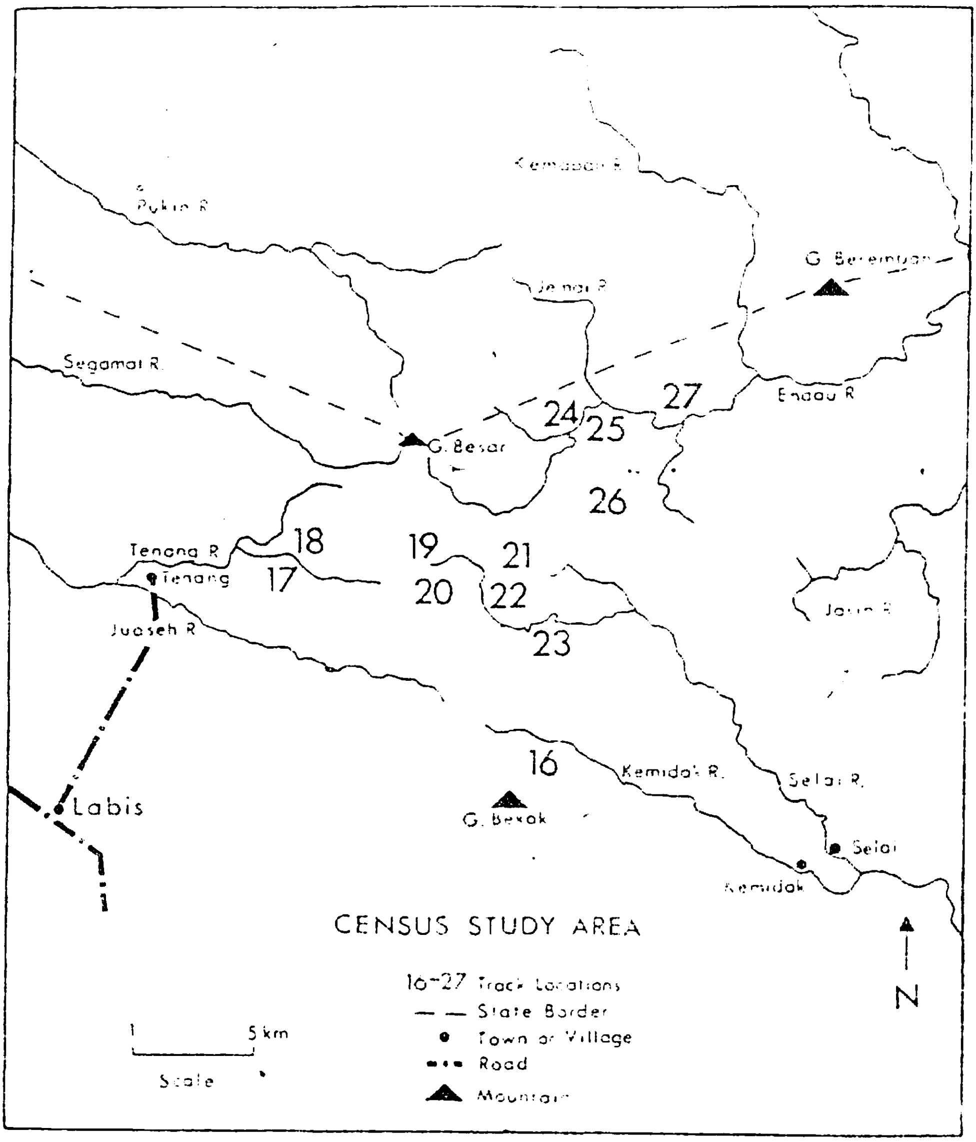

Figure 6. Locations of Sumatran rhino track observations recorded on the census study area during Census 3 which was conducted from 18 – 22 March 1979.

Table 5. *Sumatran rhino track observations recorded during Census 3 which was conducted from 18 – 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. 3.*

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.

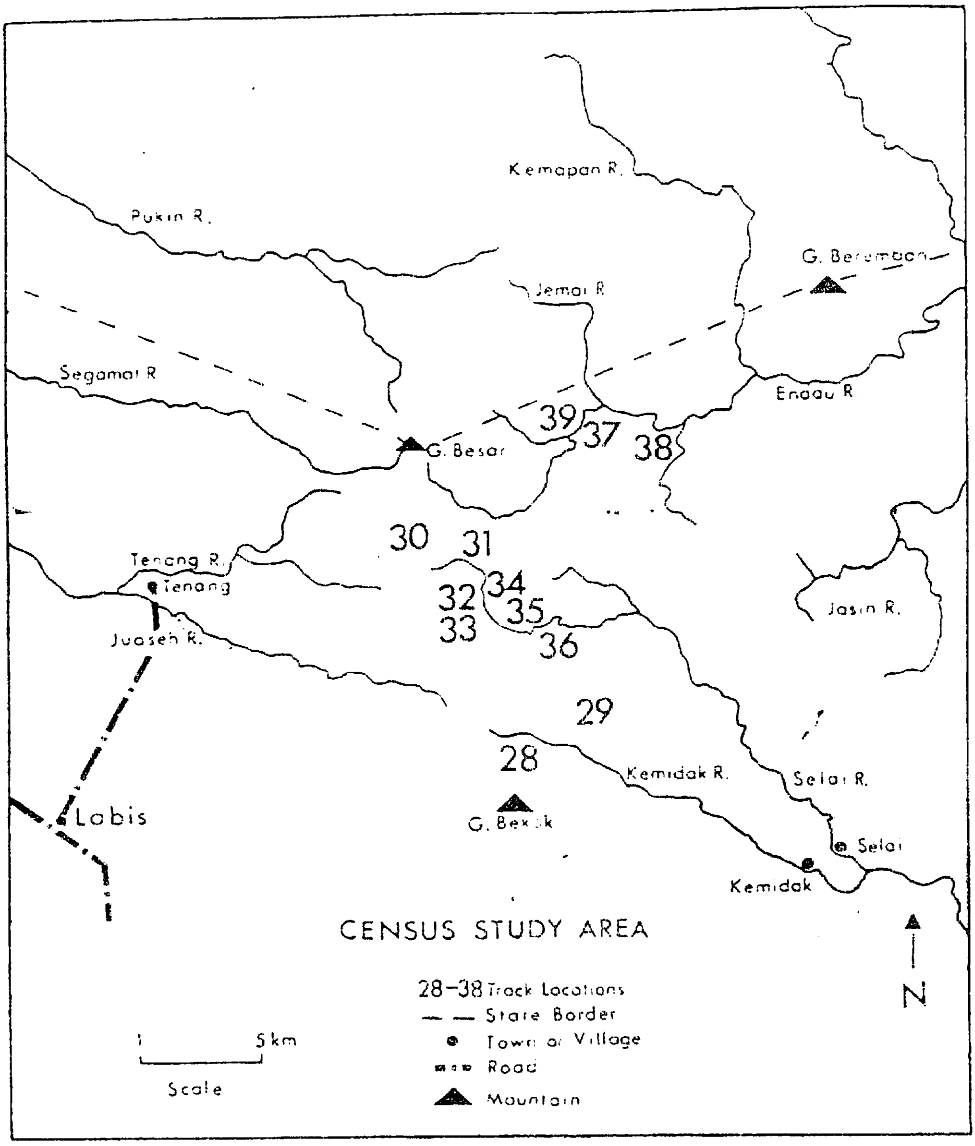

Figure 7. Locations of Sumatran rhino track observations recorded on the census study area during Census 4 which was conducted from 10 – 13 September 1980.

Table 7. *Sumatran rhino track observations recorded during Census 4 which was conducted from 10 – 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 – 18.2

Key: See Table 1.

Table 8. *Multiple comparison of Sumatran rhino track observations recorded during Census 4.*

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	S	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.

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 400 km^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. We 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 Juasch-Kemidah area. Beginning in February 1981, villagers reported a cow/calf pair in the upper Juasch-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. We 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. We 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

We 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 step 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 descending. 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 we 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 available to lead the survey teams. Some of the data collected by inexperienced groups were difficult to interpret 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 & Abdullah, unpubl. data.) confirmed the presence of rhinos in only the Endau-Rompin and Gunung Belumut areas, but the Mersing area was not searched.

Our 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. We 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, we 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 & Abdullah, unpubl. data.). 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. 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 & Laurie 1977; Borner 1978; Schenkel & Schenkel 1979; Payne 1980; Van Strien, pers. comm.; Flynn 1981; Flynn & Abdullah, unpubl. data.) 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 & Abdullah, unpubl. data.). 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 number.

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, we found several foot-snares set for rhinos along the middle Endau River near the mouth of the Kempan 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, we emphasised 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. Our 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, unpubl. data.).

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 km² 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. We 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 M$3,000 (US$1,200) 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$3,000 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 favourable 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 number 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 rhinos 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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