

NICO J. VAN STRIEN

The Sumatran Rhinoceros  
*Dicerorhinus sumatrensis* (Fischer, 1814)  
in the Gunung Leuser National Park  
Sumatra, Indonesia

*Its Distribution, Ecology and Conservation*

With 92 figures in the text and on 7 plates  
and 1 map of 'The Upper Mamas Study Area  
and the Patrol Network'



1986

VERLAG PAUL PAREY · HAMBURG UND BERLIN

## MAMMALIA DEPICTA

Eine Schriftenreihe, herausgegeben von Prof. Dr. Dr. h.c. WOLF HERRE, Kiel, Neue Universität,  
und Prof. Dr. MANFRED RÖHRS, Zoologisches Institut der Tierärztlichen Hochschule Hannover

## BEIHEFTE ZUR ZEITSCHRIFT FÜR SÄUGETIERKUNDE

Heft 12

## CIP-Kurztitelaufnahme der Deutschen Bibliothek

Strien, Nico J. van:

The Sumatran rhinoceros - *Dicerorhinus sumatrensis*  
(Fischer, 1814) - in the Gunung Leuser National  
Park, Sumatra, Indonesia: its distribution, ecology,  
and conservation / Nico J. van Strien. -  
Hamburg ; Berlin : Parey, 1986.  
(Mammalia depicta ; 12)  
ISBN 3-490-11118-4

NE: GT

Frontispiece: Adult male Sumatran Rhinoceros, caught November 1985 in Sumatra

This work is subject to copyright. All rights are reserved, whether the whole or part of the materials is concerned, specifically those rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilm or in other ways, and storage in data banks. Duplication of this publication or parts thereof is only permitted under the provisions of the German Copyright Law of September 9, 1965, in its version of June 24, 1985, and a copyright fee must always be paid. Violations fall under the prosecution act of the German Copyright Law.

© 1986 Verlag Paul Parey, Hamburg and Berlin. Addresses: Spitalerstr. 12, D-2000 Hamburg 1; Lindenstr. 44-47, D-1000 Berlin 61. Printed in Germany by Offsetdruck D. H. Siegmund, Hamburg.  
Cover design: Jan Buchholz and Reni Hirsch, Hamburg.

ISBN 3-490-11118-4 · ISSN 0301-2778

## CONTENTS

1 - INTRODUCTION	1
1.1 Aims of the study	1
1.2 Initiation of the study	4
1.3 Execution of the programme	4
1.4 Previous research	5
2 - THE STUDY AREA AND GENERAL METHODS	7
2.1 Selection and establishment of the study area	7
2.2 Organization of the expeditions	8
2.3 Description of the study area	9
2.3.1 The Gunung Leuser National Park	9
2.3.2 Physiography of the study area	9
2.3.3 Climate and weather in the study area	13
2.3.4 Plant cover of the study area	15
2.3.5 The other mammal fauna	16
2.4 The patrolling system	18
3 - THE STUDY OF THE RHINO'S TRACKS	19
3.1 Morphology of the rhino's foot	19
3.2 The art of plastercast making	24
3.2.1 Finding the tracks	25
3.2.2 Selection of the prints	25
3.2.3 Preparation of the selected prints	26
3.2.4 The casting	26
3.2.5 Preservation of the casts	27
3.3 Aids for comparison of the casts	27
3.3.1 The stereophotographs	28
3.3.2 The outline drawings	28
3.3.3 The standard measurements	28
3.4 Procedure of the sorting and identification of the casts	31
3.5 Characteristics and variability shown in the casts	34
3.5.1 General characteristics	34
3.5.2 Influence of the soil	35
3.5.3 Influence of the type of movement	43
3.5.4 Gradual changes in size and shape	48
3.6 An illustrative example	57
3.6.1 Formation of an exemplary series	57
3.6.2 Comparison with other series	58
3.7 Final results of the plastercast identification	73
3.8 Evaluation of the method of plastercast analysis	73
3.9 Recommendations for future use	75
4 - GROWTH AND AGING	76
4.1 Growth of the foot of the calf	76
4.2 Age classes	81
4.3 Sex classes and sexual differentiation in footprint	82
5 - DISTRIBUTION AND DENSITY	84
5.1 Distribution of the age and sex classes	84
5.1.1 Distribution of the females and their calves	84
5.1.2 Distribution of the sub-adults	90
5.1.3 Distribution of the males and other adults	90
5.1.4 The overall distribution pattern	92

5.2	Analysis of the individual ranges	97		
5.2.1	Female home ranges	97		
5.2.2	Home range of the calves after weaning	99		
5.2.3	Home range of the other sub-adults	99		
5.2.4	Male home range	100		
5.3	Density of the rhino in the study area	105		
5.3.1	Density calculations based on distribution	105		
5.3.2	Density calculated from the number of individuals per expedition	107		
5.3.3	Density calculated from the number of direct observations	108		
5.4	Comparative occurrence in parts of the area	110		
5.4.1	Counts of fresh tracks	110		
5.4.2	Frequency of use of the game trails	111		
5.4.3	Comparison of different areas	113		
5.5	Other methods to record the use of the trails	114		
5.6	Frequency of visits to the saltlicks	114		
6	- THE LIFE CYCLE	116		
6.1	The sex ratio of the population	116		
6.2	The mating system	116		
6.3	Birth of the young	117		
6.4	The breeding interval	118		
6.5	Development of the calf	119		
6.6	The sub-adult phase	119		
7	- DAILY ACTIVITIES OF THE RHINO	121		
7.1	The system of trails	121		
7.2	The daily movements	122		
7.3	Wallows and wallowing	125		
7.3.1	Location and form of the wallows	125		
7.3.2	Pattern of use of the wallows	127		
7.4	Marks and marking behaviour	127		
7.5	Faeces and defaecation	129		
7.6	Urine and urination	132		
8	- FEEDING AND THE MINERAL BALANCE	133		
8.1	The food	133		
8.2	Availability of food	134		
8.3	The mineral balance	135		
8.3.1	Mineral contents of the foodplants	135		
8.3.2	Mineral contents of the saltlicks	137		
9	- SUMMARY AND EVALUATION OF RESULTS	139		
10	- RECOMMENDATIONS FOR FUTURE STUDIES	142		
10.1	Plastercast in comparison to print measurements	142		
10.2	Usefulness of different measurements for censussing rhino populations	147		
10.3	Track counts for estimating rhino density	151		
10.4	Censussing rhino	152		
10.5	Recommendations for further ecological study	153		
11	- CONSERVATION OF THE SUMATRAN RHINO	154		
11.1	The chances for survival	154		
11.2	Design and management of rhino reserves	156		
11.3	A strategy for survival of the Sumatran rhino	157		
			APPENDIX A: Hoofs of Sumatran rhino	159
			APPENDIX B: Present status of the Sumatran rhino	167
			B.1 The situation in Sumatra	167
			B.2 The situation in Borneo	171
			B.3 The situation in Malaysia	172
			B.4 The situation in other countries	172
			B.5 Summary of the present status of the Sumatran rhino	173
			APPENDIX C: Rhino poaching in the Gunung Leuser reserve	175
			ACKNOWLEDGEMENTS	178
			REFERENCES	179
			PLATES	183
			SAMENVATTING	195
			RINGKASAN	198

## CHAPTER 1 - INTRODUCTION

### 1.1 - Aims of the study.

At present the world is seeing an exponential increase in numbers, together with a rapid increase in the per capita usage of matter and energy, of several taxa in the genus *Homo*, modern man. The taxa that show this technology-induced population explosion, rapidly increase the land area they occupy and the share of the world's primary production that they consume, at the expense of other species and races that cannot cope with this pressure on space and natural resources. The most notable victims of this development are other human taxa, those that do not share in the technology which increases individual survival rate, together with an ever increasing number of other non-human creatures.

Increasingly a great number of species, that once occupied large tracts of the world, are being driven out of their usual haunts by human invaders and survive only in very small numbers in isolated and often less attractive areas. Several species have already lost their last strongholds and have disappeared, many are vulnerable or endangered, while only a few can thrive in the environments created by technology-using man, who now controls most of the world's surface.

But a small section of the human population has realized that man's increasing reliance on technology and manipulation of his environment may lead to catastrophe, threatening not only a large part of the existing forms of life, but also endangering the continued existence and development of human kind and of the whole complex of life on this planet. Conservationists try to stress the environmental impact of technological developments and promote measures to alleviate their influence. One of the more successful concepts promoted by the conservation movement is the creation of nature reserves, land areas set aside by their governing bodies to protect the natural habitat and its natural ecosystems. In these areas a variety of life forms that have survived so far will have a chance for continued existence until we achieve a more balanced sharing of space and resources with coexistence of a multiplicity of creatures, human and non-human.

Throughout the world reserves are created for this purpose and, with varying success, managed by the competent organisations in a way that will give the biota protection against being eliminated by uncontrolled human invasion. But although these reserved or restricted areas nowhere occupy more than a tiny part of the area to which the human population claims exclusive rights, it is becoming more and more difficult to honour the pledge to leave them in a largely natural state. In large parts of the world the human population has increased its numbers and consumption to, or beyond, the sustainable level increasing the pressure on those few untapped resources and unsettled lands that remain.

Unless human population growth is curbed drastically, the space and resources available for the other animal species on this planet will diminish further, leaving ever smaller populations in more and more isolated areas. The first creatures to suffer are the large land animals, who need relatively large areas for their natural way of life. Several have already disappeared and many more are now surviving only in small remnant populations, often in marginal habitats.

Large areas of natural habitat, where animals and plants can survive in natural balance, will become rarer and rarer, and in many parts of the world such areas no longer exist. Conservation will have to deal more and more with populations of animals and plants that are in themselves so small, or confined to such an inadequate environment, that their long-term survival is unlikely.

Conservationists will have to continue and ever increase their efforts in the years ahead. Much can be done by protection of adequate samples of the world's ecosystems in nature reserves, but some species will need additional aid if they are not to become extinct. Some will be difficult to contain in a restricted area; others may be subject to specific threats, even in protected areas. The Sumatran rhinoceros (*Dicerorhinus sumatrensis* (Fischer, 1814)) appears to be one of those animals for which the protection of its habitat alone is not sufficient.

The Sumatran rhino is now one of the rarest and most threatened mammals, not only because of the disappearance of a large part of its habitat, but more so because of the age-long persecution for its horn and other marketable parts, that fetch high prices in several parts of Asia. This trade has caused the rhino to disappear from most of the remaining rainforest areas in its former distribution. The precarious situation of this species is well illustrated in figure 1.1, showing the known historical and present distributions. Once the animal occurred in mountainous regions from Sumatra and Borneo to the foothills of the Himalayas in Bhutan, now it is only found in small numbers at a few remote and isolated locations. Even if adequate samples of habitat can be preserved, additional measures will be necessary to protect the rhinos inside the reserve from poachers.

The Sumatran rhino is of special interest because it is the largest mammal dependant on undisturbed rainforest and as such it can be regarded as an important indicator species. Its presence indicates that the area is relatively very little disturbed and in the design of reserves meant to preserve the whole Southeast Asian fauna the habitat requirements and population structure of the Sumatran rhino should be one of the major considerations. Size and shape of the reserves should be such that they give maximum protection to a sufficient number of those species which need a large home range, have a low density and are most susceptible to disturbance in any form, and the Sumatran rhino is a typical example of such an animal.

In general one can state that a reserve that suits the needs of the Sumatran rhino and where the management can protect it against poaching, will also suffice for the smaller species that utilise the same habitat. The preservation of the Southeast Asian rainforests is closely linked to the well-being of the Sumatran rhino. Although the habits of the Sumatran rhino are poorly known, this study was initiated not only for academic interest but to test the notion that management practices can only be effective if they take into account the biology of the species they are supposed to protect. The Gunung Leuser National Park was chosen as a study site because it was the only area known at that time to harbour more than a few scattered rhinos and because there was a good basis for research there in the form of existing facilities and available literature and expertise.

The Sumatran rhinoceros was, and still is, one of the least studied and least known mammals, because of its elusive character, its rarity and the inhospitable nature of its habitat. Prior to this study very little was known about the distribution, the general life-history and habitat requirements of this species, and the available data were mainly based on fortuitous observations (van Strien, 1974). It was a major aim of this study to collect long-term systematic data which would help us to evolve a strategy to protect this species in Gunung Leuser and elsewhere.

Primarily information on distribution and numbers, habitat requirements, diet, reproduction, behaviour and social organisation were needed, but because the proposed study area was virtually unexplored and very little was known about the nature and extent of the rhino population, the study programme had to be kept very general and unspecific. In fact every aspect of the rhino's way of life was open for study, but we were limited in our observations by the difficult terrain and by luck in encountering animals. During surveys additional information on other larger mammals was also collected.

The first priority was to find and develop a study area that was accessible yet free from human disturbance. This involved penetrating the unexplored interior of the reserve, where rhino hunters and other people had not previously been. This had to be done without endangering the few surviving rhinos. The study area also needed to be large enough to overlap the ranges of a number of rhinos and cover as much as possible of the ecological variation in the rhino's habitat.

Previous field research on the Sumatran rhino had shown that direct observation of the animal is almost impossible in the dense tropical forests and the study of indirect evidence is often the only feasible procedure (Strickland, 1967; Kurt, 1970; Borner, 1973, 1974). Tracks and footprints are the most obvious signs of the rhino's passing, and it is impossible to attempt a field study of these animals without concentrating mainly on their tracks. Previous research programmes have attempted to identify individual rhinos on the size of their footprints, but the results were not very satisfactory, because the methods were too crude to identify more than a few individuals with certainty. Therefore one of the main aims of this study was to develop better ways to study the rhino's tracks, so that individual rhinos could be identified from their tracks.

Once the rhinos could be identified with reasonable certainty in this way, their movements could be followed in space and time and patterns of distribution and density could be established. Eventually it should be possible to determine age and sex classes which would give insight into the social structure of the population. Where young accompanying a female could be identified information on the breeding system could be collected. Moreover mapping of the individual tracks would reveal some of the daily activities of the rhino. Without a good technique for recognition of individual rhinos however, the study would not be able to provide much new or useful information. Therefore much attention was given to the development of a technique, involving plastercasts of rhino tracks, and the majority of the data presented in this study is directly or indirectly based on the analysis of the rhinos' footprints.

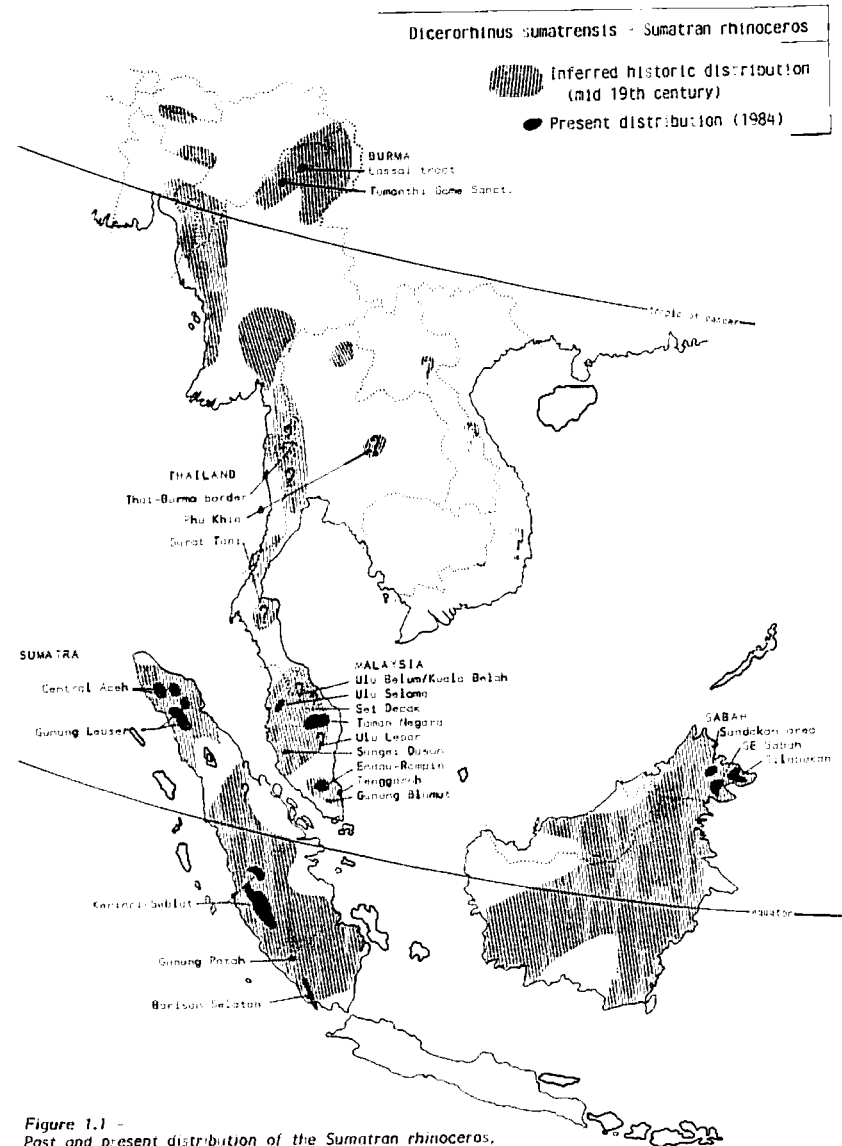


Figure 1.1 - Past and present distribution of the Sumatran rhinoceros, based on records in the literature.  
Sources - Historic distribution: van Strien, 1974; Rookmaker, 1977; Rookmaker, 1980. (the occurrence in the Indochinese region is doubtful)  
Present distribution: Recent reports and personal information. See appendix B.

Radio-tagging of Sumatran rhino was not considered for several reasons. Firstly, the risks of injury or loss of animals during darting and immobilisation were considered to be unacceptable for a species that is in such a perilous position. Also the setting up and manning of a capture operation would cause considerable disturbance in the rhino area. Secondly, it was felt, certainly in the later stages of the study when the first results of the track analysis were available, that radio-tagging would not give more or better results. Moreover with track analysis the distribution of all rhinos in the area can be studied simultaneously, while with radio tagging only a few, if any, can be followed, usually for a limited period. Thirdly, the use of radio-tags requires regular hire of aircraft, which would have increased the costs enormously.

## 1.2 - Initiation of the study

At the 10th General Assembly (1969, New Delhi) of the International Union for Conservation of Nature and Natural Resources (IUCN), the Indonesian delegation invited the World Wildlife Fund (WWF) and IUCN to carry out a preliminary investigation in the Gunung Leuser Nature Reserve in northern Sumatra, aimed at collecting basic ecological data on the fauna and the main threats to the reserve, and formulating future management practices and a research programme. This preliminary survey was carried out in 1970 by Dr. Fred Kurt, then lecturer at Zurich University, and Mr. Walman Sinaga, current head of the Indonesian Nature Conservation and Wildlife Management Division.

One of the recommendations of the survey was to initiate ecological studies of the Sumatran rhinoceros and other animals. This recommendation was followed by a proposal in August 1972 to IUCN/WWF, accepted under no. 884/1972 C/1/55.1 Sumatran Rhinoceros International Conservation Programme, for a long term rhinoceros research project in the Gunung Leuser Reserve. This project consisted of two parts, an extensive programme, to investigate the distribution of the rhino over the whole of Sumatra, and a more intensive and detailed study of the animal's ecology in the core-area of its distribution in Gunung Leuser.

The intensive programme was implemented as a cooperative venture between IUCN/WWF, undertaken by the Gunung Leuser Committee and the Nature Conservation Department of the Agricultural University of Wageningen, then under the direction of Prof. Dr. M.F. Mörzer Bruyns. Funds were applied for from various sources and the author was requested to carry out the field work for a doctoral dissertation.

Because of scepticism with regard to the feasibility of a field study of an animal that was notably rare and shy and that was almost impossible to observe, it was difficult to find sufficient funds. Only in 1974, after several organizations, companies and persons had expressed their confidence by donating small sums for the project (see the acknowledgements), a research grant was obtained from the Netherlands Foundation for the Advancement of Tropical Research (WOTRO), and a fellowship at the Department of Nature Conservation was granted from the Agricultural University of Wageningen, the Netherlands.

The extensive part of the project, a broader survey to determine the distribution of the rhino in Sumatra was conducted by a Swiss zoologist, Marcus Bömer, funded by WWF. He worked from 1972 till 1975 in Sumatra and published his results in a thesis in 1979: A field Study of the Sumatran Rhinoceros, *Dicerorhinus sumatrensis* Fisher, 1814. Ecology and Behaviour Conservation Situation in Sumatra. Juris, Zürich.

## 1.3 - Execution of the programme

After arrival in Sumatra in December 1974, I made three preliminary expeditions into the interior of the reserve with a botanical survey under the guidance of Dr. W. J. J. O. de Wilde and Dr. B. E. E. de Wilde - Duyffjes from the National Herbarium at Leiden, the Netherlands. During these trips we visited some of the highest mountains in the reserve (Gunung (mount) Bandahara, Gunung Leuser, and Gunung Mamas) and I gained much valuable experience in travelling, living and working in the Sumatran mountain forests.

In July 1975 I made my first rhino expedition to the area that had been selected for the study, the upper Mamas valley. This area was found to be suitable, because it is relatively undisturbed rhino habitat, and over the next four years 16 more expeditions were made to this area. Until December 1977 work on the study was basically full time, although considerable time was spent on other activities related to the management of the reserve and WWF's activities there. From January 1978 till August 1979 the study was continued on a part time basis while the author was employed by WWF for the drafting and implementation of a management plan for the Gunung Leuser National Park. After that date the author was appointed lecturer of biology at the School of Environmental Conservation Management at Ciawi, Indonesia, but was able to return to the Mamas for another expedition in September 1980. Results were written-up in after-work hours.

The last expedition in 1980 was joined by Popen S. Abdullah, student of biology of the Universitas Nasional in Jakarta, who made two more trips to the Mamas study area in 1981 under WWF project 1907 - Indonesia, Gunung Leuser, Rhino command - to check on anti-poaching activities and to collect additional data on the rhino.

## 1.4 - Previous research

Before leaving for Sumatra in December 1974, the author reviewed the most important literature on the Sumatran rhinoceros as a temporary assistant of the Department of Nature Conservation. A detailed review was published in 1974: *Dicerorhinus sumatrensis* (Fischer), The Sumatran or two-horned Asiatic Rhinoceros. A study of literature. Mededelingen Landbouwhogeschool Wageningen 74-16, pp 82. (also published as: Mededelingen Nederlandse Commissie voor International Natuurbescherming no 23, 1975). Since this publication covers the field in some depth, here only a brief summary will be given of some of the more pertinent references.

The Sumatran rhinoceros or Asiatic two-horned rhinoceros - *Dicerorhinus sumatrensis* (Fischer, 1814) - is the smallest of the five living species of rhinoceros. It occurred from the foothills of the Himalayas in Bhutan, through Burma, Thailand and Malaya to Sumatra and Borneo. Its occurrence in the Indo-Chinese countries cannot be confirmed (Rookmaker, 1980). It is characterized by the presence of two horns on the snout and two deep skinfolds encircling the body between the legs and the trunk. It is about 120-135 cm high at the shoulder and can weigh up to 1000 kilograms or so. The skin is dark and covered with short stiff hairs. The animal's eyesight is poor, but the senses of smell and hearing are very acute. It is usually silent, but sometimes makes soft low noises and when alarmed it snorts or barks. Single young are born at long intervals. Adult size is reached in about three years.

The Sumatran rhino is only found in dense forest, mainly in mountainous or hilly areas, but has also been recorded from low coastal swamps, and even swimming out in sea. Sumatran rhinos are usually solitary, but occasionally small groups of two or more are reported. The animals are great wanderers, capable of covering long distances apparently not deterred by thickets, thorns and steep slopes. They track around in a vast territory, occasionally wandering far out of their usual feeding grounds. Where they are common the rhinos maintain an extensive network of trails. They are most active during the night and rest during the hot hours of the day.

The Sumatran rhino swims freely and takes regular mudbaths, often in special wallows that are shaped by the frequent use. They are regular visitors to saltlicks. They are browsers and feed on leaves and stems of a great number of shrubs and trees, often pushing over trees to reach the crown. Occasionally fallen fruits are taken. Dung is often deposited in streams and occasionally in communal dung heaps. The males and females spray urine backwards onto the vegetation to scent mark. They often break and twist saplings along the trails.

This summarizes the knowledge about the biology of the Sumatran rhino before the recent fieldstudies (van Strien, 1974). The animal had been relatively rare for the last century, only to be found in difficult terrain in remote areas. Most of the information on its habits was derived from reports on accidental encounters with a rhino and from a few naturalists and hunters who developed a special interest in this animal.

The first author to write more than a few casual remarks about his own observations of the habits of the Sumatran rhinoceros, was Major G.E. Evans (1905). He recounts his experiences from many unsuccessful rhino hunts, adding other information and local tales. Ten years later G.C. Shortridge (1915) described his experiences from tracking and hunting rhino in a short paper. Some remarks from another rhino hunter, Mr. Mackenzie, are published by R.C. Wroughton and W.M. Davidson (1918).

In the thirties two more elaborate reports from rhino hunters were published. In 1935 W.S. Thom published an article in which he gives a detailed account of his observations on the habits of the Sumatran rhino in Burma, gathered during many years of rhino hunting. An even more important paper was published in 1939 by T.R. Hobbick, who tracked rhino for many years in Malaya. This paper contains a wealth of information, systematically arranged and entirely based on his own observations. All these reports were published in the Journal of the Bombay Natural History Society.

For a long time these reports were the only ones based on detailed personal observations of the Sumatran rhinoceros in the wild. They contain much valuable information, but very little of it is quantitative and it is often difficult to separate the author's own observations from repeated anecdotes and opinions from other sources. By the time Hobbick's and Thom's papers were published the rhino had become very rare and in the following decades very little first-hand information on its habits and whereabouts became available.

The first scientists to collect more up-to-date information on the Sumatran rhino were Lee M. Talbot (1960), who visited the South Sumatra reserve and other locations in Asia for the Fauna Preservation Society in 1955 and Oliver Milton (1964), who visited some locations in

Sumatra for the World Wildlife Fund in 1963. The latter also visited Gunung Leuser, but, since he only traveled along the road from Kutacane to Blangkejeren, was not able to ascertain the status of the rhino in the Leuser reserve. In 1969 Rudolf Schenkel and Lotte Schenkel-Hulliger made the same trip to gather information on the rhino, again for World Wildlife Fund (Schenkel & Schenkel-Hulliger, 1969).

In 1970 Fred Kurt was contracted by WWF to do a more thorough survey, together with Walman Sinaga of the Indonesian Nature Conservation Division, of the status of the rhino and other animals in the Gunung Leuser reserve. They made several trips into the fringe areas of the reserve, and collected much valuable information. His reports (Kurt, 1970, 1973) led to the instigation of this study.

In the meantime David L. Strickland had made the first attempt at a systematic field-study of the ecology of the Sumatran rhinoceros, during ten months in 1965/66 in the Sungai Dusun reserve in Malaysia. He followed and measured tracks, mapped movements and collected samples of foodplants. From the size of the tracks he was able to identify individuals and make a rough map of the total ranges of three rhinos (Strickland, 1967).

In 1972 Marcus Börner started a three year fieldstudy in the Gunung Leuser reserve, the results of which were published in a thesis (Börner, 1979). Besides a survey of the status of the rhino in the whole of Sumatra, he gives detailed descriptions of many aspects of the rhino's life, deduced from signs found in the field, concentrating on behavioural aspects of the feeding, defaecation, urination, tree-twisting etc. Again he used track measurements to distinguish between individual rhinos.

In 1975 Rodney W. Flynn began a fieldstudy of the Sumatran rhino in the Endau-Rompin area in West Malaysia, together with Mohd. Tajuddin Abdullah. The study concentrated on distribution and density and on aspects of foodchoice. A paper on the distribution, also using track size to distinguish between individual rhinos, was published in 1983 (Flynn & Abdullah, 1983). In recent years the small population in the Sungai Dusun reserve in West Malaysia has been studied to establish its approximate range (Mohd Zuber, 1983).

The use of indirect observations in the study of animals is an old practice, but usually it is only employed to study distribution and to estimate density. Counts of tracks, faecal pellets, nests, burrows, etc. can be related to density and these techniques are very useful for census of wildlife in habitats where the animals are difficult to see or hear. Track counts are one of the oldest wildlife inventory techniques and have been applied in various forms for many animals (van Lavieron, 1982), but rarely has the study of tracks been so perfected that individual animals could be recognized with certainty. Apparently the only studies in which individual recognition of tracks were accomplished are those on the wild tiger in India. By measuring tracks and prints and tracing the outline of the prints onto a transparent plate, scientists were able to recognize several individual tigers from the size and form of the sole pads (McDougall, 1977; Panwar, 1979).

## CHAPTER 2 - THE STUDY AREA AND GENERAL METHODS

### 2.1 - Selection and establishment of the study area

Formerly the Sumatran rhino occurred all over the Gunung Leuser Reserve, but in the last few decades poaching has exterminated it in all the more peripheral areas. By the beginning of the study, rhino could only be found in the interior of the reserve, at least a two or three days walk away from human habitation (see figure 2.1 and Börner, 1979).

During the preliminary expeditions (see chapter 1.3) to the Gunung Leuser and the Gunung Bandahara no recent signs of rhino were found. The steep slopes leading up to the Bandahara, that form the northeastern side of the Alas valley, have apparently never been favourite rhino habitat. Along the long route that leads to the Gunung Leuser only very old rhino trails were found, which had obviously been abandoned many years before. Already by the thirties no fresh signs of the presence of rhino were found in that area during the Clemens - Van Steenis - Hoogerwerf expedition (Hoogerwerf, 1939) and the George Vanderbilt expedition (Miller, 1942). Rhinos were exterminated there many years ago by the more or less professional rhino hunters from the Blangkejeren area.

We expected better results from the expedition to the Gunung Mamas, a route that had never before been opened. We hoped to reach the rhino area in the interior of the reserve crossing Gunung Mamas or that rhinos were still present on the higher slopes of the mountain. But again no fresh signs could be found. Some well developed rhino trails and some old wallows were found on the spurs leading up from the Alas and Mamas valleys to the main ridge of the Gunung Mamas, but it was clear that the rhino had left the area some ten to twenty years before. The higher slopes of the Gunung Mamas are very steep and deeply intersected. No signs of rhino were found there, and it proved to be impossible to cross over the summit into the Central Leuser Valley, where rhino were known to exist. The ruggedness of these mountains and the density of the vegetation in these parts of the reserve make travel very difficult and slow, and also rhinos seem to avoid these areas.

Therefore it was decided to try to find a suitable study area in the southern part of the reserve, where the mountains are less rugged and generally below 2000 metres in altitude, especially in the Central Leuser Valley. This valley in the centre of the Gunung Leuser reserve, running SE - NW, was discovered by a geological survey only two years before. From the surveys of Marcus Börner (Börner, 1973) it was known that this valley formed the core area of the rhino distribution. Börner surveyed the northern and middle parts of the Central Valley and had a study area in the extreme southern part of the valley.

The southern part of the valley, where it is drained through the Mamas and Silukluk rivers, appeared to be the best area for rhino. The valley is widest there and the slopes are not too steep. Therefore it was decided to try to penetrate into the southern part of the Central Valley and to develop a study area covering most of the upper Mamas and overlapping in the south with Börner's study area. The only known entrance route into this area was the route used by Börner, an old rhino hunter's route, a walk of three to four days to reach the boundary of the study area. Since the Mamas river leaves the Central Valley through an impenetrable gorge, it is impossible to enter the valley following the river. The mountain chain which must be crossed to enter the valley is, on the Alas river side, steep and deeply intersected.

People who worked in the area were of the opinion that the rhino poachers had probably not yet penetrated into this part of the reserve, and it was deemed unwise to open up a new route into the very heart of rhino country since it would only attract poachers after the study had ended. Therefore it was decided to use a helicopter to carry the survey team in and out of the study area.

At that time the interior of the reserve had not yet been properly mapped and the only reliable map available was a radar map (SLAR) on 1:25 000 scale, which gives only a rough indication of the topography. The mineralogical survey exploring Gunung Leuser Reserve in 1973 had used a heliport somewhere along the upper Mamas, but it was not known whether it was a natural or an artificial clearing in the forest. So on the first flight to the Mamas valley, in a helicopter borrowed from an oil company in Medan, a seventeen metre rope ladder was attached to the helicopter and lines were tied to the baggage, to enable us to descend if the helicopter could not land on the ground. As a last resort a known natural landing site, some twentyfive kilometres to the north could be used, from where it would be possible to reach the upper Mamas in a few days walking.

Fortunately soon after entering the Mamas valley the pilot spotted a small open space in the dense forest and he managed to land the party there safely. Because most of the valley had been under clouds, orientation was very difficult and only after a few days of mapping the major rivers could we identify the location of our landing.

The area appeared to be very suitable and it was decided to develop the study area there, with the base camp (Camp Central) at the landing site. Soon we found out that rhino poachers had entered the area a few kilometres south of the central camp, using a route over the mountains between the Mamas and the Alas valley. Because an entrance route already existed it was

no longer necessary for us to rely solely on helicopter transport, and we decided in future to use the helicopter to transport the party and the luggage to study the area but walk out along the poacher's route.

After the first landing part of the team started to survey and map the surroundings, while the rest began construction of the base camp and the landing platform. The platform, 5 x 5 metres, was made of 5 to 10 cm diameter poles, resting on small logs, in the middle of the open area. Some trees around were cut and during later expeditions a tight path was cleared to allow later landings. On each expedition the condition of the poles was checked and any rotten wood replaced.

Close to the landing site at a convenient and safe place beside the river, the central camp was built. Like the other camps that were constructed later, it consisted of a raised sleeping platform made of poles, covered with a roof of a plastic sheet and large leaves. A covered fire place was used for cooking and for drying the fire wood and the clothes. On every expedition any rotten beams and poles were replaced or, when the camp had been demolished by elephants, it was rebuilt. The plastic roof had to be replaced every 8 to 12 months. Close to the central camp a store was built in the trees on a steep slope, to keep it secure from elephants. Here all food, equipment and collected material were stored.

To make it possible to cover as extensive a study area as possible, later more camps were made, each about 5 kilometres apart, and an extensive patrol trail system, following the major game trails, was cleared, marked and mapped (see the map of the patrol network in figure 2.5). On the second expedition two more camps were constructed, one about 4 kilometres north of the central camp (Camp Aceh) and another about 5 kilometres south of the central camp (Camp Pawang), at the point where the poacher's trail starts.

On the third expedition the southeastern extension of the study area was surveyed and a camp was built on the upper reaches of the Silukluk river (Camp Lukluk), 6 kilometres east of camp Pawang. The most northern camp (Camp Uning) was constructed on the fourth expedition, 3.5 kilometres north of camp Aceh, and from the seventh expedition on a camp (Camp Pinus), built by an anti-poaching patrol group, 6 kilometres south of camp Pawang, was also included in the patrolling schedule. By that time the patrol network had been fully developed and after the sixth expedition only minor additions were made to the system of trails.

## 2.2 - Organization of the expeditions

Because of the remoteness of the study area, some 35 to 50 kilometres of hard walking through rugged mountains from the nearest village, the expeditions had to be well prepared and organised. The survey party usually consisted of the author, his wife, and three to five experienced local aides. Whenever possible the same assistants were employed, not only because of their greater experience, but also to limit the number of people who would be familiar with the route to the upper Mamas.

Besides material for the camps, the main part of the luggage consisted of food and plaster. Staple food included rice, dried fish, sugar, coffee and cooking oil, supplemented with chillies, onions, ginger root, pepper, salt and tea. All dry foodstuff was thoroughly air dried and packed in thick plastic bags in 20 litre tins. All other luggage was packed in backpacks and bags, to enable quick loading and unloading. A detailed account of the logistics of the expeditions has been issued as an appendix to progress report no 6 (van Strien, 1977).

The helicopter were chartered in Medan from an agency or from the oil companies working there. Because of goodwill for WWF's cause, they were generally hired at a non-profit rate and costs could be kept as low as possible. But this meant that the machine could only be used if no-one else wanted to hire it and we often spent long periods of waiting in Medan till the machine was available. The helicopter had to be guided to Kutacane, over the Langkat mountains, where the rest of the team and the luggage was waiting on the landing site, on standby every day till the helicopter arrived. Usually it was not possible to contact the Kutacane team, because the local telephone or office radio were not available or not working. The excess capacity of the helicopter was used to carry extra fuel in jerrycans for the return journey.

From Kutacane the team was taken to the landing site at the central camp, on one or more flights, depending on the type of helicopter. Occasionally some food was dropped at another natural landing site near the most northern camp. The plastercasts and other collected material from the previous expeditions that had been stored in the forest were loaded aboard the helicopter and carried out to Kutacane. In the later stages of the study it became more difficult to arrange a helicopter and most of the later expeditions were made entirely on foot. When a helicopter was available a large quantity of food and plaster was carried to the study area to build up a stock of at least 30 days provisions in the store at the central camp. When no helicopter was available the team could walk to the study area, which took three or four days, depending on the load, without having to add a large number of extra carriers to transport food and supplies.

In the study area the team moved every two or three days to another base camp, from which daily patrols were made along the network of patrol trails. The team was generally split up into two or three groups to survey different areas or to do other duties, like repair or transport. Each expedition lasted three or four weeks, which proved to be about the physical and psychological limit under the circumstances. At the end of the expedition the collection of plastercasts was packed in old food tins, the stores were checked and the camps prepared for the next visit. The return journey began from camp Pawang and it took 11 to 13 hours of hard walking to reach Kutacane.

## 2.3 - Description of the study area

### 2.3.1 - The Gunung Leuser National Park

The Gunung Leuser National Park (Taman Sumber Daya Alam Gunung Leuser) is one of the older and larger conservation areas in Indonesia and indeed in all of Southeast Asia. It consists of six adjoining Wildlife Reserve (Suaka Margasatwa), the oldest of which was established in 1934. Together they cover an area of almost 1 000 000 ha. In 1979 the whole complex of reserves was declared a National Park by decree of the Minister of Agriculture, but that does not change the legal status of the area.

The National Park covers more than 100 km of the Bukit Barisan range, the mountain chain that runs the length of the island of Sumatra. It stretches from the west coast of Sumatra in the southwest corner of the park, to less than 25 km from the east coast in the northeast corner, and is roughly located between latitudes 3° and 4° north and about longitudes 97° and 98° east of Greenwich.

The National Park is lengthwise almost split in two by the densely populated Alas valley. In the north both halves are connected by the Kapri Reserve, the last (1976) addition to the National Park. So far only part of the Park has been consolidated with legalised boundaries, and especially in the west and north of the park the boundaries are still provisional. Several important boundary realignments and additions to the park have been proposed in these areas. Figure 2.1 shows the location of the park, the approximate distribution of the rhino, and the study area. The rhino distribution shows only the core areas, based on the results of recent studies, but occasionally rhino are encountered outside these areas.

In the area of the Park the Bukit Barisan is most impressive, consisting of three big chains with several of Sumatra's highest mountains. There are many peaks over 3000 metres and also Sumatra's highest non-volcanic mountain (Gunung Leuser, 3445 m) is located in the northwestern corner of the park. A detailed description of the area and the park can be found in the management plan (van Strien, 1978).

### 2.3.2 - Physiography of the study area

The study area covers the valley of the upper Mamas river and the slopes on both sides of the river. The upper Mamas is part of a sequence of highland valleys called here the Central Leuser Valley. Others have used the name Central Rift or Blangbeke (or Blangpeke) Trench. The upper Mamas valley is about 24 kilometres long, and about 10 kilometres at its widest point. It is located roughly between latitudes 3°15' and 3°30' north and at longitude 97°35' and 97°50' east of Greenwich. Figure 2.2 shows the topography of the surroundings of the study area.

The morphology of the area is strongly influenced by a system of parallel faults. To the west the deep Alas valley is a part of the Semangka fault that runs lengthwise through the centre of the Bukit Barisan. The valley is drained by the Alas river which breaks through the mountains south of the study area and flows to the Indian Ocean. At the time of the Toba eruptions (late tertiary - quaternary) the drainage of the valley was apparently blocked and a lake formed in the southern part. Heavy sedimentation took place but eventually the water found a new outlet through the chain, and the valley became dry. The flat alluvial valley bottom is fertile and now converted to paddy fields. The main urban centre of the area is the town hip of Kutacane, from where the expeditions were mounted.

The Alas valley is bordered on both sides by a steep, deeply intersected mountain range. To the east is the Serbolangin chain with the highest peak (Gunung Bandahara, 3012 m) at the northern end. To the west lies the West Alas Range, with the highest peak (Gunung Kemiri, 3314 m) in the north, but the range falls to below 2000 metres in the south, near Kutacane. This West Alas Range separates the Alas valley from the Central Leuser Valley, and is dissected in three parts by the very deep and narrow valleys of the Mamas and Ketambe rivers.



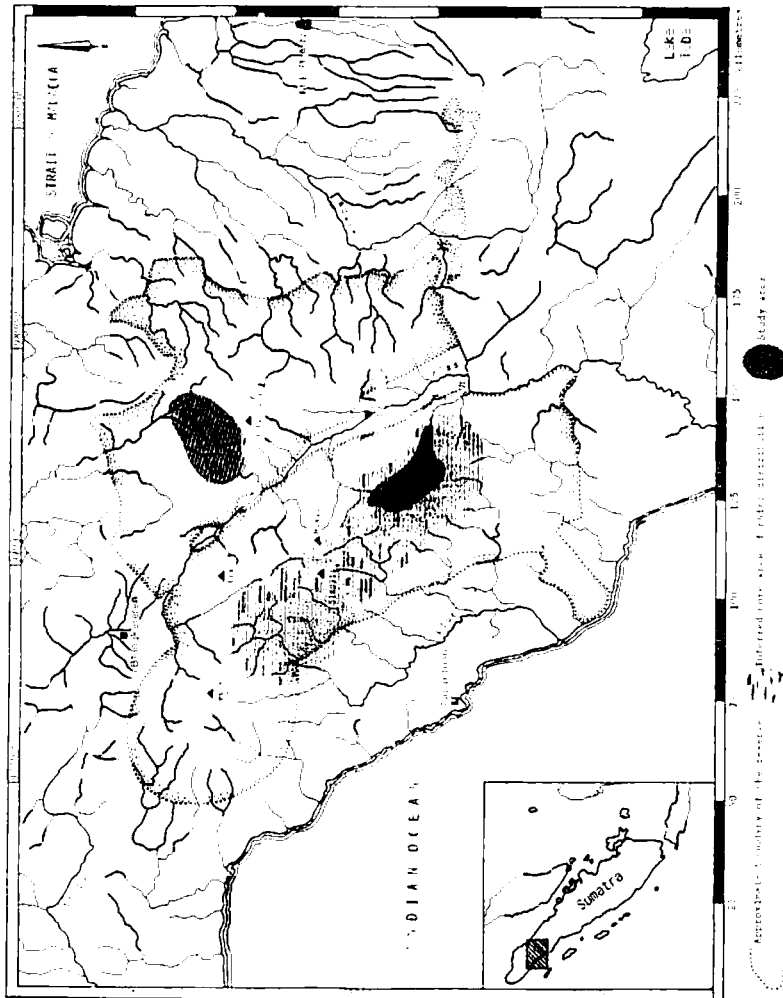


Figure 2.1 - Location map

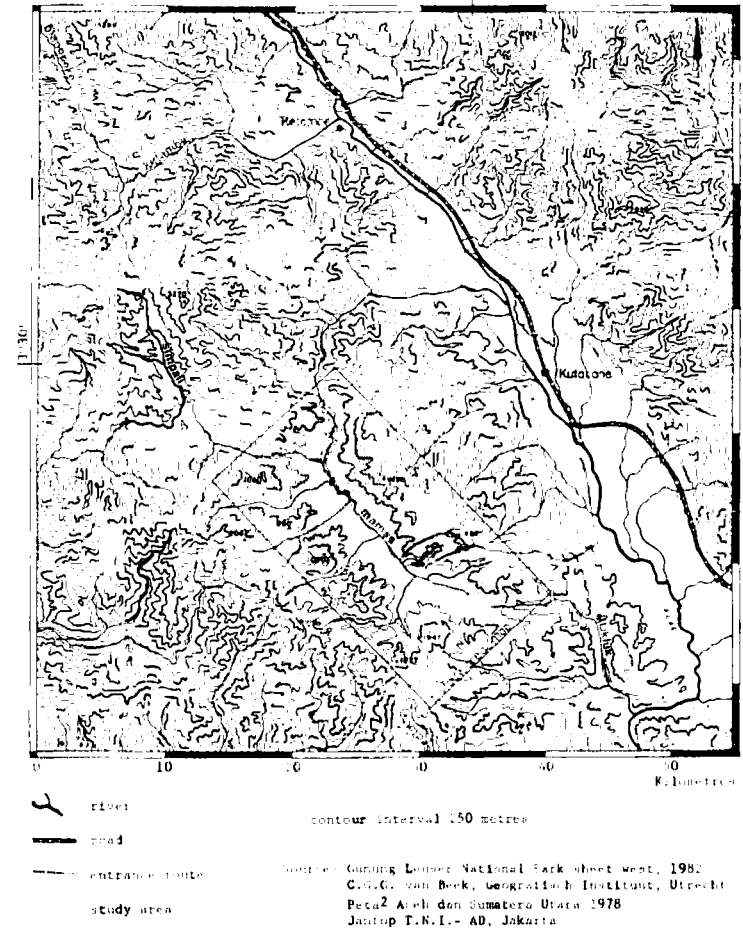


Figure 2.2 - Location map

The Central Leuser Valley is a series of highland valleys on a fault that runs parallel to the Alas faults. The northern part is drained by the Blangpeke river that joins the Alas river as it flows through the Agusani gorge. In the middle and southern part the fault cuts through preexisting drainage systems and the streams use the faultline for a short distance before breaking out to the side. The fault must therefore be of relatively recent origin (Quaternary). One small section of the trench drains to the west through a tributary of the Simpali river, then joins the Kluset river, running parallel to the west boundary of the reserve. A small section is drained by the Ketambe river to the Alas, and the southern quarter is drained by the Mamas river to the Alas. This part, called the upper Mamas, is a trench or a graben structure. The Blangpeke fault continues a few kilometres west of the river, approximately along the western limit of the study area, and the river follows a second fault, parallel to the main fault (see figure 2.3).

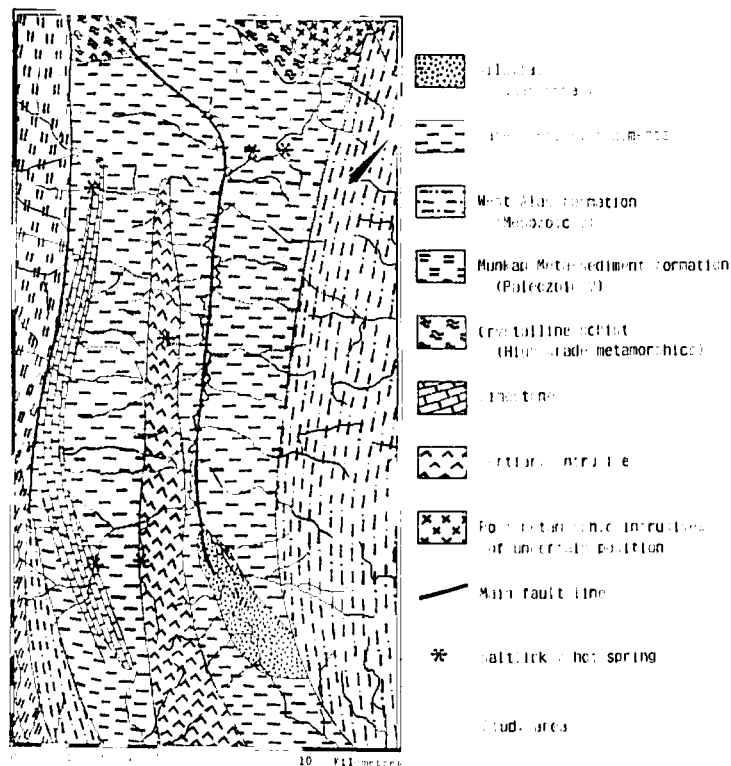


Figure 2.3 - Geological map of the study area

West of the upper Mamas lies the Leuser-Kluet range, the main range of the Bukit Barisan. In the northern half there are many peaks over 3000 metres, but to the south the mountains are lower, not much over 2000 metres. This range is deeply intersected by tributaries of the Kluet river. Most of the mountains west of the upper Mamas are composed of what has been named the Munkap-Metra Sediments of Carboniferous age. It is a monotonous series of weakly metamorphosed black and grey phyllites, silt- and sandstone, with some limestone. The mountains east of the upper Mamas are covered by the West Alas formation, presumably of Mesozoic age. They consist of black shales, silt- and sandstones, interspersed with zones of limestone and dolomite.

The basin of the upper Mamas itself is filled with sediment of late tertiary age, consisting of conglomerate, coral reef limestone, black mud, minor sandstone, agglomerate and crystal tuff. Especially in the upper reaches, towards the Silukluk river, they are covered with alluvial material accumulated from the adjoining higher areas. In the north the upper Mamas is bordered by a large area of intrusive and high grade metamorphic, granites and crystalline schists, that form the high mountains north of the Mamas. A narrow zone of tertiary intrusives, coarse-grained pink adamellite, runs parallel to the upper Mamas valley.

The escarpment east of the Mamas river is steep, rising continuously to the watershed, at 1700 to 1900 metres. The side facing the Alas valley is even steeper, with nearly vertical

cliff in many places, near to the watershed. The rivers draining the eastern slopes of the Mamas valley are short, with the exception of the southernmost tributaries. Here the watershed is more distant from the valley and the ridges lead gradually up to the watershed at about 1200 metres, after a steep rise from the river. The trails leading to the Mamas follow these ridges.

In the south the Mamas river is formed by the confluence of two tributaries. One, the Sungai Tenang, drains the valley between the Mamas and Silukluk rivers. This is a wide valley, with a flat and broadly marshy bottom, formed by the rapid accumulation of material from the unstable slopes south of the valley. The eastern part is drained by the Silukluk river, but the watershed between Silukluk and Mamas is very low and almost unnoticeable. The rivers and streams here are slow flowing and meandering. The other tributary, the Sungai Pinar, is a typical mountain river in a narrow steep-sided valley, with some alluvial deposits only in the lower two kilometres. In its upper reaches another small accumulation plain, called Medan Balak, has formed behind a massive landslide that blocks the valley.

West of the Mamas the watershed is about 10 kilometres from the river, drained by several fairly large tributaries. The largest is the Sungai Markus that drains part of the trench to the upper Ketambe river. Between this river and the Sungai Pinar there are three larger tributaries at right angles to the Mamas. These rivers separate the four major ridges leading to the central watershed between the systems of the Alas and Kluet rivers. These ridges form peaks four to five kilometres from the Mamas, three of which are over 2000 metres. Behind these peaks the ridges are considerably lower, along the main fault.

The upper Mamas river falls only about 90 metres throughout the study area, and is in most places slow flowing over a sandy or pebbly bed, with here and there bigger stones and boulders. The river meanders between the buff of the mountains, depositing alternating patches of alluvium. Between camp Aesh and camp Uning the valley narrows and the banks of the river are steep and rocky, and beyond camp Uning the river enters a narrow and deep gorge, with cliff a hundred metres or more high.

At several places along the fault springs occur, where warm water and gases emerge. The water is generally rich in minerals and around these springs encrustations and travertine domes can be found. The mineral rich water and soil around these springs attract rhinos and other animals and are therefore called saltlick.

The physiognomy of the study area is best demonstrated in the three-dimensional block-diagram (in the backcover), constructed from the 1:50 000 topographic maps produced in 1978 by the Indonesian Topographic Service (Jantop I.N.I.-AD). The study area is shown from a point northeast of the area; the horizontal plane is on the original scale, but with an obtuse angle between the NS and EW lines, suggesting perspective, without shortening or convergence of lines in these directions. The vertical scale is five times (1:10 000) the horizontal scale to accentuate the topographic features.

Most data in this chapter are taken from studies by van Beek (1982) and Helmkampff & Nagashima (1973).

### 2.3.3 - Climate and weather in the study area

The climate in the area of the Gunung Leuser National Park is characterized by high annual rainfall (average over 2000 mm/year), and the absence of a pronounced dry season. At lower altitudes temperatures are high and constant (tropical, average over 25°C). Increasing with increasing altitude. The humidity is high, and especially in the mid-altitude, the air is saturated for most of the time. Cloudiness is high and in the cloud zone on the mountain there is mist on most days.

On the coast west of Gunung Leuser rainfall shows an annual cycle with two periods of high rainfall in March/April and in September/December, interspersed with periods of moderate rainfall. On the east coast the situation is different, with a dry season in the first half of the year followed by a wet season in the second half. The rainfall records from locations in the Alas valley show an intermediate pattern. There are two wet periods, in March/May and in October/December, with the second period having decidedly more rain than the first. So far all records are for locations below 1000 metres altitude, and these are not directly comparable to the conditions at the mid- and high elevation (van Strien, 1978).

The rainfall in the Mamas study area follows essentially the same pattern as in the nearby Alas valley, but there are considerable daily differences. Daily rainfall records are available for the Ketambe Research Station (located in the Alas valley, about 30 km north of the study area, altitude about 350 m) since 1973. The average yearly rainfall there was 3155 mm (min. 1980 - max. 3591) for the period 1973-1980. The distribution throughout the year is shown in figure 2.4. Long-term records for Kutacane show a slightly lower average (2541 mm) (Institute of Meteorology and Geophysics, 1931-1960). In Ketambe the average number of rainy days (more than 1 mm of rain) per month varies from 13 in January to 13 in December (Min. 2 - Febr. 1973, max. 17 - Dec. 1973).

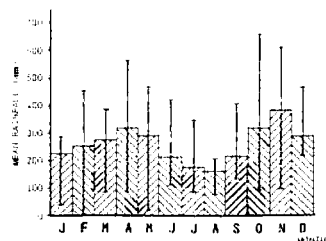


Figure 2.4 - Mean annual rainfall (shaded blocks) with the monthly range (the bars) for the Ketambe Research Station, 30 km north of Kutacane, 1972 - 1980

During expeditions daily notes were made of the rainfall - intensity (6 categories) and period - mainly for the purpose of the ageing of tracks. In the central camp a simple rain gauge was made from a small jerrycan with a small straight-sided funnel to collect rainfall. The first gauge was flattened by an elephant, but the second functioned for more than two years from the 6th till the 14th expedition. The gauge was emptied once every expedition and the amount of rain which had fallen since the previous measuring session was calculated.

Although the figures obtained with this instrument are not very accurate, they give an impression of the rainfall in the study area and it is useful to compare the results with those obtained for Ketambe. In the period that the gauge was functioning (13-VI-1976 till 1-II-1979) a total of 7565 mm of rain was calculated for the Mamas (= 2867 mm/year), and in the same period in Ketambe 8671 mm of rain was recorded (15% more). From the eight measurements that were made during this period only two showed a higher rainfall in the Mamas, the other six were lower.

During the first fourteen expeditions (317 days in the study area) the number of days with rain was 177 in the Mamas and 176 in Ketambe. Comparing the notes on the rainfall intensity with the recorded rainfall in mm from Ketambe showed that on 162 days there was no apparent difference in intensity of rainfall, while in 32 days Ketambe had clearly more rain and in 75 days the Mamas received more rain. It therefore appears that in the Mamas the number of days with substantial rainfall is slightly higher (an estimated 200 to 225 days per year), while the total amount of rain is probably slightly less than in Ketambe.

The average temperature decreases with altitude and van Beek (1982) has calculated, from numerous records taken throughout the Gunung Leuser area, that the average decrease in temperature is  $0.625^{\circ}\text{C}$  per 100 metres of ascent. According to these figures the average temperature should be about  $20^{\circ}\text{C}$  in the lower (1200 m) parts of the study area, falling to  $14^{\circ}\text{C}$  at higher altitudes (2100 m). Every day during the expeditions the air temperature in the early morning (6.00 hour) was recorded, and maximum and minimum thermometers were placed at three locations. The daily minima recorded at daybreak in the camp sites (Altitude 1200-1400 m), varied between  $11^{\circ}\text{C}$  and  $19^{\circ}\text{C}$ , with an average of  $16.2^{\circ}\text{C}$  (n=255). Lower temperatures, below  $13^{\circ}\text{C}$ , were relatively rare and occurred only during the rainless periods when the sky at night is often very clear. When the expedition was based in camp Central (altitude 1270 metres), the daily maximum was also recorded. This varied between  $20^{\circ}\text{C}$  and  $26^{\circ}\text{C}$ , with an average of  $22.6^{\circ}\text{C}$  (n=27).

The maximum and minimum thermometers showed the following readings throughout their period of operation:

Altitude 1270 m - minimum  $11.5^{\circ}\text{C}$  - maximum  $26^{\circ}\text{C}$  (period 880 days)

Altitude 1620 m - minimum  $11^{\circ}\text{C}$  - maximum  $24.5^{\circ}\text{C}$  (period 599 days)

Altitude 2030 m - minimum  $10^{\circ}\text{C}$  - maximum  $21.5^{\circ}\text{C}$  (period 285 days).

Wind velocities are generally low, although the trees are slightly deformed by persistent winds on exposed ridges and peaks. Before thunderstorms strong winds occur locally, blowing down trees and breaking off branches and occasionally large areas (up to one hectare) are completely flattened. Falling trees caused by gusts of wind are the main hazard in the area, and expedition camps have been destroyed several times by falling trees or branches.

The cloud zone is not very pronounced in the Mamas. Mist can occur at all altitudes, but is much more common and persistent above 1400 metres. But real moss forest, where everything is covered with thick cushions of moss up to several metres above the ground is not found in the Mamas. This type of forest covers extensive areas on the bigger mountain complexes, above 2000 metres.

As long as it is not raining the weather in the Mamas is very favourable for field work. During the day it is not too warm and one can walk far and fast, nor is it so cool that wading and swimming through the rivers becomes unpleasant. At night the temperatures are agreeably cool. Leeches and stinging insects are not abundant, with the exception of horseflies in the dry

periods and pestilential sand flies, that are occasionally so numerous that sleeping is almost impossible. Rain normally does not start before noon in the wet period. It continues generally till late afternoon, but occasionally it rains throughout the night and in the early morning. In the dry periods occasional showers occur, mostly in the late afternoon or early evening. Because the chances of finding clear tracks are dependent on the frequency of the rains, the expeditions were mainly concentrated in the periods with less rainfall, to have a better chance of working during a few dry days before tracks are obliterated.

### 2.3.4 - Plant cover of the study area

In this chapter only a general and superficial description of the types of vegetations found in the study area will be given. Extensive botanical explorations were undertaken in the Gunung Leuser area by botanists from the Leiden and Bogor herbaria. In 1979 the upper Mamas was visited by a team of botanists, who joined part of our 16th rhino expedition. In the chapters on the foot of the rhino (chapters 8.1 and 8.2) more details will be given about the botanical makeup of the undergrowth, the stratum of main interest for the rhino.

Virtually the whole study area is densely forested. In the lower parts of the study area, in the large valleys and on the lower slopes, the forest should be classified as submontane. In appearance it is still decidedly tropical, but the trees are not so lofty as in the lowlands. The highest emergents are estimated to be not much more than 30 metres high, with trunk diameters rarely exceeding one metre. Buttressed roots are common. The Dipterocarps and strangling figs typical of lowland rainforest are not so common and much less imposing. Below the large emergents the forest is composed of a rich mixture of trees, large and small, but all with long straight trunks, with an abundance of small saplings forming most of the undergrowth. Lianas and epiphytes are abundant, as well as rattans and small, stemless or short-stemmed thorny palms. Large high-stemmed palms are absent.

Decomposition of litter is rapid and complete and the soil is generally covered with only a thin layer of dead leaves. Along the rivers and streams and on the lower, moister parts of the slopes, the herb layer is well developed, and there is an almost continuous cover of a mixture of fleshy herbs, one to one-and-a-half metre high. Higher on the slopes and on the ridges thorny palms dominate the undergrowth, forming a dense, prickly layer two to three metres high, in which visibility is very limited.

Ascending the mountains the vegetation changes very gradually, the average height of the trees decreases and the sizes of the trees become more uniform. Although there is no clear boundary, at an altitude of around 1500 metres the forest becomes more like a temperate forest. All the bigger trees reach about the same height, around 15 metres, with trunk diameters less than 50 centimetres, and branching from the trunks starts at a much lower level. Lianas other than rattans are rare and the epiphytes are smaller. Beardmoss and other lichens cover the highest branches of the trees, and there is extensive moss cover on the ground. Because of the lower temperature decomposition of the leaf litter takes longer and a humus layer is formed. At first the moss cover is patchy, but going higher still, at around 1700 metres, it covers the forest floor and the bases of the trees, forming large clumps around trees and shrubs, where many pteridophytes grow.

These changes are more rapid and drastic on the ridges, which are more exposed to chilling conditions, than the more sheltered valleys, where high-stemmed forest occurs to a much greater altitude. On the highest peaks, and on exposed parts of the ridges, sub-alpine forest and shrubs can be found. Normally such vegetation does not occur below 2500 metres, but locally small patches are found as low as 1600 metres. The trees in sub-alpine forest are very much dwarfed with crooked trunks and branches, thickly covered with lichens, and with an undergrowth of tall ferns and shrubs. In places tree cover is patchy, but the vegetation consists of a dense mass of entwined shrubs and climbers, with here and there umbrella-shaped trees. Pitcher plants are abundant. On a few peaks, ranging in altitude from 1800 to 2100 metres small "blang" areas occur, peaty marshes formed in depressions. Extensive areas like this occur in the northern part of the reserve, above 2500 metres, but in the study area they extend over only small areas.

At lower elevations there are a few small areas without forest. Around some of the warm springs or saltlicks there are rather extensive chalk crusts that are bare or covered with a grassy vegetation. Along the Mamas there are a few small marshes: one marsh covered with a thick mat of grasses and sedges, forms the landing site at the central camp. The same vegetation is found on the rather extensive marshes of the watershed between the Mamas and the Silukluk rivers. In this area the slopes are very unstable and the accumulation of rubble in the flat parts hampers the drainage and kills the trees. These open areas are apparently of recent origin, because the dead trunks of forest trees are standing all over the area. The scene is similar behind a massive landslide that blocked one of the tributaries of the Mamas. The valley has rapidly filled with loose material and now carries a dense cover of shrub, with the crowns of trees that are buried protruding above the rubble, many still alive.

### 2.3.5 - The other mammal fauna

Besides the Sumatran rhinoceros, most of the larger Sumatran mammals are found in the upper Mamas, with the exception of the Tapir (*Tapirus indicus*) and the Javan rhinoceros (*Rhinoceros sondaicus*). The latter species is probably now extinct in Sumatra, but might once have occurred in some parts of Gunung Leuser. The tapir has never been recorded for Gunung Leuser, but was formerly found in the coastal plains of Langkat, east of Gunung Leuser (Schneider, 1905); now it probably no longer occurs north of lake Toba.

Elephants (*Elephas maximus*) are mainly found along the Silukluk and Mamas rivers, traveling to one of the saltlicks in the area. But occasionally they wander through other parts of the reserve and signs of elephants can be found everywhere in the upper Mamas, even on the tops of the mountains. Elephants enter the Mamas study area from the Silukluk valley or over the mountains between the Mamas and the Alas. The trail to camp Pawang is an important elephant route, but there is also an elephant trail along the watershed between the Alas and Mamas and probably from the lower Mamas to the saltlicks near camp Uning. From the Mamas area trails lead further north to the Central Leuser Valley. Among the regular visitors to the Mamas were two solitary elephants, one medium-sized and one large, and a group of three with a small calf.

Pigs (*Sus creta*) were only temporarily abundant in the upper Mamas, mainly in the flat area of Silukluk and Tenang. During the first two years very few signs of pigs were found, but later large groups were encountered in the south and also appeared more abundant elsewhere. It seems that they move into the upper Mamas during dry periods, often roving around in large groups (20 or more). The bearded pig (*Sus barbatus*) was not found in the Mamas, and has so far not been recorded for Gunung Leuser reserve.

The sambar deer (*Corvus unicolor*) and barking deer or muntjak (*Muntiacus muntjak*) are both common throughout the area. Sambar are found everywhere, even on the open sub-alpine areas above 3000 metres, while the muntjak seems to be less common at higher elevations. These two species use the same foods, the soft parts of the undergrowth, as the Sumatran rhino. Muntjak are usually found alone, while the sambar deer move sometimes in twos or threes. The ew (Capricornis sumatrensis) is less common and appears to be mainly found in the smaller and narrower valleys and on the steep part of the slope. The mouse deer or kancil (*Tragulus javanicus*) is apparently very rare. Its tracks were only found once in the Silukluk area. The larger mouse deer or napu (*Tragulus napu*) was not found in the Mamas. Both species occur in Gunung Leuser, and especially the kancil is very common in the lower parts.

Of the larger carnivores the sun bear (*Helarctos malayanus*) and the wild dog or dhole (*Cuon alpinus*) are those most commonly found in the upper Mamas. Signs of both species were found often in the lower parts of the valley. The dhole was usually solitary, and only once were tracks of a small group of three or four found. In other parts of their distribution (Java, India) dholes usually operate in packs, chasing large herbivores. In the dense tropical forest a solitary way of life is probably more appropriate and from faces, presumed to be dholes', it appeared that in the Mamas dholes feed mainly on rodents.

The tiger (*Panthera tigris*) is a regular visitor to the Mamas, tigers usually follow the network of game trails and their tracks could often be followed for a long distance. Tigers apparently wander around over huge areas, of which the upper Mamas is only a part. One very large tiger, whose tracks were easily recognisable (one toe had an aberrant position), was once found to have entered the study area from the north, traveled through the Mamas valley and left the area a few days later, in the south near the Kompas river. Once a fresh tiger kill was found, an adult male orang-utan.

Tracks of the clouded leopard (*Neofelis nebulosa*) were found twice, but this arboreal predator might very well be more common. Börner (1979) also reported the golden cat (*Felis temminckii*) from the area and tracks of the leopard cat (*Felis bengalensis*) were not uncommon. The hog-nosed badger (*Arctonyx collaris*) was encountered a few times, but it is probably rather common, and elsewhere in Gunung Leuser it was also found on the open sub-alpine blang areas.

In all rivers the small-clawed otter (*Aonyx cinereus*) is common and occasionally tracks were found of a larger otter (*Lutra* sp.). These tracks and the tracks of some medium-sized cats and weasels that were occasionally found, await further identification from the casts made at the time.

The Southeast Asian porcupine (*Hystrix brachyura*) is common throughout the area. The black giant squirrel (*Ratufa bicolor*) was heard and seen several times, as well as small non-descript squirrel (*Sundasciurus* sp.). The three-striped ground squirrel (*Lariscus insignis*) was seen several times, but it is not very common in the Mamas. A few rats were collected at the camp sites. The large tree shrew (*Tupaia tana*) was seen occasionally. It was much less common than another small tree shrew (*Tupaia javanica*?) that was very often seen in the understory of the forest. Once a dead short-tailed shrew (*Hylomys nullus*) was found.

Among the primates Thomas' leaf monkey (*Presbytis thomasi*) is the most common species. It can be found at all altitudes, even in the shrubs on the very highest mountains. The whitehanded gibbon (*Hyllobates lat*) and the siamang (*Hyllobates syndactylus*) seem to be less

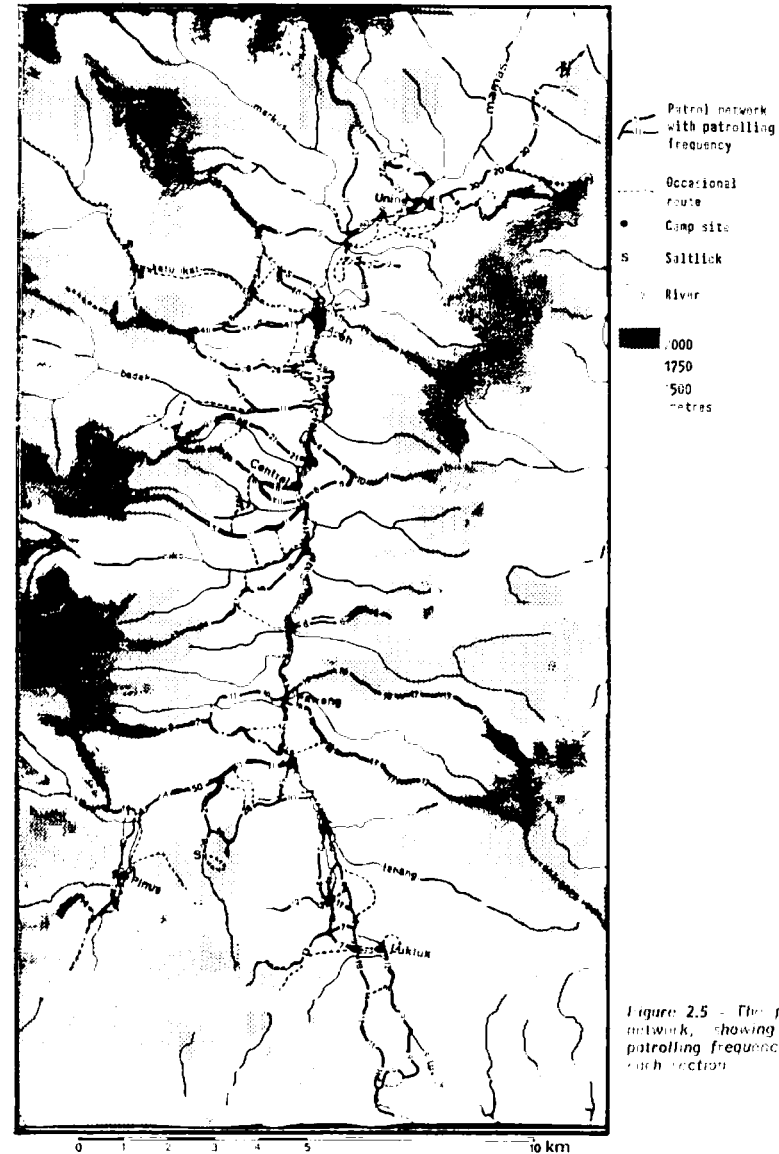


Figure 2.5 - The patrol network, showing the patrolling frequency for each section

common and they do not go so high. The gibbon occurs up to about 1900 metres, while the siamang has been recorded as high as 2200 metres. The orang utan (*Pongo pygmaeus*) is much less frequently encountered but has been recorded up to 1800 metres. The pig-tailed macaque (*Macaca nemestrina*) is by far the rarest primate. A few groups were encountered below 1500 metres. The long-tailed macaque (*Macaca fascicularis*), essentially a lowland riverine species, was never seen in the Mamas.

## 2.4 - The patrolling system

Before this study it was generally believed that the Sumatran rhino has a very low density, at best one per 10 sq km, and therefore the study area should be large to increase the chances of finding tracks of more than a few animals. On visiting the future study area it was found that there was an extensive network of wide game trails throughout the area. They follow the major rivers wherever the banks are flat, cutting off the meanders, and they lead up the mountains along the main ridges. It was decided to survey as many as possible of these trails and to develop a permanent network of patrol routes along these trails on both sides of the Mamas river. Using the game trails is the only way to cover a sufficiently large area in the available time.

The game trails along the bigger rivers and on the major ridges were generally well developed and needed only a little clearing of overhanging twig and palm leaves, to make them easily passable. During the first six expeditions the network was gradually extended and six permanent camps were erected. The trails were mapped with the use of compass and pedometer, and trails were marked when necessary, by cutting a number in the bark of a tree. A detailed map was made of the area, using the field observations and radar maps, the only maps available at that time. When the new topographic maps, based on aerial photography, became available in 1979, the working map of the study area could be further improved. By the sixth expedition about 150 kilometres of trails had been mapped, covering an area of about 170 sq km and most of the important saltlicks had been discovered. During later expeditions only minor extensions were made to the patrol network.

Figure 2.5 shows all the patrol trails as well as the other routes that were occasionally followed. Part of the entrance routes west of the watershed is also included in the network. For convenience the trails have been divided into sections of varying length. For section boundaries the contours at 1400, 1600, 1800 and 2000 metres were used, and also landmarks like wallows and junctions. The actual length of each section was calculated to an accuracy of ten metres, from the fieldmap and the topographic map, taking the slope into account. In total there are 206 sections, ranging from 260 to 1880 metres, with a total length of 152 550 metres.

The patrolling frequency for each section is also shown in figure 2.5. This is the number of times that the team or part of the team passed a certain section, and it will be clear that large differences in patrolling frequency were unavoidable. The trails connecting the camps were walked many times for transport of stores and collections, while the number of patrolling the outward sections was much lower, depending very much on circumstances. Some routes were clearly more popular than others, because they led to important saltlicks or other areas where tracks were likely to be found. Since it was not possible to walk all routes during one expedition, there was never a fixed schedule, and the decisions where to go were made on a day-to-day basis, depending on the prevailing weather and the previous results. Therefore some sections were patrolled many times, while others were only covered two or three times throughout the study period. The differences in patrolling frequency can be compensated for by relating the findings of fresh tracks to the total observation time, which is the accumulated time between the time of the patrol and the last rain, as will be discussed in chapter 5.4.

The patrolling schedule was greatly influenced by the weather. During dry weather we attempted to cover as much as possible of the study area, visiting only the saltlicks and the major trails, before the coming rains would wash away the tracks. Camp was changed every other day, and two or three teams were sent out in different directions. But during periods of daily rains the area was covered more thoroughly, and more attention was paid to surveying new routes and to following rhino tracks. On a few occasions the downstream camps could not be reached because of the high level of the river. Early rain often prevented the completion of the patrol intended for that day.

During the patrols attention was mainly focussed on the finding of rhino tracks, both old and new. When a track was found it was followed until a few good casts could be made. Notes were made on the route of the animal, on the position and nature of signs such as feeding marks, faeces, urine, etc., on the use of wallows and saltlicks, and foodplants and faeces were also sampled. All signs of other mammals were also recorded and casts made of their tracks. The primates encountered in a 30 metre wide strip on either side of the trail were counted.

## CHAPTER 3 - THE STUDY OF THE RHINO'S TRACKS

One of the initial aims of this study was to devise better ways to study the rhino's tracks so that more precise identifications could be made. During the first expedition it was attempted to trace the outline of rhino prints on a transparent plate, laid over the print. This method has been successfully used in the study of tigers (McDougal, 1977; Fanwar, 1979). But it was soon discovered that it is not suitable for studies of the Sumatran rhinos. There were several practical problems. The transparent plate fogged when it was laid over the track because of the moist atmosphere, and the poor light in the rainforest made tracing very difficult. Furthermore the rhino's foot has a very pronounced profile, with long projecting hoofs, and a tracing shows only two dimensions, length and width, and nothing of the depth of the print.

Since tracing was not useful it was decided to revert to the classic method of casting prints in plaster of Paris, notwithstanding the serious transport problems that were involved in the use of this heavy material. For each cast 300 to 500 grams of plaster is needed, and large quantities had to be carried by back-pack to and from the study area, and carried around between the different locations. In total an estimated 350 kilos of plaster was used.

In the following pages detailed accounts are given of the methods used in the making of the casts and in the subsequent study of the casts to identify the individual rhinos. The technique could be applied with success in studies of other large animals, that are very difficult to observe. With slight modifications much of what will be said in the following pages could be of use in studies of other rhino species, elephants, tapirs, large carnivores, large birds and probably even crocodiles.

### 3.1 Morphology of the rhino's foot

Before the casts were finally sorted in Bogor, a short study was made of the rhino specimens held in the Bogor Zoological Museum (Museum Zoologicum Bogoriense). Skeletons, hinds and hoofs of the Sumatran rhino, of which the museum has a substantial collection, were studied to get more insight into their structure to enable a better interpretation of the characteristics of the plastercasts.

The legs of a rhino are relatively short and columnar, ending in a flat sole with three hoofs or nails. In this typical perissodactyl foot the middle or third digit is the best developed, the second and fourth digit are slightly smaller and the first and fifth digit are completely lost. The forefoot carries most of the weight of the animal and is slightly larger; its print is a few centimetres wider and has rounder form than that of the hindfoot. Flynn and Abdullah (1983) found a mean difference of 1.5 cm between the width of the fore and the hindfoot. In normal gait the hindfoot overlaps the imprint of the forefoot almost completely, and only under exceptional circumstances, as on steep slopes or when the animal has made a sudden turn, can complete prints of the forefeet be found. During this study only a small number of casts were made of prints of forefeet. The form of the foot and the hoofs is similar to the form of the hindfoot, but the width is larger and also the nails are broader at the base. Only casts of hindfeet were used to identify individual rhinos.

The tarsus of the hindfoot consists of six bones, that are tightly joined, with each other and with the metatarsals. In this part of the foot very little bone movement appears to be possible. The tarsals and metatarsals act probably very much like a single piece of bone, articulating with the tibia. But between the metatarsals and the first phalanges there are joints that allow for considerable movement. In the third or middle digit the joint is almost cylindrical, allowing articulation mainly in the sagittal plane. The joints in the outer digits are more spherical, allowing movement in all directions. Most movement of the toes apparently takes place in these joints, while the joints between the phalanges appear to be only slightly movable. In figure 3.1 a left hindfoot skeleton is shown, drawn from a specimen in the Bogor Museum.

The extensor and flexor muscles that are attached to the digits generally have tendons to all three digits and between the digits there are strong ligaments (Beddard & Treves, 1889) and the individual toes are probably not meant to move separately. Only extension or flexion of all three toes together seems possible, but considering the weight of a rhino it is very likely that the differences in posture of the foot in descending and ascending (see chapter 3.5.3), are more the result of external forces than of muscle action.

The underside of the foot is composed of an elastic plantar cushion, several centimetres thick, on which the digits and the distal end of the metatarsals rest and this is covered on the underside by the skin of the sole. This cushion distributes the weight of the animal and functions as a shock absorber. The skin of the sole is rather thin, in dried condition between 3 and 5 mm, with a thin horny outer layer. The flexibility of the plantar cushion prevents it being damaged by sharp objects (A cross section of a rhino's foot is shown in Grasse, 1955).

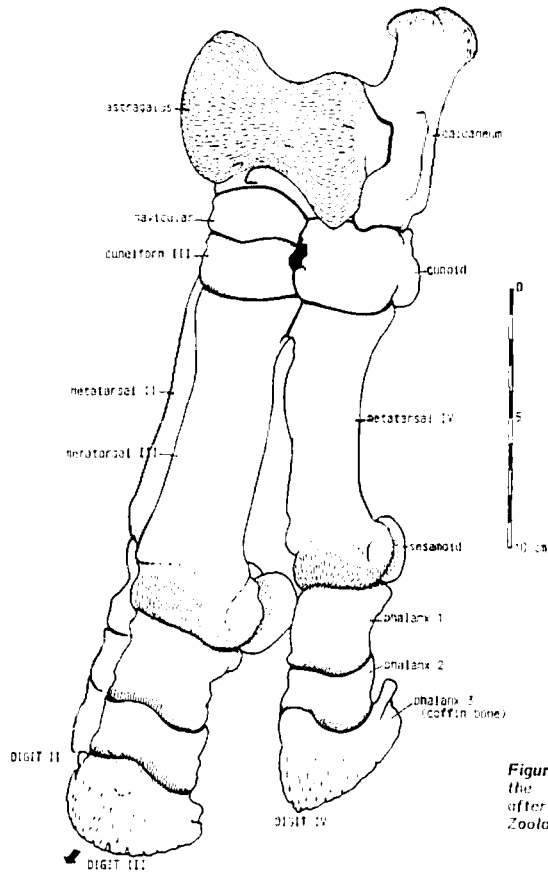


Figure 3.1 - Hindfoot skeleton of the Sumatran rhinoceros, drawn after a specimen in the Museum Zoologicum Bogoriense

The end phalanges or coffin bones are enclosed by a horny hoof, that is semicircular on the middle toe and triangular on the outer toes. The hoofs are made of horn and formed by the underlying horn-producing tissue. The hoof consists of a wall of solid horn that is formed by the coronary band, which is situated where the hoof attaches to the skin of the foot. On the inner side of the wall there are horny laminae for the firm attachment of the hoof. The flat inside of the hoof, called the plantar surface or subunguis, is less solid and consists of horny tubules, formed by the underlying tissue (Emery, Miller & Van Housen, 1977).

In figure 3.2 a drawing of the underside of a foot of the Sumatran rhinoceros is shown, with the morphological names that are used in the text. The drawing is made from a specimen in the Bogor Zoological Museum. To illustrate the impression of the form of a foot in a plaster-cast of a print, figure 3.2 below shows a simulated drawing of an imaginary cast of the same foot. The morphology of the hoofs is shown in figure 3.3 in more detail.

The dorsal or outer surface of the hoof's wall is long and smooth, the inside is very short, forming the basal ledge. In some hoofs the basal ledge is pronounced, in others the inner wall grades smoothly into the plantar surface. In the front hoof the outer wall curves around the sides of the hoof and forms the side lobes on the inner surface. In some prints these side lobes are thick and distinct, in others they are hardly visible and the inner surface of the hoof is smooth and flat. In the side hoofs the basal ledge has a groove in the middle, separating a posterior and an anterior lobe. The anterior lobe is generally the most pronounced.

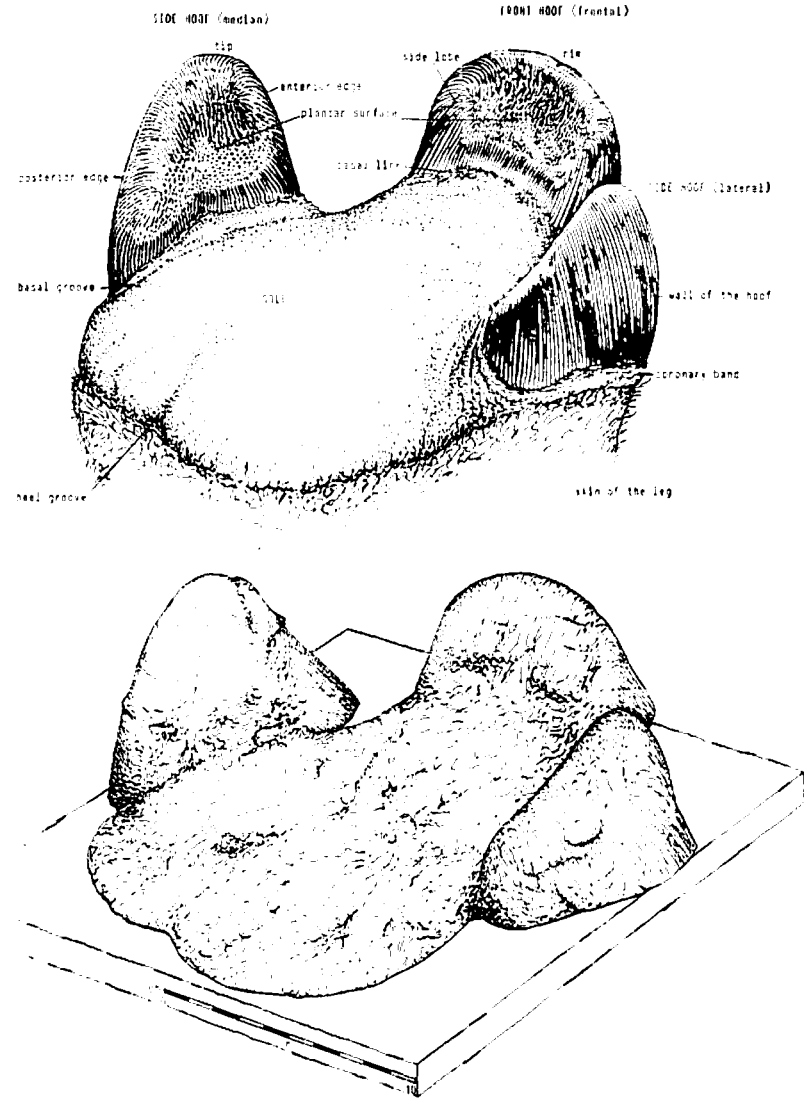


Figure 3.2 - The underside of a hindfoot of the Sumatran rhino (above), drawn from specimen (No 6970 and 8440) in the Museum Zoologicum Bogoriense, and a simulated drawing of a plaster-cast of the same foot (below)

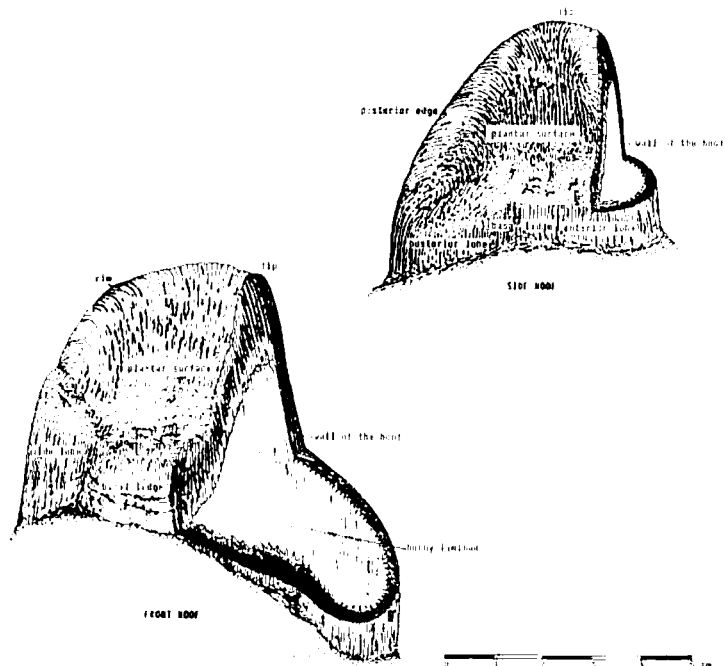


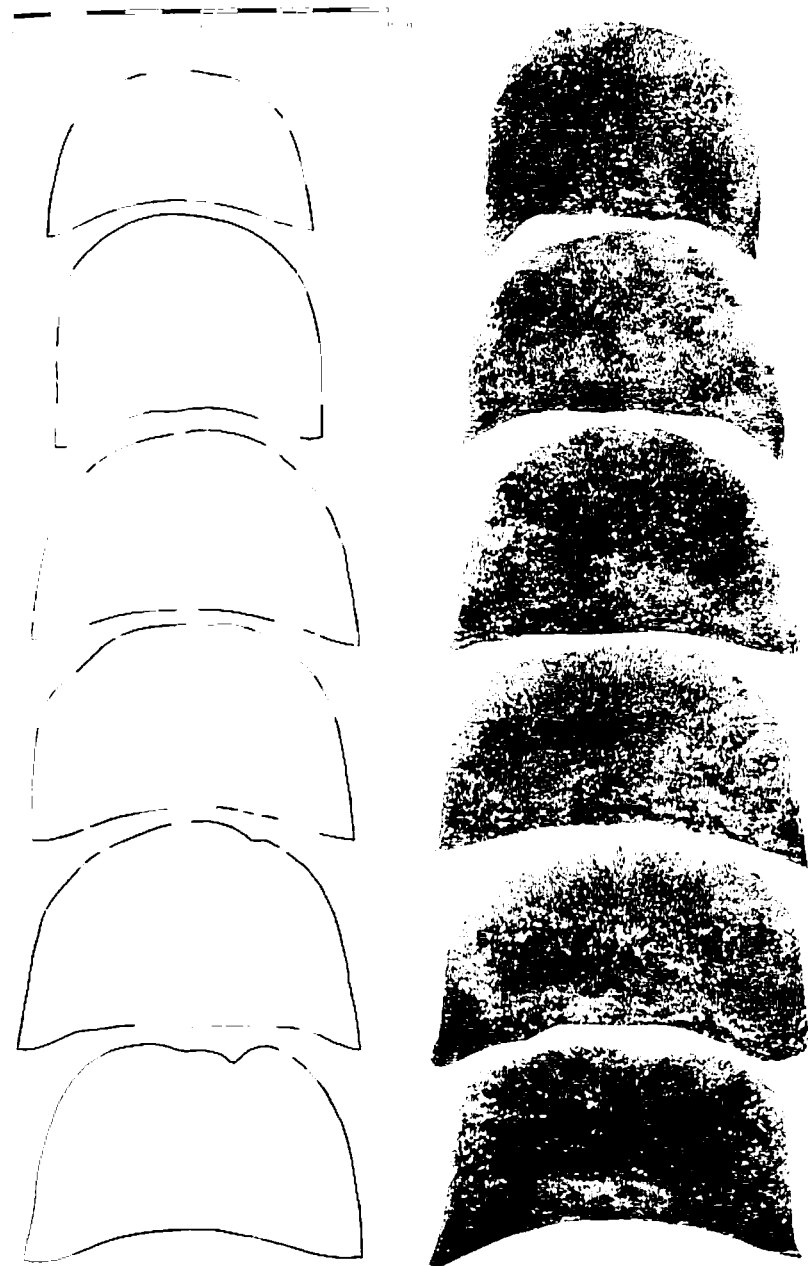
Figure 3.3 - The front and side hoof of the Sumatran rhino, sawn open to show the internal structure. Drawn from a specimen in the *Museum Zoologicum Bogoriense*.

The Zoological Museum in Bogor contains a large collection of hoofs, confiscated by the government in the thirties, after the rhino had been declared protected in the Animal Protection Ordinance of 1931. These hoofs were measured and sketched to get an idea of individual variation, for comparison with the variation found in the actual plastercasts. All sets of hoofs were found to be clearly distinct and there was a great variation of sizes and forms. In figure 3.4 photographs and profiles of a selection of the front hoofs are shown.

It is remarkable that among the front hoofs from the Bogor museum, which originate from various localities in Sumatra and Borneo, many are of large size, well over 80 mm in width, a size that is relatively rare in the Mamas collection. This could indicate that the rhinos in the Mamas are relatively small, which is probably related to their mountainous habitat. Most of the museum specimens seem to originate from lowland localities.

opposite page

Figure 3.4 - A collection of outline drawings and photographs of front hoofs of the Sumatran rhino, to show the individual variation. Taken from specimen in the *Museum Zoologicum Bogoriense*.



### 3.2 - The art of plastercast making

Rhino tracks are rare and good, clear and complete prints are rarer still, even in a good rhino area like the upper Mamas. Plaster is heavy and therefore always in limited supply in the field. Plastercasts are not only heavy, but also rather fragile. All of these factors together make working with plastercasts a craft, requiring much patience, experience, skill and a good organization. In this chapter the different techniques employed in the finding, making and preserving of the plastercasts will be described in detail, also as guidance to others who might wish to attempt a similar study.

The following figures serve to illustrate the frequency with which we encountered tracks of sufficiently good quality to make one or more casts. Plastercasts were collected from the second till the seventeenth expedition. During these expeditions 358 days were spent in the study area during which period 3816.42 kilometres were patrolled. During that period plastercasts were made from 360 different tracks, of which 166 were fresh. This means that on average one set of casts could be made per day in the field with an average 10.6 kilometres walked to find a suitably clear impression. Considering fresh tracks only, it takes about 23 kilometres of patrolling and a little over 2 days to find one fresh track.

Per expedition these figures vary widely, mainly depending on the weather conditions. The largest number of casts were obtained on the fourteenth expedition, when in 23 days and 295.4 kilometres of patrolling, casts were made of 53 tracks, 35 of which were fresh. The weather was very favourable during this expedition, with only two days with substantial rain. The poorest results were obtained on the fifth expedition, when in 24 days and 210.4 kilometres of patrolling only 3 tracks were found, in the first week of the expedition. In the last fourteen days of the expedition not one track, nor anything else worth recording, was found. During this expedition there were only five rainless days.

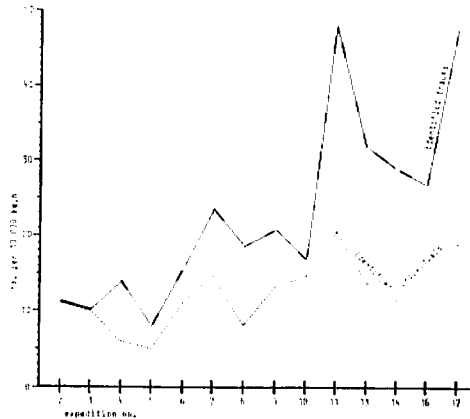


Figure 3.5 - The results of the track analysis per expedition, expressed in the number of tracks and the number of individuals that could be identified, against the km.h score for each expedition. The km.h score is a measure for the intensity of the patrolling (see chapter 5.4)

Experience is an important factor in identifying individuals from plastercasts of their tracks as is shown in figure 3.5, where the results for each expedition, expressed in the number of tracks that could be identified and in the number of different individuals that could be identified, are plotted against the km.h score (= length of patrol in kilometres X hours since last rains or previous patrol). This score is a measure of the probability of finding fresh tracks. See chapter 5.4). Both curves show an increase in numbers of useable casts and identified individuals from the earlier to the later expeditions. Some of this might be attributed to the gradual extension of the study area, during the first six expeditions, but most is due to increasing skill in the finding, selecting and casting of footprints, especially of older and less perfect ones.

#### 3.2.1 - Finding the tracks

The first step in making plastercasts is to find the rhino tracks in the field. Under normal circumstances, and in the Mamas that means frequent rains and a moist soil, the tracks of a rhino are not easily missed. Even on relatively hard soil the sharp impressions of the hoofs are clearly visible and the track can be easily followed. But after a few rainless days the soil dries out, especially on the ridges, and rhino tracks become much less noticeable. The hoofs hardly leave any impression in the hard soil and the print is further obscured by the layer of fallen leaves which cover the soil. The longer the dry weather conditions last the more difficult it becomes to follow a rhino track, unless one proceeds on hands and knees and carefully moves the leaf layer to look for the shallow impressions of the hoofs underneath. Under these conditions it becomes increasingly difficult to find prints that can be cast.

Although the tracks are often surprisingly faint for an animal as large as a rhinoceros, they are not easily missed by the trained eye, especially when the animal follows the trail for some distance. Most patrols were made with groups of three or more people, each alert for rhino tracks. The one walking in front may miss faint tracks, because his attention is mainly concentrated on the area ahead, but the second and third person generally pick up the tracks missed by the front man. Most patrols go up and down along the same route and on the return journey we rarely found new overlooked tracks.

Prints are best preserved in places where there is no litter and the soils are clayey, around saltlicks, wallows and on worn out sections of the trails, or where the prints are somewhat protected against the rain by racks, treetrunks or big leaves. During the study it was found that old rain-blurred tracks can sometimes be restored and useable casts made. The techniques to restore old prints will be described below.

#### 3.2.2 - Selection of the prints

After a track has been found the prints to be cast have to be selected. In principle two right and two left prints should be cast for each rhino, but often this was impossible because four good prints could not be found or the plaster was in short supply. Sometimes when enough plaster was available more than four casts were made from one track, to get a longer series from which to study variations caused by the terrain. It is often not easy to judge the print before the cast has been made and lifted. In the dim light of the tropical forest fine details are difficult to see, especially in deep prints. A small mirror or a torch can be very useful for inspecting prints that appear to be suitable for casting. But even after careful selection of the prints, the casts often show deformations that were not noticed in the prints.

From old tracks it is often only a single print or just one or a few hoof prints that are suitable for casting. But fresh tracks suitable for casts are also generally rare. Prints left in normal forest soil are seldom good. The soil is crumbly because of the high content of organic matter and the layer of dead leaves obliterates the details of the print. Places with soil that leaves clear sharp prints are relatively rare in the forest. Generally good prints can be found only in those places where organic material cannot accumulate, as on saddles and narrow ridges or on steep slopes, or where organic material is removed, along rivers and streams or on the more frequently used game trails. When a rhino visits a saltlick or a major wallow, a fair number of suitable prints can be found, but when it wanders through the forest away from the large game trails, it is often very difficult to find enough good prints, and on several occasions not one suitable print was found although the track was followed for a considerable distance.

The type of movement of the animal influences the shape of the print (see chapter 3.5.3) and it is therefore important to select those prints, that are made on level ground, by a rhino moving calmly in a straight line. This is seldom possible in a mountainous area and one often has to take prints that were made under less ideal conditions.

When a larger number of apparently good prints were found, a number of them were cleaned out before a selection was made. Selected prints should be as complete as possible, showing a clear and complete imprint of all three hoofs and the hoofs should not have been forced into an unusual position by underlying stones or treeroots. Too shallow prints will not show the base of the hoof and too deep prints are difficult to inspect and are generally partly deformed with the sides caving in.



### 3.2.3 - Preparation of the selected prints

It was rare to find fresh prints that could be cast without being cleaned out first, and old prints generally needed extensive cleaning and restoration before a useful cast could be made. When the rhino lifts its foot in walking, particles of the loose top layer of the soil are dislodged and fall into the print. These particles should be carefully removed before the plaster is poured in. Even a few soil crumbs can prevent the plaster from filling the deeper parts of the print and important areas will be missing in the cast. The largest particles can be removed with the fingers. For smaller fragments a pointed twig or a pair of tweezers, made on the spot from a split twig (preferably a palmleaf stalk). The very finest particles can be blown out. To prevent more particles falling into the print the loose top soil is removed around the print.

In clayey soils removal of the soil particles is generally very easy, as the compacted clay forms a fairly hard layer around the print, but cleaning impressions in sand is more difficult, as the edge of the print is easily damaged. Generally some leaves or twigs are pressed into the print. If they are firmly embedded in the soil they should be left, but otherwise they should be carefully removed or the loose parts trimmed away. While cleaning tracks, one should not tread on the soil immediately next to the print. In very sticky soils parts of the wall of the prints are partly or completely torn out when the foot is lifted, especially by the outer edge of the hoofs. These should be pushed back gently with the fingertips into the original position.

Cleaning and restoring of old prints needs more skill and patience, and often half an hour or more has to be spent on one print. Prints in sand or loose forest soils are very quickly levelled by the impact of the raindrops, but prints in clayey soils can withstand light rains and occasionally also survive heavy tropical rains. Light rain softens and joins the soil particles that have fallen in the print, gradually filling up the deeper parts of the prints. But usually this soil can be dislodged with gentle action by a pointed twig. In a way the soil fill protects the print against the mechanical impact of the rain. If the soil fill is very moist and the soil around the print still hard, it is best removed by washing with water. Water is poured into the print and the soil fill is loosened with a soft twig, or better still a soft brush. The soil-water mixture is then pumped out of the print with a syringe, which is used also for the final cleaning.

Only under exceptional circumstances can a print survive hard tropical rain. In very sticky and rather dry clayey soils, prints that are shaded from the rain by leaves, rocks, tree trunks or other objects can sometimes remain relatively unaffected and suitable for casting. Sometimes a thin layer of leaves is pressed into the prints and by gently pulling out these leaves, together with the soil fill, the form of the print can be clearly revealed.

Sometimes there were more good tracks and prints than there was plaster available to make casts. The prints that could not be plaster cast immediately were covered with a few large leaves or a piece of plastic, supported by a few twigs, to protect the prints against rain till the next day. Sometimes a rim of clay was built around the print to prevent surface water from filling the print.

### 3.2.4 - The casting

The casts were made with medical or dental plaster of Paris, derived from the mineral gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ). When the powder is moistened it becomes hard or sets. The dental plaster is more expensive, but finer and hardens better. If properly mixed the cast made from dental plaster is fairly strong and can be made thinner, thus saving weight. Dental plaster is sold in Indonesia in convenient 1 kilogram packages. Depending on the size of the print, between 300 and 500 grams of plaster are needed for one cast. Each patrol group usually carried 2 or 3 kilograms of plaster and during the study an estimated 350 kilogram of plaster was used in the field.

The plaster is mixed in an old tin, generally a two-liter cooking-oil tin, with a spatula cut from a branch. Water is taken from a nearby stream or puddle or from water flasks. First the plaster powder is poured into the mixing tin and then water is added gradually, stirring vigorously, until the mixture has the consistency of a smooth light batter. With too little water the mixture will not pour easily, but more water can be added quickly. If too much water has been added hardening takes a long time and the cast will be soft and brittle. In this case more plaster can be added, but it is difficult to make a smooth mixture before it starts to set.

The less water added to the mixture the better, as the cast will harden faster. But the mixture soon starts to set and it must be poured quickly, within one minute of mixing. When the plaster mixture is ready, the impressions of the hoofs are filled first, using the mixing spatula to direct the flow. Then the rest of the print is covered with a thin layer of plaster. When the first layer has thickened somewhat, a second layer is poured on the basis of the hoofs, to reinforce the cast.

When water or very soft mud is left in the prints, the mixture should be made as thick as possible and mixed with the water or mud remaining in the print, using the pumping action of the syringe. If the print is full of water that cannot be pumped out, a very thick plaster mixture is poured in and later more plaster powder is added and left to sink and settle. Casts made in this way remain very soft. Once the plaster has set it will not soften again and the cast can be left in the print and collected later. When the plaster is properly mixed it hardens in 15 to 25 minutes, but maximum hardness is only reached after one or more hours and thorough drying.

After the cast has hardened sufficiently - when a finger nail leaves only a superficial scratch - the cast must be lifted carefully from the print, and the necessary data are scratched on the back. It is generally necessary to dig out the soil surrounding the cast, with a stick or bushknife, then dislodge the casts with one's fingers. Pulling gently upward with both hands will dislodge the cast, but part of the hoofs may break off. The casts were wrapped in soft leaves and carried to the camp, for cleaning with water, using the fingertips to rub off the soil and a pointed twig to clean out hollows. It was then dried as thoroughly as possible. Casts were carefully wrapped in paper and plastic and put in the empty food tins for carriage out of the study area. Each 20-liter tin can hold about 12 casts.

All casts were numbered in the field, and the number with the side (right or left) were scratched on the back of the sole and on each nail. After the casts had been mounted for further study, a new number was given. All casts from one track were given the same number, with a decimal number for each cast, eg. 12.1, 12.2 etc.

### 3.2.5 - Preservation of the casts

After the casts had been transported out of the study area, they were preserved and prepared for further study. Most of the casts were broken, either when they were lifted from the print, or later in transport. Sometimes they were even deliberately broken to allow tighter packing in the tin. It was generally not possible to dry the casts in the forest and therefore they were later dried in the sun for a few days, until the plaster was thoroughly hard. The data originally scratched on the back of the cast was copied on the front, in china ink, and each cast was mounted on a piece of wood, roughly 21 x 27 cm. The broken off pieces were carefully replaced in the original position, and the whole cast was glued firmly to the wooden base with synthetic neoprene wood glue.

When necessary the back of the cast was planed with a kitchen rasp, and protruding parts were supported with pieces of wood or plaster or white cement. Mounting the casts is very precise and time-consuming work. One of the local assistants developed a special skill for this work and mounted most of the casts.

When the casts were mounted they were dried once more, the last soil particles were removed with a needle and a brush, and they were coated with clear varnish, two or three times. Collection numbers etc. were painted on the wooden base. The finished prints were stored in special boxes, long enough for 10 to 12 casts. Three of these boxes fit like drawers in a wooden crate. To protect the tips of the nails of the casts a piece of foam rubber was glued to the back of the wooden base of each cast. All casts were transported from Sumatra to Java in these crates, wrapped in paper, plastic and foam rubber.

### 3.3 - Aids for comparison of the casts

Several techniques were developed to describe, recognise or quantify the characteristics of the casts. It is impossible to capture every aspect of a cast in a set of numbers or pictures, but some characteristics can be expressed in measurements or drawings and this makes comparison easier. After some trials three techniques seemed the most useful: stereophotographs, outline drawings and sets of standard measurements. The stereophotographs were made as backup material in case the cast is lost or damaged. Outline drawings on tracing paper were used to compare the dimensions of the various casts by overlaying them on a light table. The standard measurements were not used in the sorting process, but only afterwards, to find out which measurements on a print are most useful for a simplified identification system.

### 3.3.1 - The stereophotographs

Although stereophotographs were primarily made as backup material, occasionally they were also used to check the features of certain casts. The stereophotographs were made on normal 35 mm black-and-white film, with a 50 mm lens. The cast was positioned in a calibrated frame at the bottom of a special wooden stand, supported by three sliding wedges. By moving the wedges the cast could be placed in a standard position.

The camera was mounted in a slide on the top of the stand, allowing the camera to move parallel with the focal plane. The distance from the focal plane to the film was 85 cm and the best stereo-basis (the distance between the positions where the two photos were taken) was experimentally established as being 50 mm. The pictures were exposed with the help of an automatic electronic flash. The prints were mounted as stereo pairs and filed by collection number. Some are used to illustrate the ensuing chapters. For the stereoscopic effect a pocket stereoscope can be used.

### 3.3.2 - The outline drawings

From each cast an outline was drawn to scale on thin tracing paper. These drawings show the precise contours of the sole and the hoofs, with the hoofs folded out in the plane of the sole. On a light-table several of these outline drawings could be viewed together superimposed one upon another and easily compared. Next to direct comparison of the casts this was the most useful method of comparison.

The drawings were made with the help of a drawing compass and a profile gauge, an instrument consisting of a row of parallel metal bars that slide in a holder. How the profiles and outlines are taken from a cast is shown in figure 3.6. First the points between which the outline will be constructed are indicated with a fine-tipped marker on the cast. The points A form the two base points from which the rest of the outline is constructed. They lie on the basal groove of each side hoof, where this groove is crossed by the contour of the posterior edge of the side hoof, when looking vertically down on the plantar surface of that hoof. The points B are constructed similarly with the frontal edge of the side hoofs.

Point C lies in the middle of the basal line of the front hoof and point D in the heel groove. The other points are placed on the hoofs, point E in the middle of the rim of the front hoof, and the points F on the tips of each of the side hoofs. The tip of the side hoof is that point furthest from the middle of the basal groove. Finally two points are selected on the plantar ledge, the points where the ledge is thickest in the posterior and anterior lobe, of each side hoof. Now the distances between the points A and between the points A and the other points on the sole are transposed to the paper with the drawing compass, fixing the position of each point (A' to D'). The lines between the points A' and D' and between the points B' and C', the contours of the sole in an imaginary transversal plane, are then sketched in.

The outlines of the hoofs are made separately. The outline of the rim or edge is taken with the profile gauge, pressed against the rim of the hoof, parallel to the plantar surface of the hoof, until the rods close neatly around the cast. The rod that rests against the points E or F is pushed back to indicate the position of these points (E' and F') on the rim, and the profile is transferred to paper. For the side hoofs two overlapping profiles are taken, one from the posterior and one from the anterior edge. On the outline of the side hoofs the position of point A' is fixed with the drawing compass and from the points A and F the position of the points B and G are fixed and finally the plantar ledge is sketched through the points G'. On the profile of the front hoof the position of point C is taken over (C'). When all profiles are finished they are drawn again and joined in the points A', B' and C', on another paper, with the line A'A' in a standard position. Collection numbers, measurements and other data are written on the sketch.

### 3.3.3 - The standard measurements

Five measurements were taken from a cast, because they give the most consistent and complete characterization of its overall form, and because the measuring points can normally be located fairly precisely. They can also be taken from a print in the field.

Two of the five standard measurements are taken from the cast, the others from the outline drawings. On the cast the width between the tips of the side hoofs - the points F - is measured with a pair of compasses, and the width of the front hoof is measured with callipers.

The width of the front hoof is measured between two points on the sides of the hoof, as close as possible to the tip, because the base of the front hoof is often not clear in the cast. Because the selection of these points is critical for the outcome of the measurement, a whole series is usually measured together to reduce bias. Figure 3.7 shows some different front hoofs and the positions where they should be measured.

On the outline drawings the width of the sole is measured between the two base points A' and A'F' is measured on both side hoofs and added with the width of the sole to give the distance F'A'A'F', called the span. The distance from the middle of the line A'A' (aa) to the point C' and the distance C'E' are also measured, and together give the length of the sole. All measurements were taken to the nearest millimetre and recorded with the outline drawings.

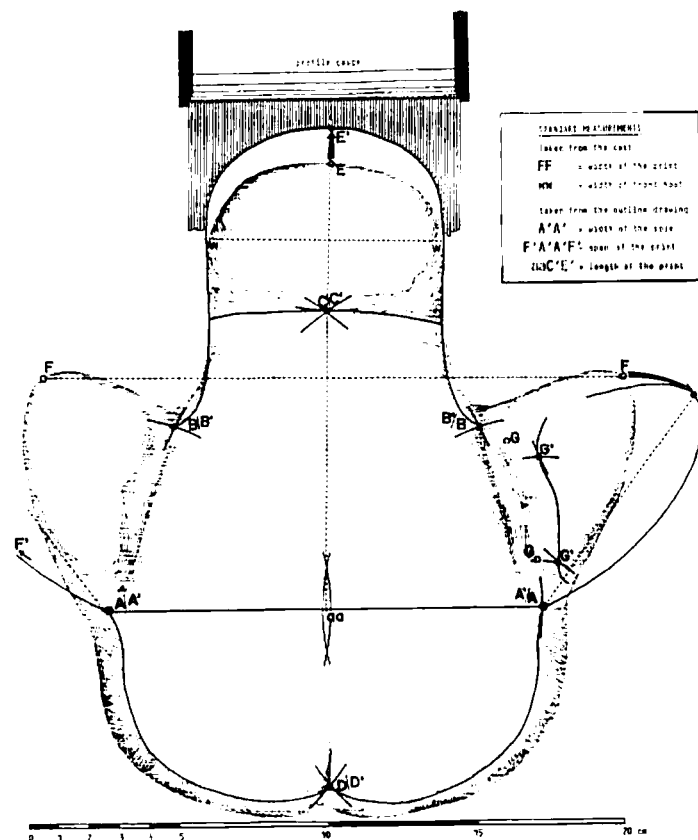


Figure 3.6 - The technique of making the outline drawings and taking the standard measurements of a plastercast. A drawing of a plastercast (no 49.7 L) with the measuring points A - G is superimposed on the outline drawing, constructed around the measuring points A' - G'. The position of the measuring points are taken over from the cast to the outline drawing with a drawing compass, and the profiles of the hoofs are made with a profile gauge. The complete procedure is described in chapters 3.3.2 and 3.3.3

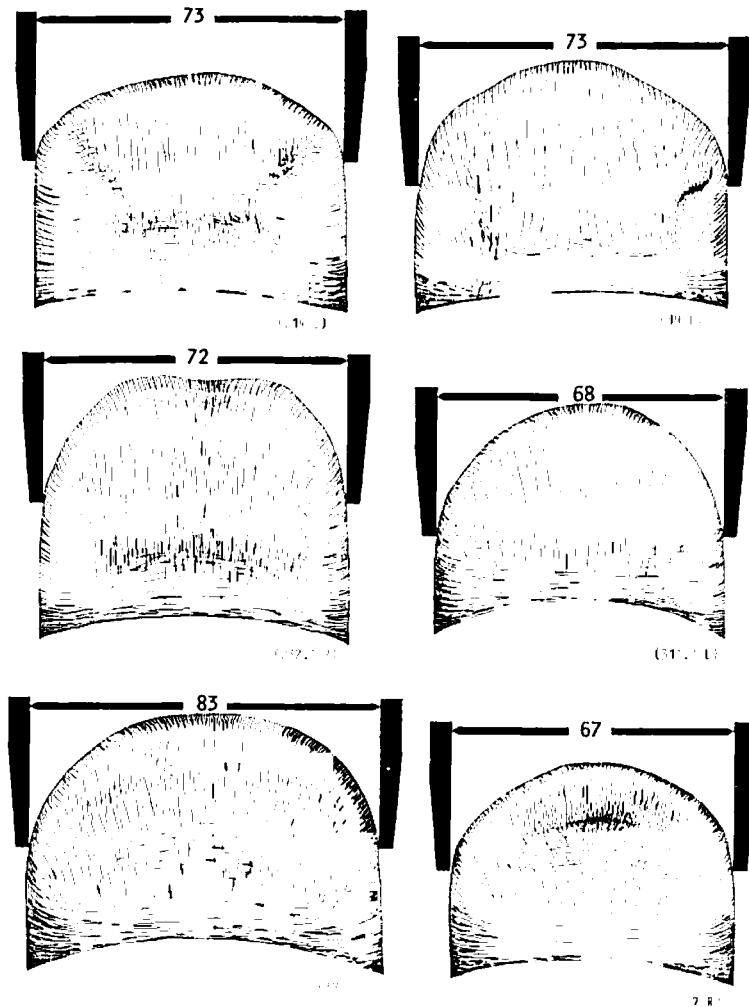


Figure 3.7 - A selection of front hoofs of plastercasts to illustrate the points on the rim where the width of the front hoof is measured.

### 3.4 - Procedure of the sorting and identification of the casts

From the very beginning of the study with plastercasts it was clear that there are characteristic differences between the prints of different tracks, and that prints from the same track are similar in appearance. Some prints, those which show special characteristics in the form of the foot or the hoofs, could be sorted out easily, and these were often already recognised from the print or the cast in the field and given names such as 'flatfoot', 'square', 'thickbase', 'sharp' etc. But the majority of the prints are all rather similar and more difficult to identify to individual rhinos. The casts from one expedition could generally be sorted to different individuals without too much difficulty, but it was much more difficult to decide on sets of casts from the same individual rhino found on different expeditions.

As soon as the first casts became available for further study, attempts were made to identify the different individual rhinos, and gradually the collection was extended. Gradually more insight was gained into the characteristics of the rhinos' feet and how these are expressed in a plastercast, influenced by external factors like soil, weather, position, mode of movement etc. Through lengthy comparisons of large numbers of casts it was learned which part of the physiognomy of each cast reflects the form of the foot and the hoofs, and what is only a deformation caused by external forces or the result of less perfect casting. Perfect prints and casts, showing all parts of the foot with the same detail and sharpness, are extremely rare, and most casts are somewhere deformed or have some parts obscured by objects such as leaves, twigs, stones, tree-roots etc.

Although working with a large number of plastercasts is cumbersome - they are heavy and take up a lot of space - there is no suitable alternative method for identifying casts. Much of the identification work can be done with the outline drawings, but in the end it was always necessary to go back to the casts themselves and compare them one by one, looking for important and often crucial characteristics that do not show in the drawings.

Because correct identification of the casts is vital for interpreting the rest of the study, much attention and time was given to this problem. After the end of the fieldwork the definitive sorting and identification of the casts took place in Bogor, a process that took almost two years or an estimated 2000 hours of part-time work. Casts were spread out on the floor or on special racks, so that they could be compared easily.

Plastercasts were arranged in sets, each set containing all the casts from one track and thus undoubtedly made by the same rhino. Sets with sufficient similarity throughout the study were placed into series, so that a series contains all sets made by the same rhino. Each series was given a three digit number that was recorded on the cast, on the outline drawing and in a logbook. A small number (47) of sets could not be assigned to a series or were of questionable identity, because the casts were incomplete or too bad to show distinctive characteristics.

The whole process of the sorting out and identification of the plastercast collection can be split into two main stages. During the first stage attention was mainly focussed on the sets, the complete collection was systematically reviewed and the outline drawings and standard measurements were made. The first preliminary series were formed, containing casts of a certain general type rather than casts made by one particular rhino. As more sets of casts were examined, the series were further split up. At the end of the first stage, when all measurements and drawings were made, it was clear that the system of series was still far from perfect. Consequently the second stage concentrated on further comparisons until all good sets of casts were assigned to homogeneous and distinct series.

In the first stage of the sorting process the whole plastercast collection was systematically examined three times. The first time all casts from one expedition were laid out set by set, and from each set the best casts were drawn in outline. The second time each preliminary series was laid out, set by set, and the remaining outline drawings were made. More comparisons of casts and drawings were made and the series were further split up in a first attempt to identify individual rhinos. From each series the three best prints of left and right foot were set apart for comparison with other series. These test series were placed on special standing racks for easy reference. The third time the standard measurements were taken from each cast and further modifications were made to the series. This time also other factors, like the place and the time of finding were taken in account. Once casts had been associated to series (belonging to individual rhinos) it was possible to make preliminary distribution maps, showing the movements of individual rhinos.

Initially it was estimated from previous rhino surveys (Kurt, 1970; Borner, 1979), that no more than about ten rhinos would live in an area the size of the upper Mamas. New series were created only reluctantly, but soon there were more than ten series and it became clear that, although the sorting and identification was far from completed, that there were considerably more rhinos in the study area than was previously thought and the number of different small tracks indicated that several births had occurred during the study.

In the second stage the series were checked for homogeneity within the series, and they were compared with other series. Whenever a set was removed from one series to another the complete series were reviewed again, and most series have been scrutinised many times. Careful examination was made of the cow and calf pairs, to find out which sets formed the continuation of the series after the cow and calf had separated.

At one time there seemed to be more than 60 series (apparently representing 60 different individuals) but closer examination revealed that some series were very similar and occurred in the same area, and others seemed to replace one another in the course of time. After close examination several series could be combined, because the differences could be explained by differences in soil condition or position of the foot, or by gradual changes of the shape of the hoofs, and the total number of series was reduced to 39.

When sets or series of casts were compared, the procedure aimed primarily at checking the casts for similarity, that is to show that the casts could have been made from prints of the same pair of feet. When the differences were such that the casts could not have been made by the same feet, the consistent distinctive characters were sought. The main criteria used to show similarity were those of dimension and form. The dimensions show most clearly in the outline drawings, that were compared by overlaying them on a light table. Form was further compared by laying the casts side by side. The standard measurements were not used, because they show a large individual variation (see chapter 10) and are, in essence, also incorporated in the outline drawings.

The overlaid outline drawings were checked for a "good fit", not only of the whole outline but also for the form of the plantar surfaces of the hoofs. The outline of the foot was considered to have a good fit if the lines followed the same curve, deviating not more than a few millimetres to either side, especially along the hoofs. The variation on the soft parts of the foot, between the hoofs and the heel part are of course much wider. Because the hoofs are not fixed on the foot, moderate shifts in position of one or more of the hoofs was allowed. The front hoof might be shifted to the left or right and the side hoofs can be rotated for 5 or 6 centimetres around the centre of the foot and can also be shifted one or two centimetres in- or outward (see the figures 3.19 and 3.20, showing outline drawings that were considered to have a good fit). These variations in the position of the hoofs are mainly caused by soil type and the animal's movement (see chapter 3.5.2 and 3.5.3). By moving the sheets of outline drawings on top of one another one can see fairly easily whether differences in position are within reasonable limits or not. Especially on the sharp posterior edge and around the tips of the hoofs, the lines should not deviate more than one or two millimetres and only for part of the curves, in good casts.

When the outline drawings of casts were considered to have a good fit their condition was reviewed to see if the casts were of comparable quality and made under comparable conditions. If there was no good fit, the casts were checked to see if this could have been caused by imperfections or deformations in the casts. The form of the sole and the hoofs, and the position of the hoofs are important criteria, as well as minor features like the development of the basal ledges and the curvature of the plantar surface.

When comparing outline drawings or casts, the condition of the casts is of prime importance, to judge whether differences reflect real differences in the foot that made the print or are caused by external factors such as soil condition. The variation in size between casts from the same track can be considerable and many aspects of the form of the foot can only be seen in some of the casts. Whether a difference in size or form of the cast is significant will depend very much on the quality of the plastercast. For example a difference of only 2 mm in the width of the front hoof might be significant when the casts are very good and sharp, but with less good casts tracks from the same animal might vary by as much as 10 mm.

Therefore one can never rely on just one characteristic, but must consider all aspects of dimension and form before deciding whether or not the casts could have been made by the same pair of feet, i.e. by the same rhino. Here experience helps with judgement. Sorting and identification of plastercasts is a slow and exacting process with some casts identified easily and others allocated to a series only after long and continuous examination.

When sets were recognized to be similar they were allocated to the same series. If a set of casts was found to be different from the rest of the series, it was removed from the series and checked against other series. Series were continuously re-assessed and several times other evidence indicated that one series contained tracks of two animals. For example, in a certain period tracks of this series were found with a calf, while other tracks without a calf were found, or tracks were found at widely separated locations at about the same time. Circumstances like this proved that certain sets could not be from the same animal and that the series should be split, even though the tracks were similar. Morphological differences alone were sometimes insufficient to justify splitting a series. Sometimes as better casts became available minor differences were detected between sets and a series was split.

The process of sorting and identification came to an end when further comparisons failed to reveal more aberrant sets or series that should be split or merged. All aspects had been considered and weighed carefully and repeatedly. All good sets were placed in series that showed

good homogeneity or reasonable modification with age, and were unambiguously distinct from one another. At the end of the process there were always the same sets, mostly incomplete and made from very old tracks, that posed problems in the identification. During the last review, when all series were laid out and compared for the last time, a decision was made concerning all doubtful cases and from that moment on the identification was not changed anymore.

In total 39 different series, representing tracks of 39 individual rhinos, were represented in the plaster collection and from these records information was obtained on distribution and ecology of the Sumatran rhino as described in chapters 4 to 8. It is impossible to describe all sets of casts with reasons for the identification, but in the next chapters the formation of one exemplary series will be described in detail and its characteristics will be compared with a number of other series.

In chapter 3.9 some recommendations will be given for future studies in which plastercast identification may be attempted.

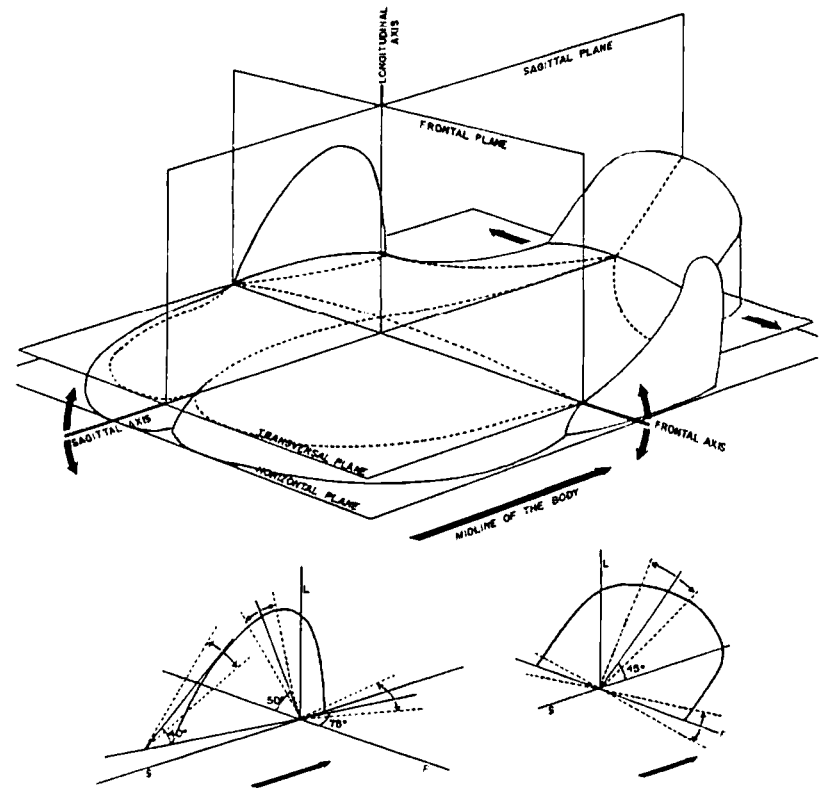


Figure 3.8 - Stereographic model of a foot and hoofs, illustrating the planes and axes that can be used to describe the form of the foot and showing the usual or normal positions of the sole and hoofs

### 3.5 - Characteristics and variability shown in the casts

#### 3.5.1 - General characteristics

In this chapter the various characteristics of size, shape and position of the foot and the hoofs, as visible in the casts, will be described. Some of the different forms and postures are illustrated with stereophotographs and drawings of example casts. Since no previous study had attempted to identify individual animals from plastercasts it was very much a question of trial and error to develop a suitable technique for comparing casts taken at different times and on different soils and places. The technique of comparison and the importance of the various characteristics of the casts were learned during the sorting of the casts and therefore the sorting procedure has been explained first.

Size is an important characteristic and in the tracks in the field one can easily distinguish four to five size classes, besides the very small prints of calves. This is about as much as can be distinguished by measuring the width of the print. The casts themselves could easily be separated into size classes. Later the size and dimensions of the casts were used by comparing the outline drawings (see the previous chapter and chapters 3.6.1 and 3.6.2, where a whole series is discussed). Another aspect of size, the standard measurements, were not used to identify the casts, but only afterwards to evaluate their usefulness in censusing rhino.

The type of the soil and the movement of the animal affect the form and the size of the cast. Within one set the values of the standard measurements vary between the casts and within one series the variation is even larger. In figure 10.4 in chapter 10 the variability found in one set (49) and within the series (520) is shown graphically. The differences between the largest and the smallest values in one set may be as much as 10% (6 mm for the width of the front hoof, 39 mm for the span, 28 mm for the sole, etc.) and the variation in the whole series lies between 15% and 30%. For the comparison of individual casts these values are not very useful.

Figure 3.8 is a stereographic model of a typical cast and of typical hoofs in the most common or normal position, showing the planes and axes that can be used to describe its form. The arrows indicate deviations from the normal position. An abnormal position of the foot or hoofs in the cast can often be explained by the terrain or the movement of the animal, but in some series there are more consistent deviations in the position of the foot. In some the transversal plane is generally not parallel to the horizontal plane (the flat backside of the cast is the horizontal plane). In a few series the foot appears to be either more inclined towards the front hoof, with the fore part of the print being deeper, or towards the heel. In other series the foot shows an inclination towards one of the side hoofs or the front hoof is shifted sideways with respect to the sole and the side hoofs. These deviations from the normal position, probably caused by differences in gait or in the way the animal puts weight on the foot, are relatively rare and often of limited importance for the identification, because larger deformations can be caused by terrain or movement and mask the supposed asymmetry of the foot.

The print of the flexible sole of the foot is not very distinctive; its form is largely determined by the soil and the type of movement. The only useful characteristic is the ratio of length to width. Some prints have a rather long and narrow form (See the stereophotograph of cast 78.2 L (series 140) in figure 3.24), with a long narrow portion in front of the side hoofs; others are short and broad, with a short, somewhat tapering, front portion (See the stereophotographs of cast 38.1 L (series 840) in figure 3.24).

One of the most important characteristics of the foot is the position of the hoofs, with respect to one another and to the midline of the foot. This position is fairly constant, even when the foot is deformed. It is also one of the few characteristics generally visible in bad prints, and it is therefore of great importance for the identification of the less than perfect prints, that form a substantial part of the collection.

The front hoof generally makes an angle of about 45° with the transversal plane (See figure 3.8 and the stereophotographs of casts 49.7 L (series 50) in figure 3.9 and 38.1 L (series 840) in figure 3.24). But in some series this angle is considerably smaller (See the stereophotograph of cast 78.2 L (series 140) in figure 3.24), in others larger (See the stereophotographs of cast 71.3 R (series 196) in figure 3.24 and cast 26.3 L (series 440) and 200.2 L (series 440) in figure 3.14). In most series the midline of the front hoof is more or less in the sagittal plane, but in a few series the front hoof is tilted towards the side (See the stereophotograph of cast 58.3 R (series 296) in figure 3.25).

The side hoofs show more variation in position. In most series both side hoofs lie symmetrically on either side of the midline of the foot (See the stereophotographs of casts 276.3 R (series 192) in figure 3.25, set 49 (series 520) in figures 3.9, 3.12, 3.14, cast 38.1 L (series 840) and cast 78.2 L (series 140) in figure 3.24), in others there is clear asymmetry, with one hoof lying in a different position from the other (See the stereophotographs of casts 58.3 R (series 296) in figure 3.25, cast 71.3 R (series 196) in figure 3.24, cast 26.3 R (series 440) and cast

200.3 R (series 440) in figure 3.14). Sometimes there is also a difference between the right and the left foot.

The most common or normal position of the side hoof is shown in figure 3.8. The plantar surface of the hoof makes an angle of about 50° with the transversal plane, and an angle of about 75° with the frontal plane. The tangent line at the middle of the posterior rim makes an angle of about 40° with the transversal plane. The normal position of the side hoofs is best demonstrated in the stereophotograph of cast 276.3 R (series 192) in figure 3.25.

In some series the tangent of the posterior edge is smaller, and the side hoofs are pointing forward (See the stereophotographs of cast 27.2 R (series 700) in figure 3.25), in others it is larger and the hoofs are pointing sideward or upward (See the stereophotographs of casts 58.3 R (series 296) in figure 3.25 and cast 71.3 R (series 196) in figure 3.24). If the plantar surface makes a smaller angle with the transversal plane the prints are flat (See the stereophotographs of casts 38.1 L (series 840) in figure 3.24 and 259.1 L (series 610) in figure 3.26), if the angle is large the hoofs protrude more than usual from the plane of the sole (See the stereophotographs of the casts 58.3 R (series 296) in figure 3.25 and cast 71.3 R (series 196) in figure 3.24).

The most significant aspect of the position of the side hoofs is the angle with the frontal plane, because this angle is apparently fairly constant and under most circumstances clearly visible in the prints and casts. In the most common or normal position the plantar surface, in particular the tip half, makes an angle of about 75° with the frontal plane, which means that the plantar surfaces of both side hoofs converge slightly toward the front hoof (See the stereophotograph of cast 276.3 R (series 192) in figure 3.25). In some series the plantar surfaces of one or both of the hoofs converge more strongly (See the stereophotographs of cast 58.3 R (series 296) in figure 3.25 and cast 71.3 R (series 196) in figure 3.24), in other series the plantar surfaces of the side hoofs are almost parallel to each other or there can even be slight divergence toward the front hoof (See the stereophotographs of casts of set 49 in figures 3.9, 3.12, 3.14).

The form of the hoofs is very variable. Apart from size the front hoofs vary in the ratio between length and width, in the general outline of the nail, in the thickness of the rim, in the development of the basal ledge and the side lobes. Some show peculiarities like a point or notch in the middle of the rim, very thick side lobes, a hollow plantar surface or asymmetry. To illustrate the differences and the rate of variation encountered, a front hoof from each series is shown in appendix A.

The side hoofs show very much the same sort of differences, and drawings of a selection of these are also shown in appendix A. All drawings of the hoofs are to size and based on the outline drawings of the best casts from each series, with the structure of the plantar surface shaded. The drawings are idealised, and sometimes details were taken from other casts. Generally less detail is visible on one single cast.

No two casts are identical, not even those in the same set and made by the same foot. Even between two good casts of the same foot there are always some differences in size and shape and for sorting it is very important to know how the form can be influenced by external and internal factors. One should be able to see how the cast might have been deformed and to what degree the cast still reflects the original shape of the animal's foot. In the following chapters a general account will be given of the kind of differences that were noted due to environmental factors, e.g. soil condition, and the gradual changes in shape that can be attributed to growth and aging or other factors that influence the shape of the rhino's foot. Some characteristic series will be described in detail.

External factors that influence the shape of the print and the cast are the soil - texture, composition and moisture - and the type of movement of the animal - speed, slope, direction. Changes in shape take place in young animals through growth, but were also found in full grown individuals, apparently caused by changes in balance between growth and wearing of the hoofs. Occasionally injuries to one of the hoofs caused changes in shape.

#### 3.5.2 - Influence of the soil

Some remarks on the influence of the soil on the prints have already been made in the chapters on the selection and cleaning of the print (chapters 3.2.2 and 3.2.3). Here the effects will be described in more detail and illustrated with some characteristic examples from the collection.

All the best casts came from prints that were made in moist clayey soils, at places where there was no litter or stones. A fine example of such a cast is shown in figure 3.9 (Set 49, series 520). This is one of the most perfect casts ever made and it can be assumed that the form of the cast is a fairly precise copy of the foot of the rhino. Suitable soils with the right degree of plasticity were only found in certain places and the predominant soils in the

Figure 3.9 - Stereophotographs of three plastercasts made in different types of soil

A - An unidentifiable cast made in forest soil heavily mixed with plant remains. Soils of this type are common in the study area and good clear prints are rarely found there

B - A cast (series 195) made in sand along a riverbank. The hoofs appear to be more massive and fine detail cannot be seen

C - A near perfect cast (series 520) made in fine moist clay. Soils with the right degree of plasticity and free of litter and stones are only found in particular places, for instance around wallows, siltlicks, and on the major trails

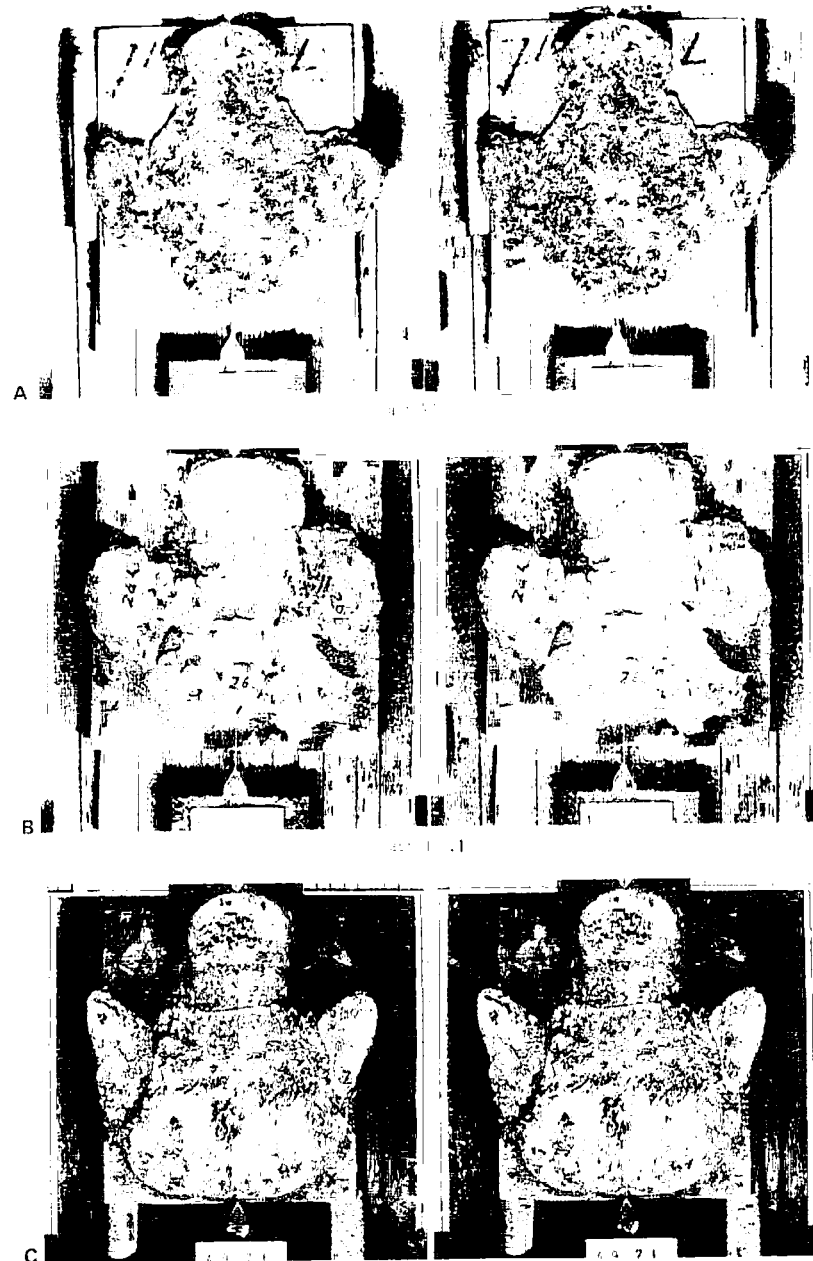


Figure 3.10 Stereophotographs of three plastercasts of the same animal (series 460) made in soils with a different degree of firmness:

A - A cast made in hard chalky soil near a saltlick. The print is very flat with the hoofs protruding little from the plane of the sole



B - A cast made in much softer soil. The hoofs are in the usual position. Whenever possible prints like this were selected for casting



C - A cast made from a very deep print in very soft soil. The hoofs project far from the plane of the sole and are in an unusual vertical position



Mamas were much less suitable for good and clear prints. These dark forest soils are superficially heavily mixed with plant humus and covered with a thin layer of dead leaves. They are generally crumbly and rather spongy and casts taken there show little detail; often also the form is blurred because of the nature of these soils. A typical example of a cast taken in such a soil is shown in figure 3.9 (set 47, unidentifiable). Casts of this quality were generally unidentifiable and were only made in desperation when better prints could not be found.

Prints left in the coarse sand by major rivers appear to be very good, because of the uniformity of the sand, but generally the casts turn out to be not very useful. The prints are difficult to clean without disturbing the print and the fine details do not show in the coarse sand. Because some sand is cemented to the plaster the hoofs appear to be much more massive on casts made in sand than on casts made in finer soils. A typical example of a cast made on a sandbank along the river is shown in figure 3.9 (Set 162, series 195).

The firmness of the soil plays an important role in the form of the print. The firmer or harder the soil the shallower the print and the more the hoofs are forced into the same plane with the sole. On really hard soils, like dried-out clay or salterusts, round salticks only the tips of the hoofs are visible as short crescent-shaped imprints and the central part of the sole forms a shallow impression. These prints are useless for identification, because the base of the hoofs are not visible. The softer the soil the more vertically the hoofs are placed and the more they appear to project from the plane of the sole. In fairly firm soil the front hoof has its plantar surface in a close to horizontal position, and the forepart of the sole is flat. The softer the soil, the more the front hoof is placed in a vertical position, and ultimately virtually vertical. In very soft soils the forepart of the sole becomes strongly concave.

The influence of soil firmness is well demonstrated by the prints shown in figure 3.10 made from two sets found on the same expedition and assigned to the same series (sets 142 and 144, series 460). Cast 142.2 R was found in the hard chalky soil around one of the salticks, showing a very flat print, with the hoofs protruding little from the plane of the sole. The middle picture shows a cast - 144.2 R - of the foot in normal position, in moist and moderately soft soil. The third picture shows a cast - 144.4 L - of a print that was made in deep, wet and very soft soil. Here the hoofs are sticking out very far from the plane of the sole and they are in an unusual vertical position.

In figure 3.11 the three outline drawings of the same casts are shown superimposed (The left foot reversed). Apart from the fact that the hard soil print is slightly narrower and longer, all three outlines are very similar, showing that the different positions of the hoofs are largely compensated for when outline drawings are made. In general the use of outline drawings allows for easier comparison of prints made under different soil conditions.

It will be clear that this can have a great influence on the dimensions of the cast, especially on the width of the print. Flynn & Abdullah (1983) reported that tracks made in soft, muddy soil were significantly larger than tracks made on firm ground, by as much as 2 to 4 mm. For the Indian rhino (*Rhinoceros indicus*) Laurie (1978) reported differences of up to 10 cm in the width of footprints of rhino tracked through wet and dry areas. However, measurements taken from the same animal's tracks made in hard and soft soil in the Mamas showed only very slight differences. This can probably be explained by the different ways of measuring in the two studies. Measuring the width of the print between the tips of the hoofs with a pair of callipers is likely to reduce the influence of the soil, except in extremely wet or dry soils.

Often one of the hoofs is forced into an unnatural position by a stone or tree-root under the foot. Sometimes very peculiar prints are made, but it is generally obvious what has caused the deformation and these casts do not pose special problems in identification. Similarly overlapping imprints of fore and hindfoot can create front hoof casts that appear to be unusually wide to the casual observer.

The form of the hoofs as well as of the whole print is influenced by the firmness of the soil. In soft, wet soils, the hoof prints are considerably narrower and thinner, with a sharper edge. This is probably the result of a sucking action when the foot is lifted from the wet soil and collapse of the soil especially in very deep prints.

The reduction in size of prints in soft soils is most noticeable in the width of the front hoof, where the variation can be several millimetres. A good example is illustrated in figures 3.9c and 3.12a, showing stereophotographs of several casts from the same set. Cast 49.2 L (figure 3.12a) is a typical example of a print made in rather deep and soft soil, whereas cast 49.7 L (figure 3.9c) is made by the same foot in firmer soil. The hoofs of the cast in wet soft soil are slender and sharper than those from the firmer soil. In the outline drawings of these casts, shown in figure 3.13, the difference in width of the front hoof is apparent (almost 10 mm).

Because the width of the front hoof is one of the standard measurements, a simple experiment was carried out to demonstrate the influence of the soil on this parameter. A model of a front hoof was fashioned from wood, attached to a pole with a footstep. By standing on the footstep the hoof model could be pressed into the soil, and then lifted out with the pole, thus suggesting the walk of a rhino. Several series of imprints were made in suitable places, and casts made from the best imprints. After drying the casts were measured in the usual way.



The width of the artificial front hoof was 69.0 mm. The first series of casts was made in rather dry yellow clay, and the average width of the casts was 66.98 mm ( $n=5$ , s.d. 1.72). In a second series made in wet sandy clay the average width was 64.44 mm ( $n=16$ , s.d. 1.19). The last series was made in rather dry, hard sand and the average width was found to be 69.87 mm ( $n=18$ , s.d. 1.14). The lowest value in all three series was 61.2 mm, the largest was 73.2 mm.

Even prints made with an object of known size - the wooden hoof - vary considerably in width, variations which can be attributed to the character of the soil and probably also the animal's movements. The prints made in drier soils are fairly close in size ( $\pm 2$  mm) to the original hoof, but the casts from soft soil are narrower - sometimes by 1 cm or more - than the original. Usually the surface of the cast shows the subtype where it was made.

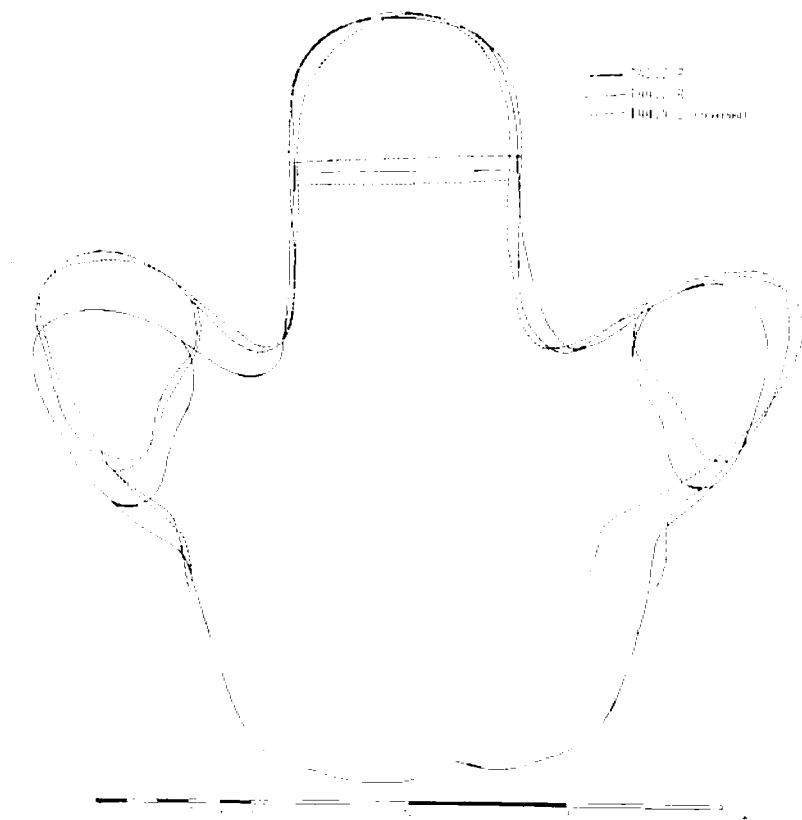


Figure 3.11 - The superimposed outline drawings of the same three cast shows in the stereophotographs in figure 3.10. The large differences in position of the hoofs seen in the casts show only little in the outline drawings. Differences caused by varying soil conditions are largely compensated for when making outline drawings, making comparison of prints more easy.

### 3.5.3 - Influence of the type of movement

The most important influence on the form of the print is that of slope of the terrain. There are clear differences in the position of the hoofs in relation to the slope. When a rhino is descending the side hoofs are spread outward and backward. When it ascends the side hoofs are much more vertical, much closer to the sole and more forward. The steeper the slope the more pronounced the effect is. Prints made on level or slightly sloping terrain are intermediate. Prints on ascending tracks are much narrower and prints on descending tracks are wider than those on level ground.

When a rhino changes direction in its walk the symmetry of the foot can be distorted with the front hoof shifted in the direction of the turn. Also the speed of walking influences the shape of the print. Most prints were taken from rhinos that apparently walked at leisure, but some were taken from animals that were running. In the latter case the hoofs are more than usual splayed and projecting, while the sole is flatter or even concave, probably due to greater pressure on the foot.

Good examples of the influences of soil and movement are found in set 49, series 520, stereophotographs of which are shown in figures 3.9c, 3.12 and 3.14a. Cast 49.7 (figure 3.9c), one of the most perfect casts ever found, was made in very fine plastic clay. Cast 49.3 L (figure 3.12b) is a good cast, but made in softer soil, showing the more pronounced profiles. Cast 49.2 L (figure 3.12a) was made in very soft soil, and shows the protruding hoofs and the slender and sharp rimmed appearance of casts taken from too soft soils. The front hoof is also considerably narrower than in the other prints. Cast 49.5 L (figure 3.12c) was made in rather firm soil, but on an ascending track. The shortening and narrowing of the print during climbing is obvious. Cast 49.6 R (figure 3.14a) was made in firm soil, but on a left bend of the trail.

In figure 3.13 the outline drawings of these casts are shown. The differences between 49.7, from firm clay, and 49.3, from the softer soil, are slight, with only a shift in position of the hoofs probably due to a meandering walk. The cast from very soft soil (49.2) is slightly wider with narrower hoofs. Torsion caused by turning (49.6, in reverse), and the compression caused by climbing (49.5), are also reflected in the outline drawings.

The type of movement influences the print width. Flynn & Abdullah (1983) analysed several series of print width measurements made under different conditions. In a track series of animals walking uphill the width measurement distributions tended to be skewed to the right, and when walking downhill the distributions tended to be skewed to the left. Similar results were shown by a series of print width measurements made during this study. Some examples are shown in table I below. For each series the measurements were made on different parts of the same track.

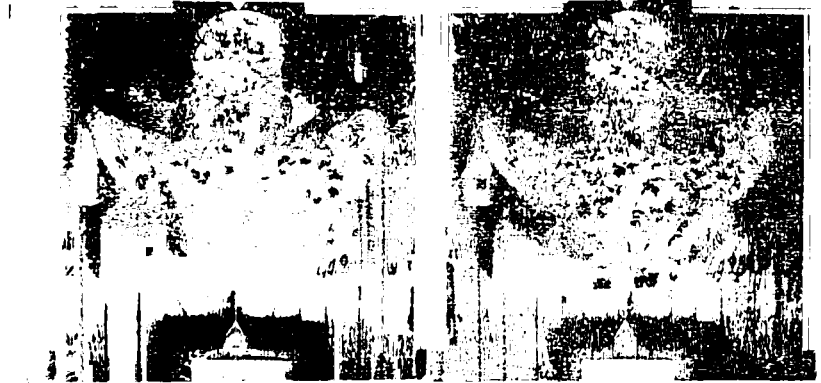
Table I: Influence of slopes on the width of rhino footprints. (sizes in mm)

		number	mean	standard deviation
series 168	descending	9	222.6	4.4
	horizontal	12	221.7	10.7
	ascending	18	182.7	5.3
series 520	descending	5	217	7.4
	slightly asc.	18	207	16.5
	strongly asc.	10	189.6	13.4
series 196	descending	10	219.3	4.9
	slightly asc.	5	203.6	10.0
	strongly asc.	10	196.1	10.0

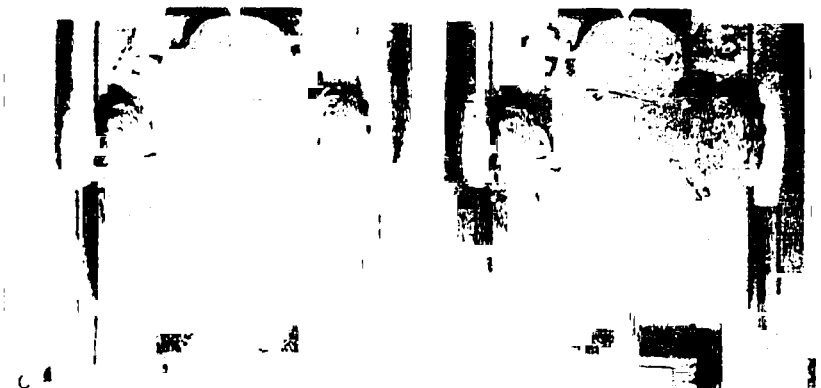
Descending tracks are slightly wider than horizontal or ascending tracks on a slight slope, and climbing tracks are considerably narrower. This is clearly visible, also in the field, and is explained by the varying burden on the hoofs, that forces them apart in descent and into a more forward and inward position for ascent. For track measurements one should therefore select level or gently sloping terrain if possible. For choice no tracks should be casted or measured on slopes steeper than about 10 degrees.

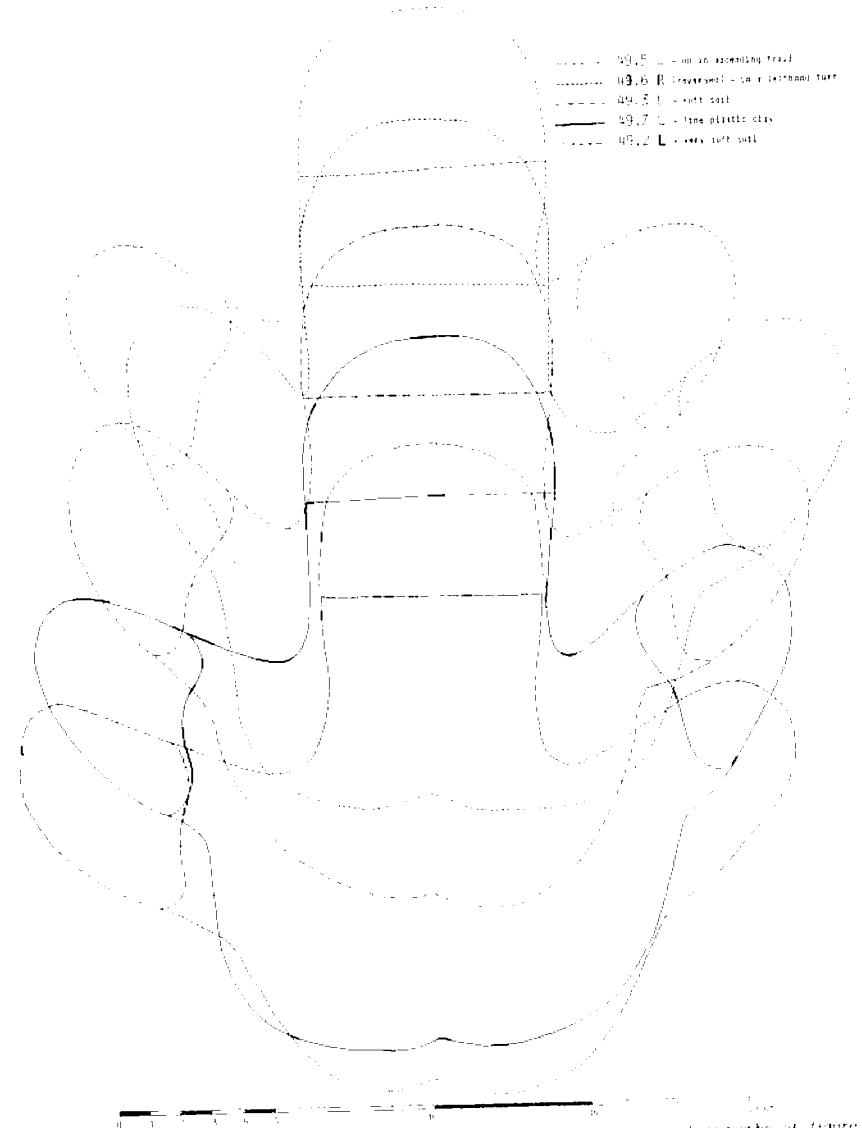
Figure 3.12 - Stereophotograph of three photographs of the same animal, showing difference in hoof shape attributable to difference in soil and movement. The stereophotograph on the page 49 and 51 is a part of this series.

A - A cart made in very soft soil, showing the typical form with butting hoofs that are narrow and harp-rimmed. The profiles of the hoofs are often unreliable in these carts.



B - A cart made in soft soil, showing a pronounced or harp profile, but to a lesser extent than in the photograph above. This is a good cart showing most characteristic.





**Figure 3.13** - The outline drawings of the same casts shown in the stereophotographs of figure 3.8c, 3.12 and 3.14a. All casts are from the same track, showing differences caused by soil and movement. The differences between the lower three profiles, made in soils of varying plasticity are slight, the one made in very soft soil (49.2) is slightly wider with narrower hoofs. The torsion because of the turn in the trail (49.5) and the compression of the foot while climbing (49.5) are clearly visible in the outline drawings too.

### 3.5.4 Gradual changes in size and shape

The changes in size and shape of the footprint of the growing calf are discussed in chapter 4.1. Here the changes that were observed in the footprints of full grown rhinos will be analysed. From the beginning it was anticipated that certain changes might occur. The form of the hoof is the result of its growth and the rate of wearing down through contact with the ground. When both counteracting forces are constant the resulting shape of the hoof will also be constant, but when they are not constant, changes in shape can be expected. The growth of the hoof will be influenced by the condition of the animal, and wear will be influenced by ground conditions and by the activity pattern of the rhino. Although it was expected that the shape of the foot of full grown rhinos would remain essentially the same over the relatively short period of the study, changes in certain aspects of the print were anticipated and during the final sorting it became obvious that this was so.

Such changes are best illustrated in series 440, one of the females that nursed a calf in the northern corner of the study area. From this rhino several complete sets, with generally good casts, were available and identification was aided by the presence of a calf from the 7th till the 10th expedition. Two sets, that undoubtedly belonged to this series, were found from before the calf was born. All material until the 10th expedition was very uniform and showed several typical features, establishing the animal's identity beyond doubt. But initially it seemed we had no casts from this female after the 11th expedition, when her infant had become independent. Good rhino prints were found later in the same area, virtually on the same trail leading north from the saltlick at camp Uning, but they seemed sufficiently different to be classified as another rhino.

Closer examination revealed that there were real differences (the casts were of such quality that the differences could not be explained otherwise), but that they were caused by only one parameter, the length and form of the side hoofs. In all other aspects (overall size, front hoof, the rather peculiar position of the side hoofs) they were identical and it seemed likely that they were made by the same female, but that the length and form of the side hoofs had changed over the course of time. When the shape of the side hoofs in the older sets was studied more carefully, it was found that the length of the hoofs showed a gradual reduction in length from one expedition to the next and the later series was merely a continuation of this process. It was therefore concluded that the earlier and the later sets were made by the same rhinoceros, and both series were merged.

In figure 3.15 the outlines of the best side hoofs from each set are pictured. The left foot prints were chosen because they form a more complete sequence of good casts. It is clear from the figure that the lateral hoof shows marked changes in shape, while the median hoof remains more or less constant. In the earliest sets the lateral hoof is long and has a very wide tip, becoming more triangular on the 9th and 10th expedition and shorter and broader in the later expeditions. It appears that it becomes more rounded again in the 16th expedition. In figures 3.14b and 3.14c a stereophotograph of an early print of series 440 (26.3.1, expedition 4), and one of the later casts of this series (200.2.1, expedition 13) are shown.

Series 440 is by far the best documented series in which an apparent change in shape has taken place, but it was also found in other series. In series 158 a very large change in the length of the side hoof was found, in the lateral as well as the median hoof. A similar effect was noted in series 196, but only in one hoof. Prints belonging to both series were only found at long intervals. Some of the sequences of side hoof profiles are shown in figure 3.16. All show an extreme shortening in the length of the hoofs. In the right foot of series 158 the tip of the lateral hoof has apparently broken off. This is also visible in the other casts of this set. Most of these casts were kept in separate series until good proof of the occurrence of changes in size in side hoofs was found in series 440. Then these other casts were also re-examined and several problems of identification could be cleared up.

Injuries to the hoof were found relatively seldom. In series 155 the left foot shows a notch in the posterior rim of both the side hoofs from the 10th expedition. In subsequent expeditions this developed into a straight or slightly hollow section in the edge, but on the 16th expedition the edge again showed the usual curve. Sequences of profiles of series 155 are shown in figure 3.17. Similar notches were seen in some of the hoofs from the Bogor Museum. One of the calves had a large chunk, the median quarter, of the front hoof broken off when it was about 6 months old. On the next expedition, about three months later, this injury was still faintly visible as a flattened off part of the rim, but two months later the front hoof had a normal rounded profile.

For comparison in figure 3.17 (lower row) an arrangement of side hoof profiles of all the casts of set 49 is included, demonstrating once more the variability in casts from the same hoof. All lateral hoofs of both left and right foot are pictured (those of the right foot are reversed for comparison). The curve of the edge is very similar in most drawings, except for the lower part of the hoof. The base of the hoof is usually less well preserved in the print, and this part is more flexible. The thin edge of the hoof is usually fairly constant, but the basal part

varies in curve and length. In cast 49.2 the basal ledge appears to be much higher, but that is probably an error, because the ledge is hardly visible in the cast (See figure 3.12a). Also the profiles of 49.1 and 49.4 are different. Cast 49.1 has a little point near the tip and 49.4 is longer and more forwardly curved. Both aberrations are caused by a forward drag of the foot from the place of rest. This is fairly common and the hoofs cut a furrow in the soil, that is also filled with plaster during the casting. The tip and the anterior edge of the side hoofs are then often not clearly visible, causing aberrations in the outline drawings as demonstrated here.

Because substantial changes in shape of the side hoofs are apparently not unusual, sequences of side hoof profiles were also made for some of the better series that did not show clear changes. Two of these are shown in figure 3.18 (Series 520 and 610). Series 520 was found to show a slight shortening of the side hoofs, and at one stage of the sorting process this led to the splitting up of this series (see chapter 3.6.1). In series 610 no change in length can be detected, but it appears that the profile is more triangular in the older casts and more rounded in the later sets.

A few of the outlines do not fit very well in the series. In series 520 cast 66.3 is longer and cast 120 shorter than the rest. Both are cast from old tracks. Cast 66.3 made in rather moist soil and the tip of the hoof is not very well preserved. Cast 120 was made in hard soil and required much cleaning and restoration before the casting, and the tip of the hoof was probably not cleaned out sufficiently. In series 610 cast 79.1 is longer with a broader tip, but this hoof is a double print with parts of the print of the fore-foot also preserved and it is difficult to see where the tip of the hindfoot hoof should be located.

It seems that large changes take place only in the side hoofs of some of the individuals. In no series was a notable change observed in the size or shape of the front hoof. It also appears that changes in shape of side hoofs are more common in females than males, and were never seen in the tracks of young or sub-adults. Such changes might be related to pregnancy, because both series 440 (figure 3.15) and 158 (figure 3.16) have the longest hoofs before birth or when the calf is still young and much shorter hoofs by the time the young is independent and in series 440 it seems that the hoofs are again a little longer later. The females have different ranges when they are with a calf and probably their activity pattern is also different then (see chapter 5.1.1); this could shift the balance between growth and wear of the hoofs.

The climate probably also plays an important role in the trends in hoof shape described above. It is well known that the growth and resiliency of the horse's hoof is greatly influenced by moisture. In a moist climate, when the ground is soft and muddy, the hoofs appear to grow more rapidly, but they also become weaker, more pliable and less elastic than normal, and they tend to lose their most efficient shape. The moisture causes the horn tubules to loosen and the hoof is subject to injury. Also the type of food available to the horse is known to influence the quality of the horn and thus the shape of the hoofs (Emery, Miller & Van Hoesen, 1977).

The amount of rainfall and the duration of the dry periods varies considerably from year to year in the Gunung Leuser area. In some years the soil will probably never dry out, in others the soil can be dry and hard for a few months at a time. The very long side hoofs were only found in the first half of the study, but since detailed weather records are not available, no correlation can be made. In the first half of the study there was certainly more rain during the expeditions than in the second half, but that could be coincidence. Rainfall in Ketambe was fairly high in 1974 (i.e. 3450 mm) and 1975 (3591 mm, 221 rain days), about average in 1976 (3260 mm, 211 rain days), 1977 (3199 mm, 212 rain days) and 1978 (3126 mm, 193 rain days) and low in 1979 (1980 mm, 206 days). It could be that the occurrence of excessively long side hoofs is caused by a prolonged period of uninterrupted wet soil conditions in 1974 and 1975.

Figure 3.14 - Stereophotographs of plastercasts

A - A cast made on a left bend of the trail, showing distortion of the foot. This is a rather exceptional cast, normally torsion is much less obvious (Series 520)

B - A cast of an early print of series 440, showing long and slender broad-tipped side hoofs. Compare with the photograph below

C - A cast of a later print of the same series 440, with much shorter triangular hoofs. Compare with the figure above. From the period in between a series of casts is available, showing a gradual change from the long and slender hoofs to the shorter triangular type (see figure 3.15)



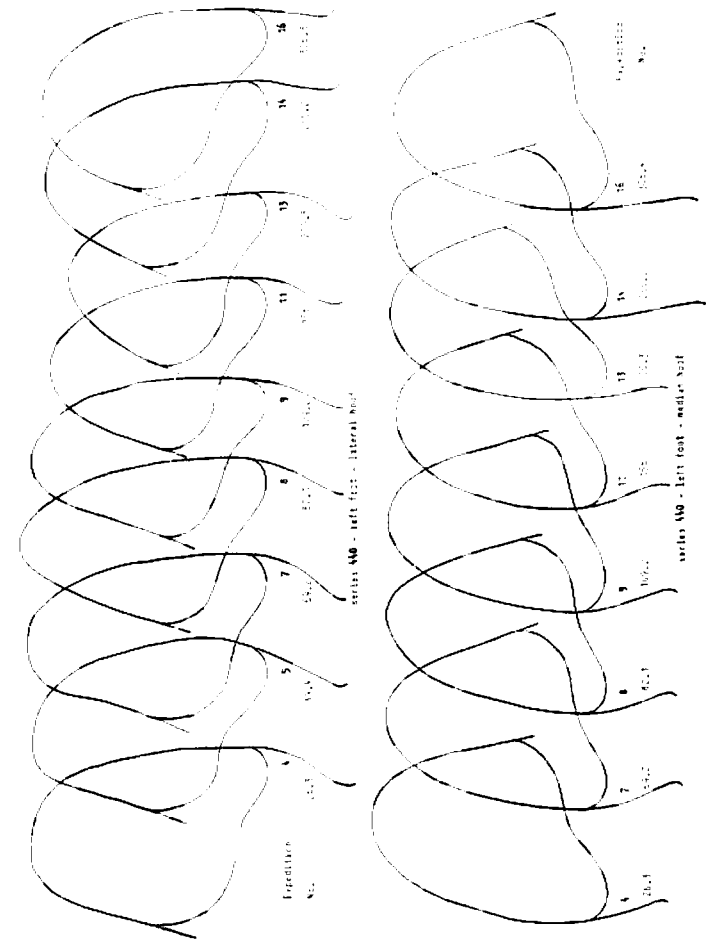


Figure 3.15 - Chronological series of side hoof profiles of the left foot casts of series 440. All median hoof profiles are very similar, but the lateral hoof shows a marked change in shape, from long broad-tipped to short triangular and later again somewhat longer. In all other aspects the casts are identical and were certainly made by the same animal. Stereophotographs of the casts 16.3 and 200.2 are shown in figure 3.14

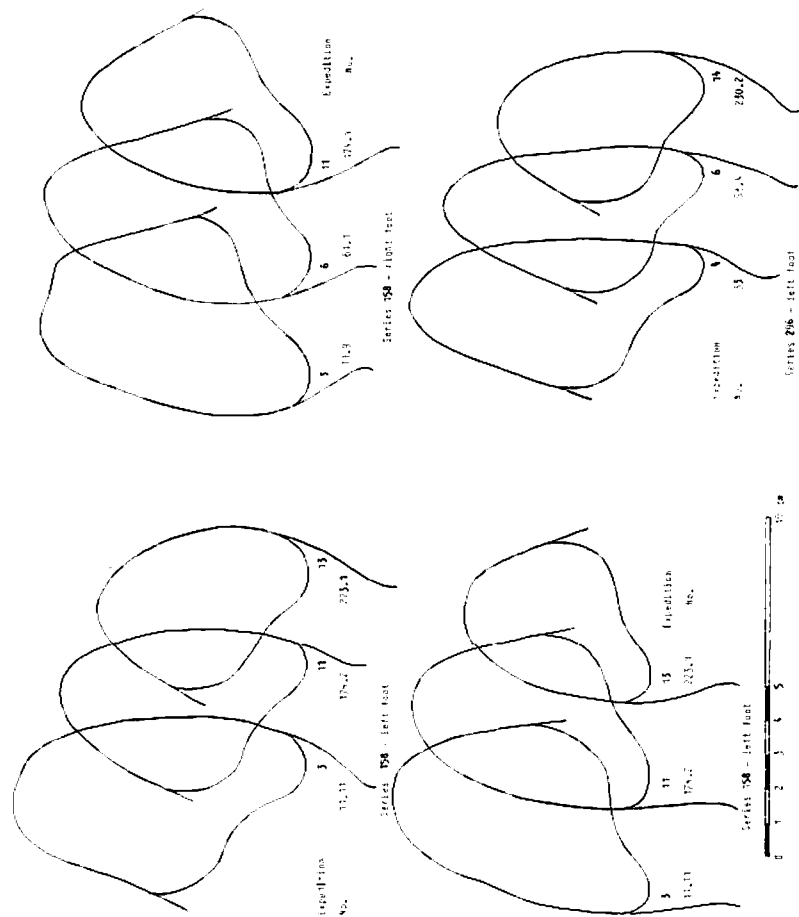


Figure 3.16 - Chronological series of side hoof profiles showing extreme changes in shape with time. In series 158 the shortening of the side hoofs occurred in all hoofs, in series 296 only in the lateral hoof of the left foot. The tip of the lateral hoof of the right foot of series 158 has apparently broken off shortly before the third expedition.

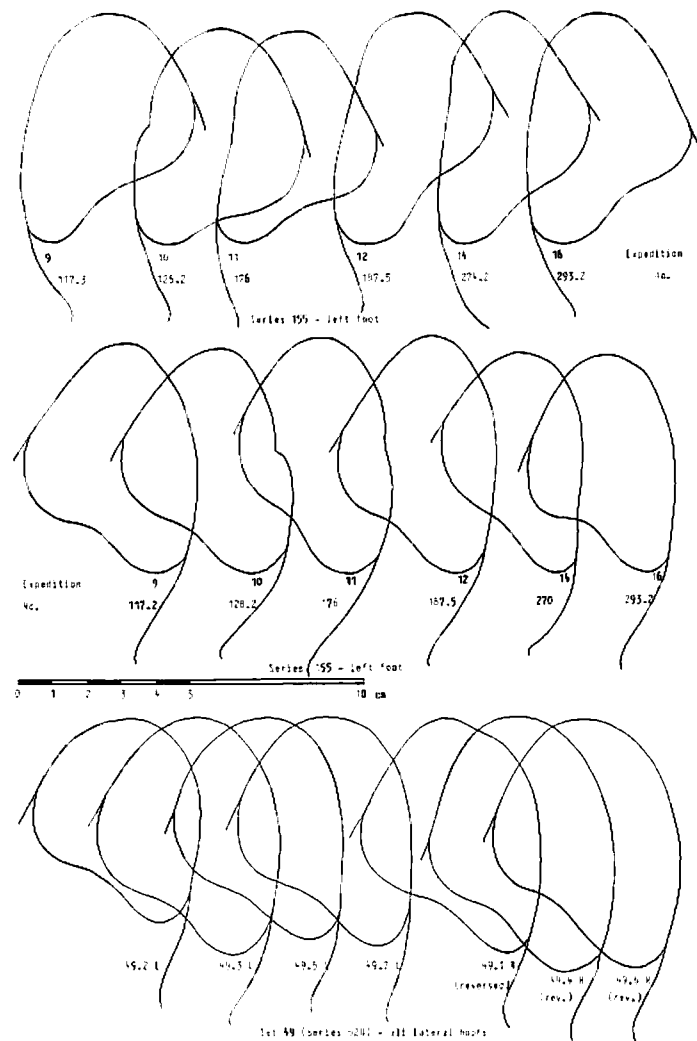


Figure 3.17 - Chronological series of side hoof profiles of series 155, showing a change in shape caused by an injury to the hoofs. A conspicuous notch is visible in the rim of both side hoofs of the left foot during the tenth expedition. In subsequent expeditions it is gradually worn away. The lower row shows all lateral hoof profiles of set 49 for comparison. All casts were made of one track, demonstrating the variability of the profiles in casts made of the same foot. Stereophotographs of most of these casts are shown in figures 3.9c, 3.12 and 3.14a. The major differences between the profiles can be explained by imperfections in the casts.

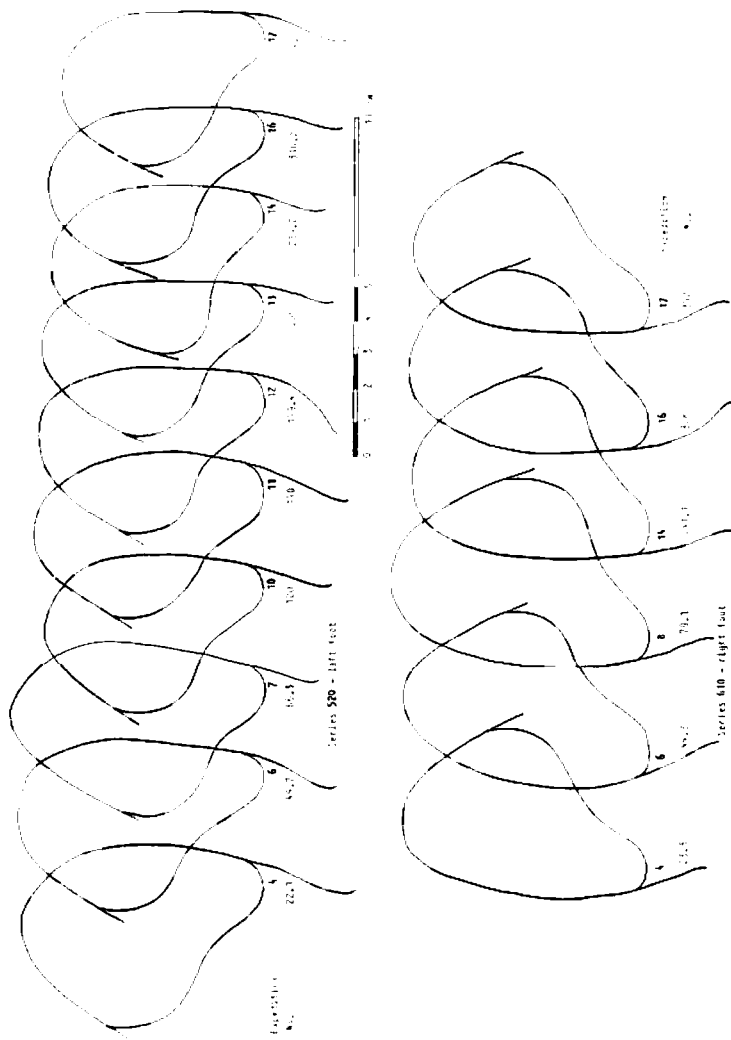


Figure 3.18 - Chronological series of side hoof profiles of two series that did not show a large change in shape. In series 520 there appears to be a slight shortening of the hoofs (This led initially to a splitting of this series - see chapter 3.6.1), and in series 610 the hoof appears to be more triangular in the earlier and more rounded in the later casts. The few aberrant profiles are caused by imperfections in the casts

### 3.6 - An illustrative example

#### 3.6.1 - Formation of an exemplary series

Some aspects of what has been written in the previous pages will be illustrated here with a description of the process of formation of one series. The selected series - 520 - is one of the largest and most complete series available. A number of stereophotographs of casts from this series are used for illustration in the previous chapters. In this and the following chapter the formation of this model series is described and compared with several other series, to illustrate the nature of the differences.

Rhino 520 has been found on all expeditions, with the exception of the 3rd and 5th, in the area east of Camp Aceh. The animal's footprints were called "square" because of the squarish form of the foot and the front hoof (See the stereophotographs of set 49 in figures 3.9c, 3.12, 3.14a) and already in the early stages of the study these casts were recognised as being distinct and probably made by one and the same rhino. They were often recognisable in the field, mainly because of the parallel or even slightly diverging position of the side hoofs, a comparatively rare phenomenon. The casts were easily picked out during the preselection and during the sorting process this series has been laid out many times for comparison with other series or to check the homogeneity of the series. Because this series is so well represented in the collection and tracks were often found in different places during one expedition, the possibility of more than one rhino with similar prints could not be ruled out. Therefore this series was scrutinized for slight differences between the sets that would justify the separation into two or more different series.

The only differences that could be found were slight differences in the position and the length of the side hoofs, and in the width of the front hoof. Based on these differences at one stage three different series were made. One sub-series (A) had rather long and thick and slightly diverging side hoofs and a large squarish front hoof. The second sub-series (B) differed in having slightly shorter side hoofs, that were less diverging and more parallel to each other. The third sub-series (C) had a narrower and less square front hoof, and contained most of the sets. The ranges of all three sub-series were completely overlapping.

The differences between the series were so slight that it was often difficult to assign a set to one of them, and in some cases that was even impossible. This is illustrated in figure 3.19, that shows outline drawings of the best casts, three of each sub-series. The solid lines are from earlier sets of the sub-series A, the long dashes are from later sets of the sub-series B, and the small dashes are from casts of the sub-series C. Apart from the slightly greater length of the side hoofs in sub-series A, the outlines are very similar in size and shape. With increasing insight into the influence of soil and movement on the prints, and after the study of other series had shown that the length of hoofs can change in the course of time, a revision was needed. The series were laid out once more and casts and outline drawings were compared again.

It was found that differences in length of side hoofs do exist, but the longer hoofs are found only in the older sets, and the later sets do not show a difference in side hoof length between the sub-series. The differences in position of the side hoofs are so slight that they are often less than the variation that is found between casts of one set, and the differences in width of the front hoofs are also not significant. All casts with a narrow front hoof were obviously made in rather soft soil, which accounts for the reduced width (see chapter 3.5.2). Therefore it was concluded that all sets were probably made by one rhinoceros and the three series were merged into series 520, in which the side hoofs show a small reduction in length throughout the study (see figure 3.18).

In figure 3.20 the amount of variation that was found in the outline drawings of series 520 is illustrated. In the lower drawing the outlines, without the plantar ledges and the basal line, of the ten best casts of the left foot are superimposed, so that they show the most complete overlap. The outline of the front hoof was placed in the same position and the outline rotated around that position until the best overlap of the side hoofs was attained. The left foot casts were chosen because in some sets they are better and more complete than the right foot casts. In the upper figure the outline of the best cast (cast 49.7 L) is drawn with the tips of the hoofs from all 37 complete left foot prints in the series (the dots). They were superimposed in the same way as the outlines in the lower drawing.

From this figure it will be clear that there is considerable variation in the position of the side hoofs, as has been explained already in chapters 3.5.2 and 3.5.3, probably caused largely by external forces. But the variation in the direction of the length of the hoof is relatively small, compared to the variation in the direction perpendicular to the length axis. Most dots are located in a more or less crescent-shaped area, 5 - 6 centimetres long and 1 - 2 centimetres wide. The shaded area in the upper figure covers 50 % of the tips that are closest to the middle or medial axis of the whole group of dots. The outline and the shaded area are shown also in the figures 3.21 to 3.23, where this series is compared with other series.



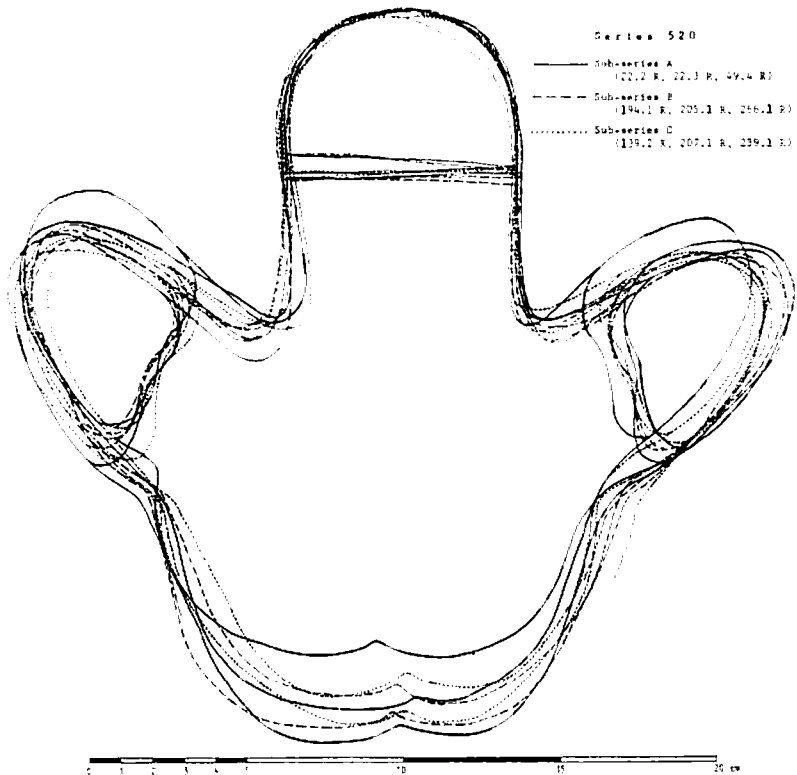


Figure 3.19 - Superimposed outline drawings of the three sub-series that were initially formed from the casts that were later grouped as series 520. This is the largest and most complete series and was chosen as a model series to explain the differences that exist between the different series of casts. The only difference between the three sub-series was a slight difference in the length of the side hoofs (see also figure 3.18). Later the differences were found to be inconsistent and most likely caused by a gradual shortening of the hoofs (see also chapter 3.5.4), and all casts were merged into one series.

### 3.6.2 - Comparison with other series

To illustrate the nature of the differences found between the series, the model series 520 is compared with those series with which it has a superficial resemblance, and with those series that have an overlapping range in the study area. The comparison of the outline drawings is illustrated in the figures 3.21 to 3.23 where the outline of the best cast of series 520 (the thin line) is overlaid with the outline of the best cast of the compared series (the bold line). The shaded area covers the middle half of the positions of the tips of the side hoofs, as in figure 3.20, of series 520. The dots represent the positions of the tips of the side hoofs of the other series.

Figure 3.21 shows the outline of series 520 in comparison with three series that show a superficial resemblance to the model series, in the form and position of the hoofs. Series 191 is the most similar series and the prints appear identical on first sight. The front hoof is very similar, rather thick rimmed, squarish, without thickened lobes or ledges, and also the form of the side hoofs is very similar. The outlines shown in figure 3.21 do not show any clear differ-

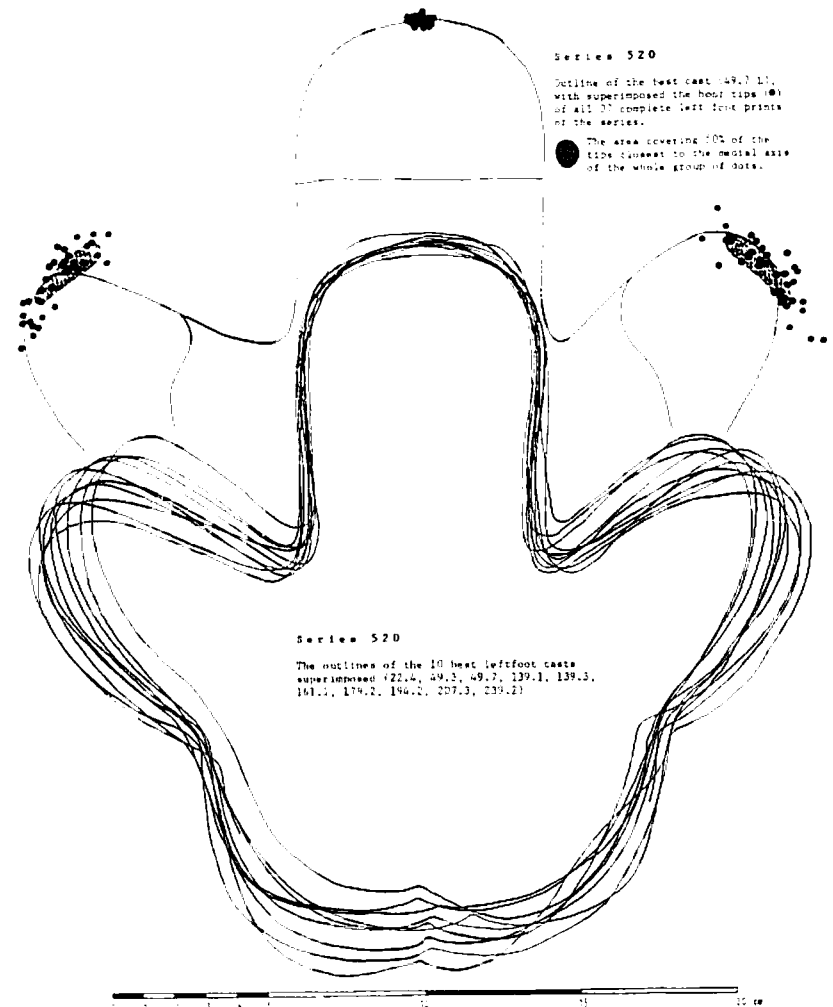


Figure 3.20 - Outline drawings of the model series 520, as used for comparison with other series. The lower figure shows the superimposed outline drawings of the 10 best casts of the series. The differences within one series are mainly in the position of the side hoofs, caused by external forces (see chapter 3.5). Similar pictures were obtained during the process of sorting by superimposing the outline drawings on a light table. Small series of outline drawings could easily be compared in this manner. The upper figure shows the compound outline drawing of series 520, with the outline of the best casts and the tips of the hoofs of the other casts, that were made to illustrate the differences between the various series, as described in chapter 3.6.2. The same figure is shown together with the compound outline of other series in the figures 3.21 to 3.23.

once. The left side hoof appears to be much broader in series 191, but that is only so in this cast, and is most likely an aberration. The only consistent point of difference between these two series is the position of the median side hoof, that is parallel to slightly diverging in series 520 (see the stereophotographs of set 49 in figures 3.9, 3.12, 3.14) and that is in the more normal converging position in series 191 (see the stereophotograph of cast 35.1 L in figure 3.26). A difference like this cannot be seen on the outline drawings, but it is clearly visible on the casts, even on the poor ones.

In the multiple analysis of variance of the standard measurements (see chapter 10) these series were found to be significantly different in the width of the front hoof only (Series 520: mx 73.0 sd 2.4. Series 191: mx 75.0 sd 1.4). Another indication that these series are made by different rhinos is their distribution in the field. Series 520 is found in the northern half of the study area, while 191 is found in the southern part, and between these two distribution centres there is a distance of three kilometres where tracks of this type were never found (see chapter 5.1.3).

Series 192 was found only around the *Pinus saltlicks*, and is clearly different from series 520 in the position of the side hoofs, which are converging, and by the form and width of the front hoof (see the stereophotograph of cast 276.3 R in figure 3.25b). The front hoof is clearly broader (mx 78.8 sd 1.5) and much more rounded in shape. Series 192 shows more resemblance with series 191, and also their ranges are overlapping, making it difficult to separate the two. It is only the shape and the width of the front hoof (the difference was found to be significant) together with a more diverging position of the lateral side hoof on the left foot that has led to separation of these two series.

The third series that shows some resemblance in general appearance to series 520, is series 880, found in the extreme north of the study area. The front hoofs are similar, but the prints are much smaller, which is also clearly shown in the outline drawings (see also the stereophotograph of cast 155 L in figure 3.26b). Differences between these two series are clear and unmistakable. These series differ significantly in the span of the print (series 520: mx 320.2 sd 9.7. Series 880: mx 305 sd 4.6).

Six other series have a range that overlaps with the range of model series 520. The outlines of these series are shown in the figures 3.22 and 3.23. In general these series are all clearly different from series 520, and this shows in the outline drawings. Series 610 is much larger in all aspects (significant differences in all standard measurements), with very flat hoofs (see the stereophotographs of cast 259.1 L in figure 3.26c). Series 110 has a smaller width (not significant), but a peculiar and remarkably large front hoof (mx 83 sd 2.5. See the stereophotograph of cast 198.1 L in figure 3.27a), which distinguishes it from all other series. Series 460 has wide and flat prints, resembling series 610, but with much smaller front and side hoofs (front hoof mx 69.0 sd 1.9. See the stereophotographs of the casts from set 142 and 144 in figure 3.10). The differences with the model series are clear (significantly differing in the width of the front hoof), but the distinction between this series and the other series that have small hoofs is much less clear.

Series 199 has a much smaller front hoof (mx 70 sd 1.1) than series 520, but resembles this series in the form and the position of the hoofs. In size it resembles series 460, but can be distinguished on the form of the front hoof, which is squarish in form (especially on the right foot) and in the position of the side hoofs. In series 460 the lateral side hoof is strongly convergent, while in series 199 it is almost parallel. The width of the print was found to be significantly different (series 460: mx 206.7 sd 12.7. Series 199: mx 221 sd 5.7).

The series 140 and 146 are both clearly different in size from series 520 (see the stereophotographs of casts 78.2 L in figure 3.24a and 210.1 L in figure 3.27b), but these small prints are difficult to separate because they show few special characteristics. Small differences in shape and position of the hoofs are often the only characteristics available for distinguishing between individuals. The series 140 and 146 can only be separated with difficulty, on the front hoof, which is slightly broader and shorter, more rounded and with a hollow plantar surface in series 146 (The front hoofs differ significantly in width. Series 140: mx 66 sd 1.5. Series 146: mx 68.2 sd 2.1). For the rest they are similar. The ranges of these two series are adjoining, but on two occasions tracks of both series were found far apart, while in the area in between no tracks of this type were found, another indication that there are indeed two rhinos with almost identical footprints.

(Figure 3.21 - continued)

that is clearly broader and more rounded (see stereophotograph 3.25b and the front hoof drawings in appendix A). Series 191 and 192 are found in the same area and are difficult to separate. They can be distinguished only on the size and shape of the front hoof and on the different position of one of the side hoofs.

Series 880 - The front hoof and general appearance are similar to series 520, but the casts in this series are clearly much smaller (see stereophotograph 3.26b)

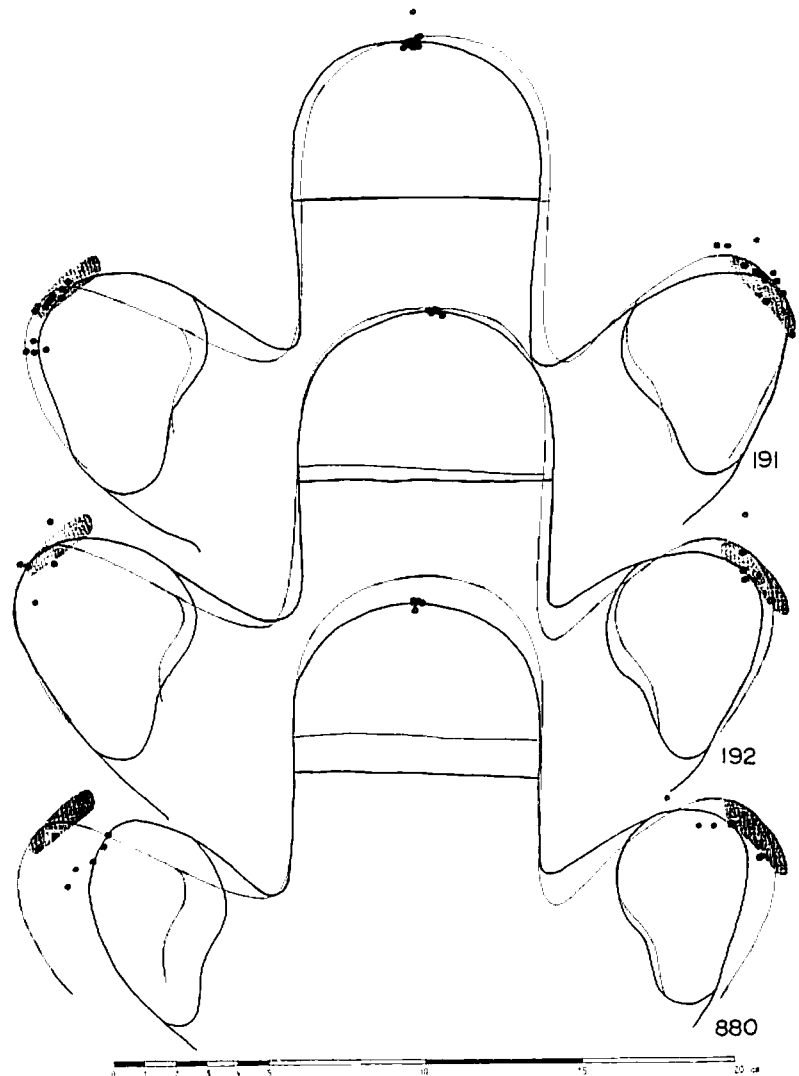
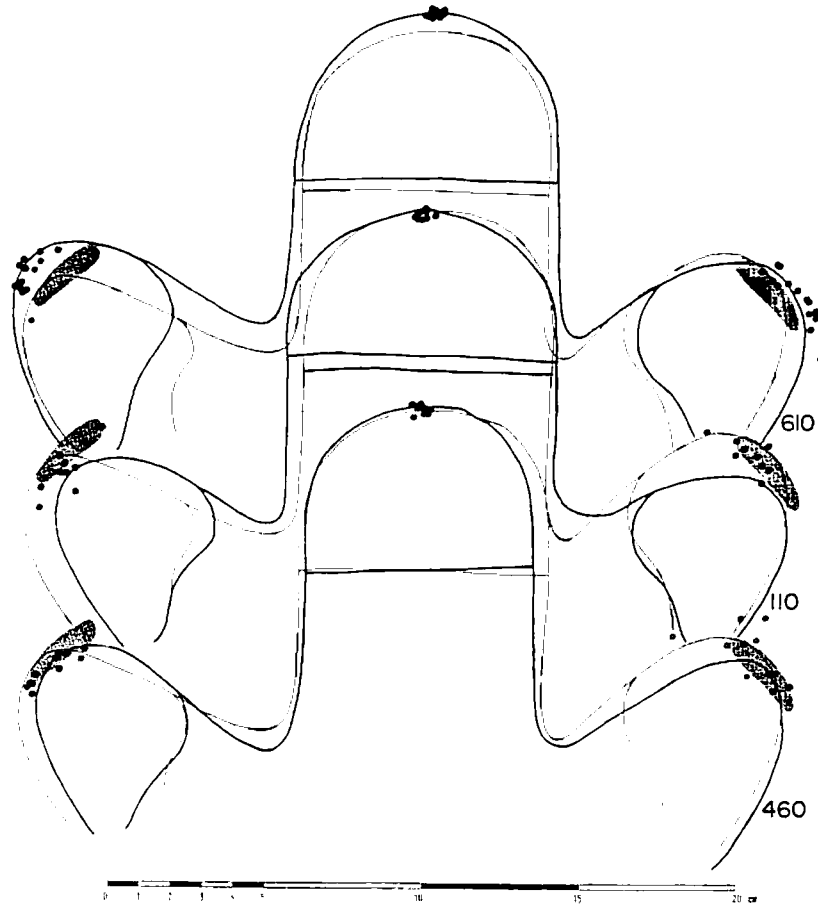


Figure 3.21 - Comparison of model series 520 with three other series that are superficially similar in form. Compare also the stereophotographs of series 520 in figure 3.9c and those in the figures 3.26 and 3.27.

Series 191 - This series is most similar to series 520, and the outline drawings show no consistent differences. But in the position of the side hoofs they clearly differ. In series 520 the plantar surfaces of the side hoofs are slightly diverging, while the side hoofs in series 191 are in the standard position (see the stereophotograph in figure 3.26a). Both series were also found in different areas.

Series 192 - Differs from series 520 in the position of the side hoofs and in the front hoof. (continued opposite page)

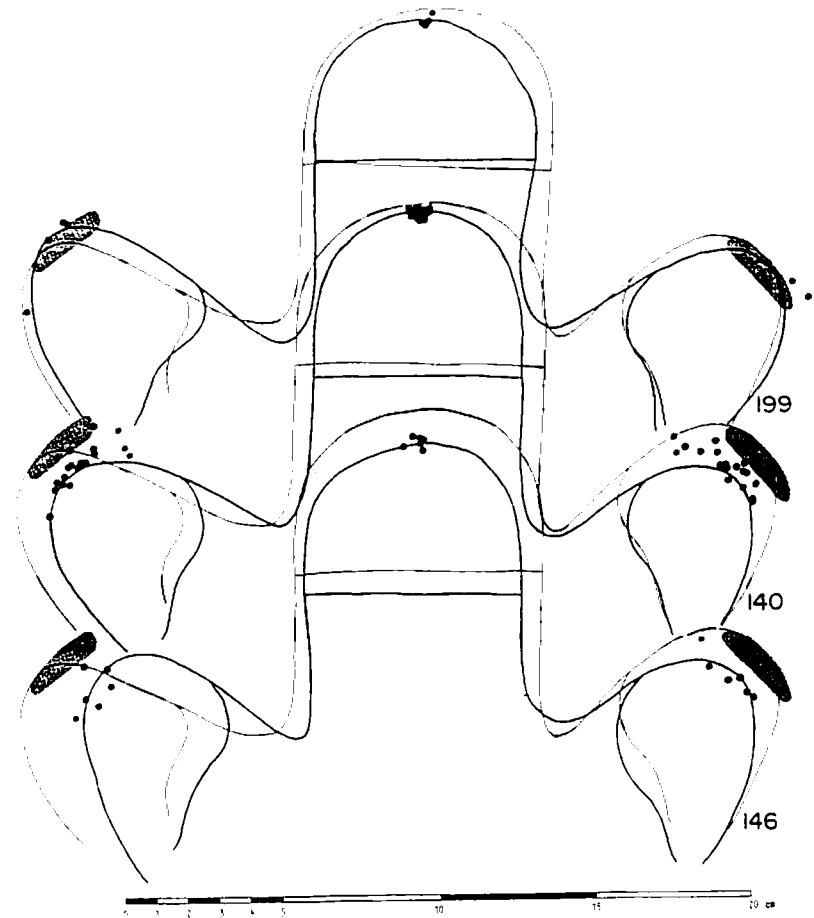


**Figure 3.22** - Comparison of model series 520 with three other series that have overlapping ranges. See also the stereophotographs of series 520 in figure 3.9c and those in the figures 3.26 and 3.27

**Series 610** - much larger than series 520 in all aspects and with flat outstanding side hoofs (see stereophotograph 3.26c)

**Series 110** - A series with an extremely large front hoof (see the front hoof drawing in appendix A and stereophotograph 3.27a)

**Series 460** - A much smaller front hoof and flat outstanding side hoofs (see the stereophotographs in figure 3.10). In general appearance this series resembles series 610, but the front and side hoofs are much smaller



**Figure 3.23** - Comparison of model series 520 with three other series that have overlapping ranges. Compare also the stereophotographs of series 520 in figure 3.9c and those in the figures 3.26 and 3.27

**Series 199** - This series is rather similar in form and position of the hoofs, but the front hoof is much smaller (a stereophotograph of this series is not available). In size this series resembles series 460 (figure 3.22), but they can be separated on the form of the front hoof and on the position of the side hoofs

**Series 140** - In all aspects much smaller than series 520 (see stereophotograph 3.24a)

**Series 146** - In all aspects much smaller than series 520 (see stereophotograph 3.27b). The small prints like those of series 140 and 146 are difficult to separate because they lack clear distinctive characteristics. There are only small differences in the shape of the front hoof and in the position of the side hoofs

Figure 3.29 Stereophotographs of plaster casts illustrating different shapes and sizes.

A - Series 140. A foot with a relatively long and narrow sole, with a long and slender portion before the side hoof. The front hoof is in a more horizontal position than is normal. The side hoofs are in a symmetrical position with respect to the midline.

B - Series 840. A foot with a relatively short and broad sole with a short tapering portion before the side hoofs. The front hoof is in the normal position, making an angle of about  $45^{\circ}$  with the transversal plane. The side hoofs are in a symmetrical position with respect to the midline, but they are more inclined toward the transversal or horizontal plane than is normal.

C - Series 196. A foot with the front hoof more vertical than is normal, making an angle of more than  $45^{\circ}$  with the transversal plane. The side hoofs are asymmetrically positioned with respect to the midline; they are in an unusual vertical position and the plantar surfaces converge strongly toward the front hoof.

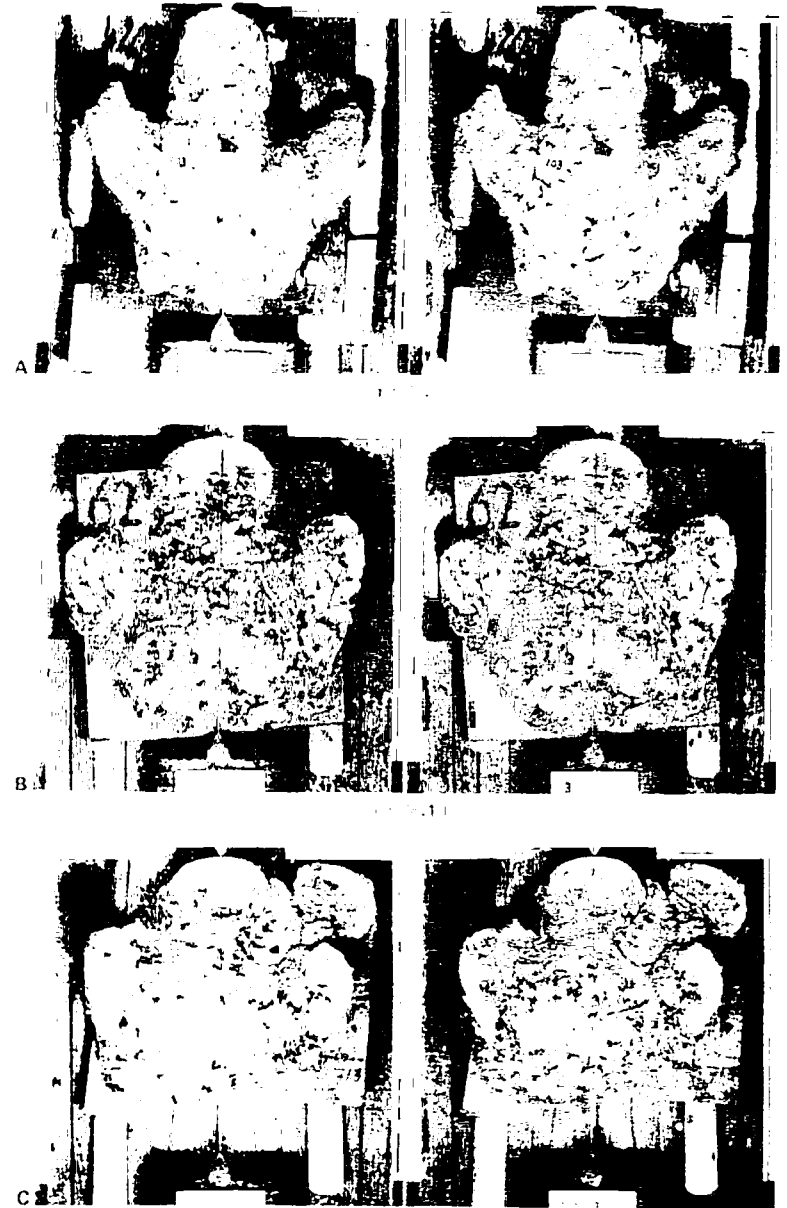
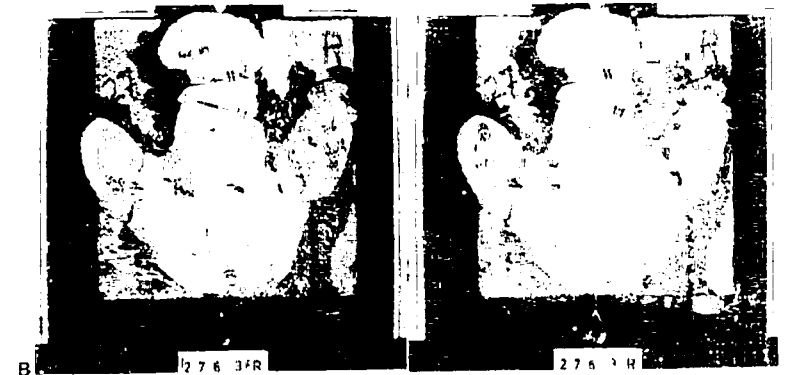


Figure 3.25 Stereophotographs of plastercasts illustrating different shapes and sizes.



A

A - Series 296. A foot hoof strongly tilted towards the side. The side hoofs are in an asymmetrical position with respect to the midline, they are more vertically placed than is normal and the plantar surfaces converge strongly towards the front hoof.



B

B - Series 192. A foot that in all aspects comes closest to the standard or average horse hoof. The hoof are in the normal position and there are no peculiarities in form or shape. This cast was used as a standard for comparison with other casts.



C

C - Series 700. A foot with the side hoofs pointing more forward than is usual. The basal ledges of the side hoofs are extremely thick. This is one of the most distinct series and easily recognizable from the cast as well as from the prints in the field.

Figure 3.26 Stereophotograph of plaster cast for comparison with the model from 50. Compare with the stereophotograph of series 50 in figure 3.9, and several of the outline drawings in the figures 3.11 to 3.13.

A - Series 191. Differs from series 520 mainly in the position of the side hoofs. The plantar surfaces of the side hoofs of this series are almost parallel, and in series 520 they clearly diverge.

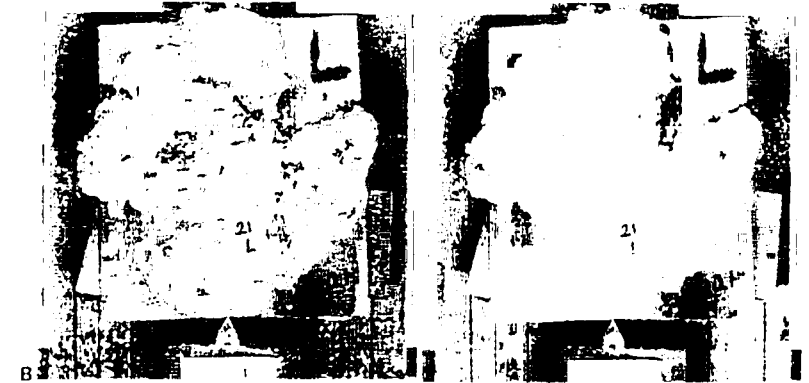
B - Series 880. In general appearance rather similar to series 520, but with a different front hoof and much smaller pan.

C - Series 870. In all aspects larger than series 520, with characteristic flat outstanding side hoofs. This rhino was called 'flatfoot'. In general appearance this series is very similar to series 880 (see figure 3.24b), which is smaller in the width and length of the print. Both series could only be separated after rhino 840 was found with a calf.



Figure 3.27 Stereophotograph of plastercast for comparison with the model series 20. Compare with the stereophotograph of series 20 in figure 3.1c and see also the outline drawings in the figures 3.21 to 3.23.

A - Series 110. A series with a very characteristic broad front hoof. See also the front hoof drawings in appendix A.



B - Series 146. In all aspects much smaller than series 20. In general these small prints are more difficult to identify than the larger prints. They lack diagnostic features, and can only be separated on small differences in the form of the front hoof and in the position of the side hoofs.



C - Series 400. A cast of a calf about 9 months old. See also the drawings in chapter 4.

### 3.7 - Final results of the plastercast identification

By the end of the sorting and identification process there were 39 different series, representing 39 different rhinos, in the plastercast collection. Among these there were 8 cow and calf pairs, with the calves born during the period of the study. In figure 3.28 the record of each rhino throughout the period of the study is shown, arranged by sex and age class (For this arrangement see chapters 4.2 and 4.3).

Most individuals were found on a number of expeditions, but there were often large gaps between successive records. A few animals were found only once in 17 expeditions. The few doubtful records in this table concern sets of poor quality that could not be assigned with certainty to a series.

From the total of 371 sets of casts collected during the study, 324 (87%) could be identified with certainty. The rest were either classified as unidentifiable (22 sets) or were tentatively assigned to a certain series (25 sets). These were invariably incomplete sets, sometimes consisting of just one hoof cast, or cast of very poor quality that did not show any distinctive characteristics. After identification of the casts a distribution map was made for each individual rhino, showing the course and direction of all the identified tracks, the wallows and the saltlicks visited and the dates. The growth of the foot of the young was studied and the possibilities of sexing and ageing based on footprints were considered. Of the 39 animals 8 were identified as females and 4 as males, there were 9 adults of uncertain sex and 17 sub-adults, 12 of which were born during the period of the study.

In the rest of the study the animals that made each series of tracks will be described as 'rhino', or 'male', 'female', 'sub-adult' or 'calf', followed by the series number.

### 3.8 - Evaluation of the method of plastercast analysis

Individual rhinos can be recognized from the form and size of their footprints. Using the techniques described above with experience one can judge casts for possible aberrations and deformations, and from comparisons determine whether two sets of casts from different tracks were made by the same rhino or by different rhinos. Although there are slight changes in form and growth of rhinos feet, most animal's tracks could be readily identified.

Each of the 39 series is based on good plastercasts that clearly show distinctive characters and often supported by other evidence. In fact the number of 39 rhinos in the study area is a minimum. Although a few casts could not be allocated to a series and might belong to rhinos not included in the 39 animals in the study area, with the existing large collection of plastercasts it is unlikely that a regular resident of the study area could pass unnoticed. Any rhinos other than the 39 recognised individuals can only be rare visitors to the study area.

Because so much time and energy was spent on finding the tracks there was temptation to try and identify them all as far as possible. If a set is not assigned to a series, that record is lost. If a cast is wrongly identified the rest of the conclusions will be based on false data. Doubtful cases were reviewed several times but some sets of casts had to be excluded as it was impossible to assign them with any degree of certainty to a series.

Proper identification of all individuals can only be successful when a substantial number of casts have been collected. Some rhinos' feet are similar in form and size, and can only be distinguished after comparison of several casts of good quality. For a few animals the form or the position of the hoofs is distinctive, but most casts do not show any striking features, and the differences between individuals are subtle. Since good prints are rare track analysis requires long periods in the field. Quick results are not possible.

This is well illustrated by a preliminary sorting carried out after the 12th expedition (progress report nr 8, 1978). The 400 plastercasts that were available at that time were sorted by sight and comparing outline drawings of hoofs. Then 15 different series were made, among which three were cow and calf pairs. During the final sorting of the whole collection, from the same material (see figure 3.28) 30 individuals could be recognised, among them 7 cow and calf pairs. Partly this was due to the primitive method of comparison, but it was only after many expeditions that there was sufficient good material to warrant separation of series.

The feet of the Sumatran rhinoceros are variable enough to make individual recognition possible, even on poor plastercasts. Once the tracks have been identified the whereabouts of the different rhinos can be pinpointed. In a habitat where visual observations are almost impossible this is a very valuable tool. Because tracks are preserved for some time if it does not rain, footprints give information on what happened in the recent past. Studying rhino movements from plastercasts of their tracks does not require expensive equipment or intricate organization, but it does require a large amount of plastercasts and a lengthy study. The method could be used to study other large animals that are otherwise difficult to locate. The procedure followed in this study was very time consuming, but it may be possible to simplify the track analysis (see chapter 10).



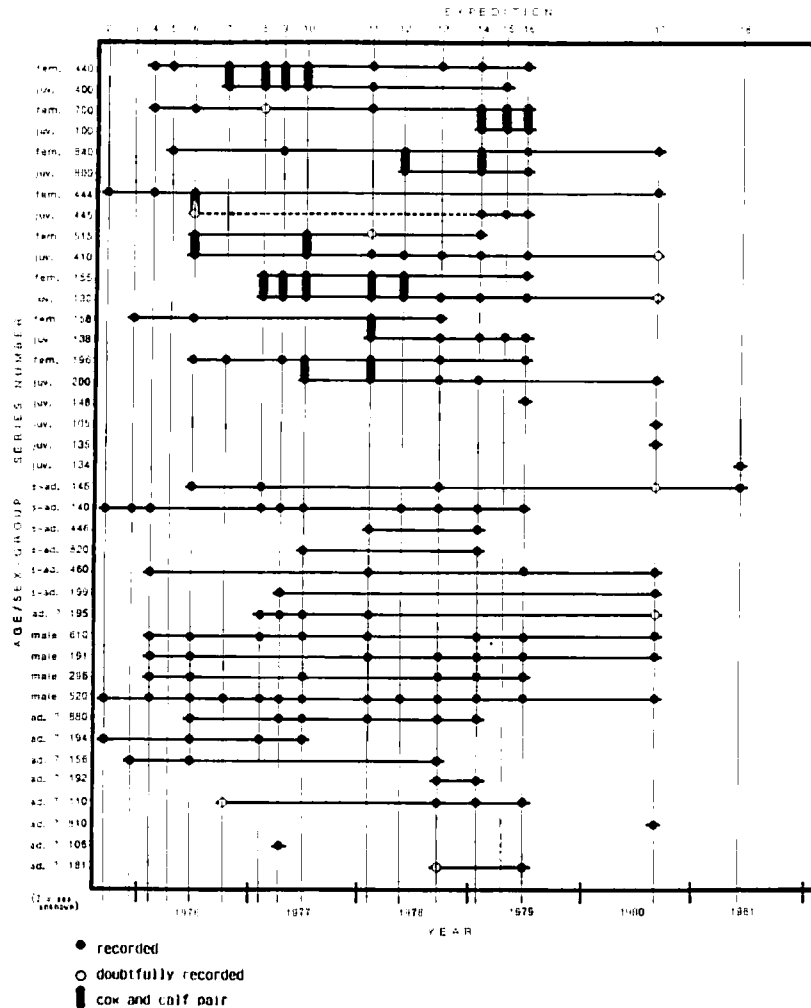


Figure 3.28 - The occurrence in the study area of the different rhinos recognized in the plastercasts, throughout the period of the study

The results of track identification are in many aspects similar to those that can be obtained by radio-tagging animals, namely a series of locations and dates concerning individual animals. Track analysis requires more time and more energy, but the results can be much more extensive and cover a wider study area. All animals in a certain area can be monitored, and the tracks give information on the activities of the rhinos. Radio-tagging was not attempted in this study, because of the risks to the animals and for financial reasons, although it would have provided a perfect counter-check on the identification of the tracks.

### 3.9 - Recommendations for future use

Track studies with the help of plastercasts can be very useful for ecological field studies on larger animals, but it is not an easy nor quick procedure. The recommended procedures for a simple census to distinguish individual animals and estimate the minimum number present, will be discussed in chapter 10. For a census a few measurements and casts from front hoofs will be sufficient (see chapter 10), but for ecological studies where one must recognize individual animals every time their tracks are found, one must use casts of complete footprints.

The quality of the casts is of prime importance for successful identification. Incomplete casts and those of poor quality are very frustrating to work with. In the field one should take enough time to follow fresh tracks until several good casts can be made. With old tracks one is dependent on luck to find suitable prints, but with fresh tracks one can usually find a number of good prints if one follows the animal's track. Two good casts of each foot should be sufficient, but one should try to have enough plaster to make a few more if necessary. In the field it is not always easy to see which prints are most suitable for casting and cast should be inspected as soon as they are hard and can be lifted, so that more can be made if needed. If complete prints cannot be found it is useful to make some casts of single hoofs.

To sort and identify casts with accuracy takes practice. The best way to accustom oneself to the different forms and the variability in plastercasts is to make a larger number of casts from a few different tracks. While following the track one should make casts in different soil types and on different slope gradients, a few at each location to learn how soil and slope influence the form of the casts. Later one should always try to avoid making casts from prints in extreme positions or on less suitable soil types, but often there will be little choice.

The sorting procedure in this study was lengthy and repetitious. Although it is good practice to start comparing casts as soon as possible, no reliable results can be expected before a sizeable collection is accumulated, probably 50 to 100 sets of good casts. Identification should be revised and compared throughout the study.

Outline drawings were found to be very useful for comparison. Casts can also be pre-selected on size and certain peculiarities in form. Cow and calf pairs are often easy to separate because there are two sets of tracks to compare. Single animals can be sorted later, starting with those with an extraordinary form of some part of the foot. The hardest part of the sorting procedure is dealing with the many cast that show no distinctive characters.

After these first selections one should review the whole collection several times, gradually refining the identification and placing the questionable casts. In this final stage of the sorting other considerations, like the time and place of finding, are taken into consideration. One should pay special attention to aberrant records, tracks found at odd places and times, and careful comparison of casts from individuals which have largely overlapping ranges or seem to replace each other in time. Finally one should compare all individuals whose feet show some degree of similarity or have overlapping ranges.

## CHAPTER 4 - GROWTH AND AGING

When comparisons of plastercasts are made over a long span of time effects of growth and ageing of the foot can be expected. Growth in young animals is obvious, but full-grown animals are also likely to show some very slow growth and changes in form of the foot through ageing. Because the breeding biology of the Sumatran rhinoceros is virtually unknown, much attention was paid to the tracks of cows and calves. Tracks of cows with a calf have been seldom reported previously (Hubback, 1939; Borner, 1979), but during the present study a good number of such tracks were encountered and several pairs could be followed for a long period.

The sorting out of these cow and calf tracks was very difficult and time-consuming. As long as the calf is accompanying the mother it is fairly easy to identify, but once the young is independent distinguishing its tracks from other small tracks is much more difficult. The difficulties were aggravated by the fact that some sets of casts included only a few examples of calf prints, because the possibility of more than one cow and calf pair using almost the same area, was not anticipated during the field-work. Often to save on plaster only a few casts were made of a cow and calf pair because they were assumed to be identical to tracks found shortly before; only later were they identified as made by different cows, both having a young of similar age.

Ultimately eight cow and calf pairs could be recognised, and another four calves were already independent of the mother when found for the first time, but from their size they were obviously born during the period of the study.

### 4.1 - Growth of the foot of the calf

The form of the foot of the young Sumatran rhino has been described and drawn by Bartlett (1873), in his account of the birth of a young rhino on board a ship in the London docks. At birth the hoofs are long and pointed and turned under the foot. Once the long points are worn away the proper form of the hoof can be seen. Unfortunately no size of the foot or hoofs is given, nor is there a scale to the figure of the foot in the article. The newborn animal is described as being "3 feet in length, and 2 feet high at the shoulder". Using this scale for the drawing of the youngster, the feet will be something between 80 and 90 mm in diameter. The drawing of the underside of the foot, published by Bartlett (1873), has been re-drawn to this scale (85 mm diameter) in figure 4.2.

Once tracks of a newborn young were found (rhino 700 with calf 100). When first found the tracks were very small, smaller than any calf track found before, and the front hoof had a remarkable squarish profile, as if the long down-turned point had just worn off. Older tracks of the mother, who has a very characteristic print, were found nearby, but not accompanied by a young. These tracks were at most 12 days old, indicating that the infant had begun accompanying the female only recently. Bartlett (1873) relates that the newborn rhino spent most of his time sleeping in a dark place, so it is likely that they normally do not follow the mother the very first days after birth, but remain hidden. Therefore the young was judged to be about 15 days old when it was found for the first time (January 27, 1979, exp. 14). Fresh tracks of the same calf were found on the 15th expedition and old tracks were found on the 16th expedition.

From slightly older calves several series are available, but the best material is found in series 400, calf of rhino 440, and series 130, calf of rhino 155. From series 400 good sets of casts were found three times while it accompanied the cow, and another good set was obtained more than two years after birth. From series 130 the material from the period that the young was following the mother is much less complete, but good sets are available from around the time that the young separated from the cow. Good material is also available from series 410, calf of rhino 515, over a two year period after becoming independent. These four series serve as a reference for the evaluation of the less complete series of the other calves.

In figure 4.1 the growth curves of these four series (100,400,410,130) are shown, represented by the average width of the front hoof, the span, and the width of the print on each expedition. The curves of the series are superimposed so that visually the best fit is attained. The horizontal axis shows the number of days since the presumed date of birth. The length of the print is not considered here, but it follows a similar curve. The age at which the young became independent is given for all the cow and calf pairs. The last record of a cow and a calf walking together and the first record of the cow or the calf moving independently are shown.

For all the calves similar curves were made and these were compared with the curves in figure 4.1, to estimate the date of birth. The presumed dates of birth will be further discussed

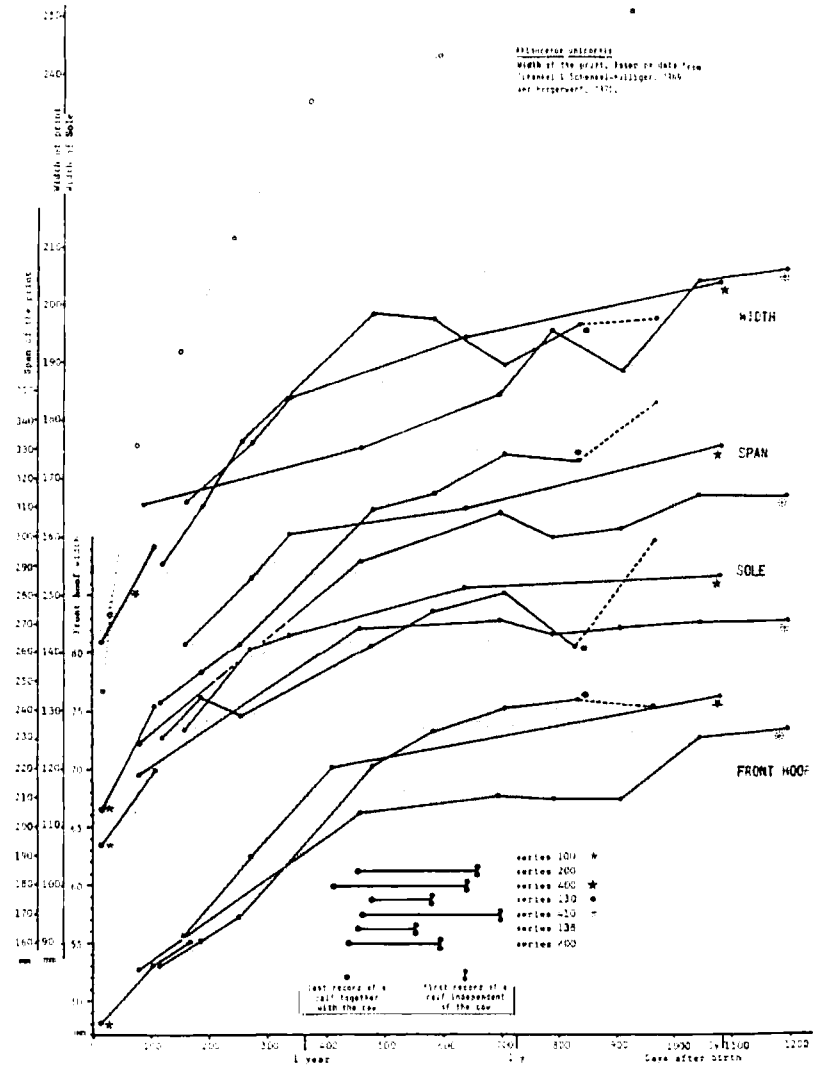
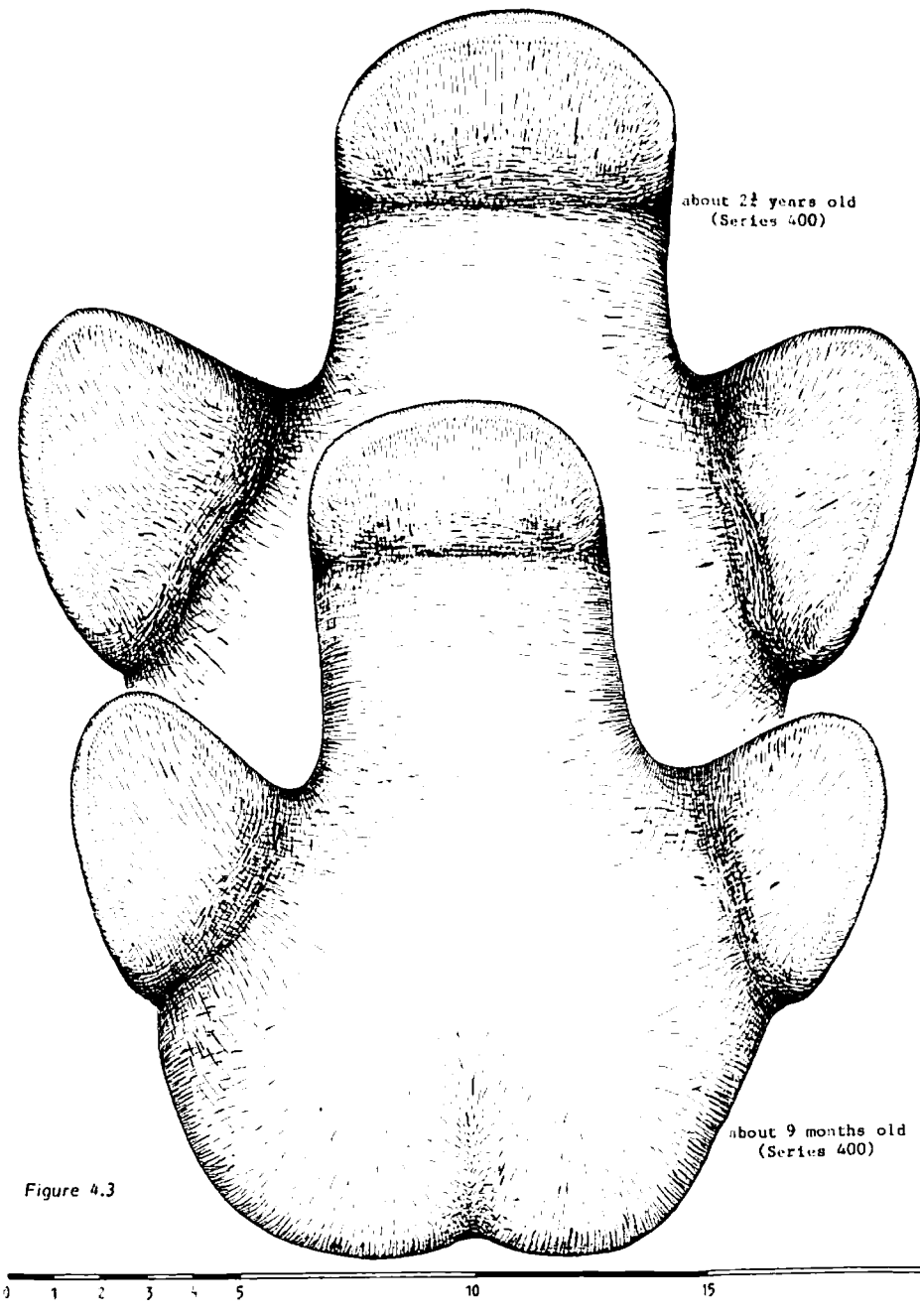
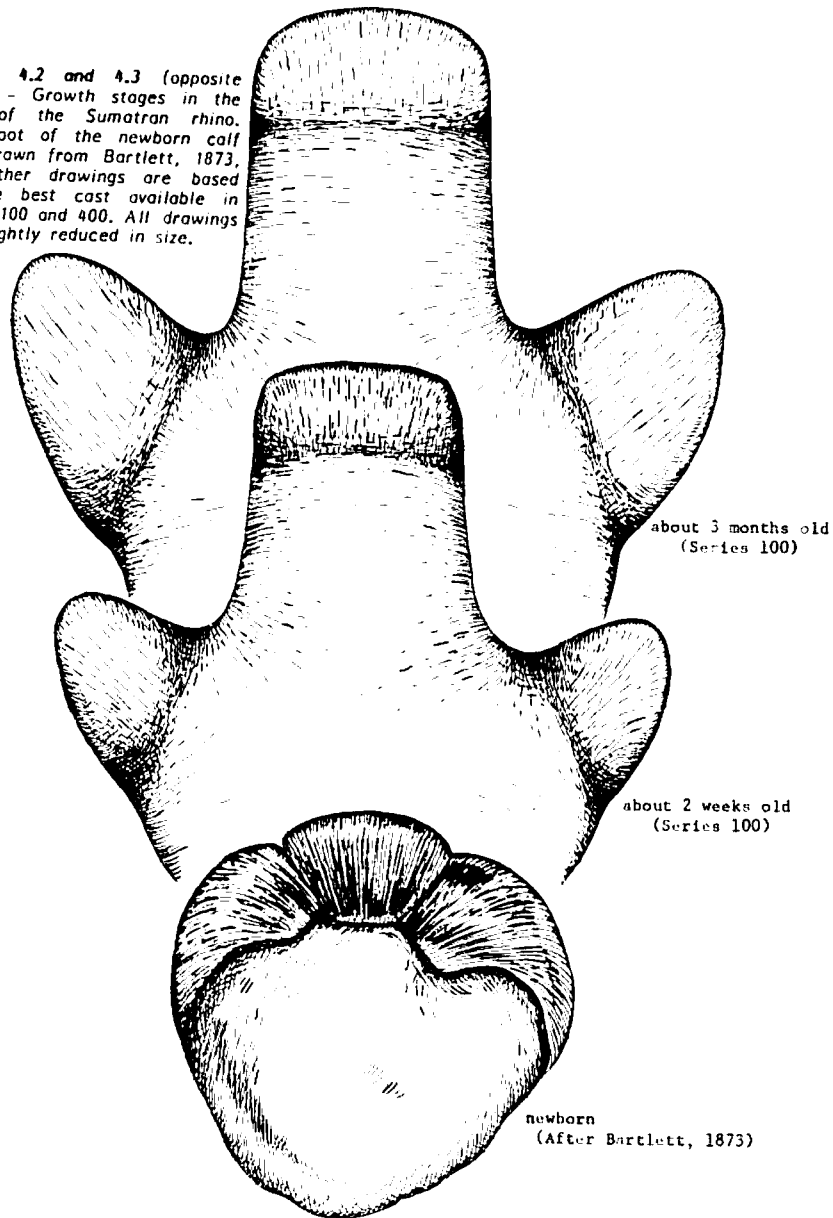


Figure 4.1 - Growth of the foot of the calf, expressed in the growth-curves observed in four standard measurements. The curves observed for four of the calves born during the study are superimposed, so that the best fit is attained. The shaded area, indicating the approximate variance in the values, was sketched in based on the growth curves of all calves. The bars in the lower part of the figure indicate the period between two successive records in which the calf became independent. For comparison a growth curve for the width of the foot of the Indian rhino is added.

Figure 4.2 and 4.3 (opposite page) - Growth stages in the foot of the Sumatran rhino. The foot of the newborn calf is redrawn from Bartlett, 1873, the other drawings are based on the best cast available in series 100 and 400. All drawings are slightly reduced in size.



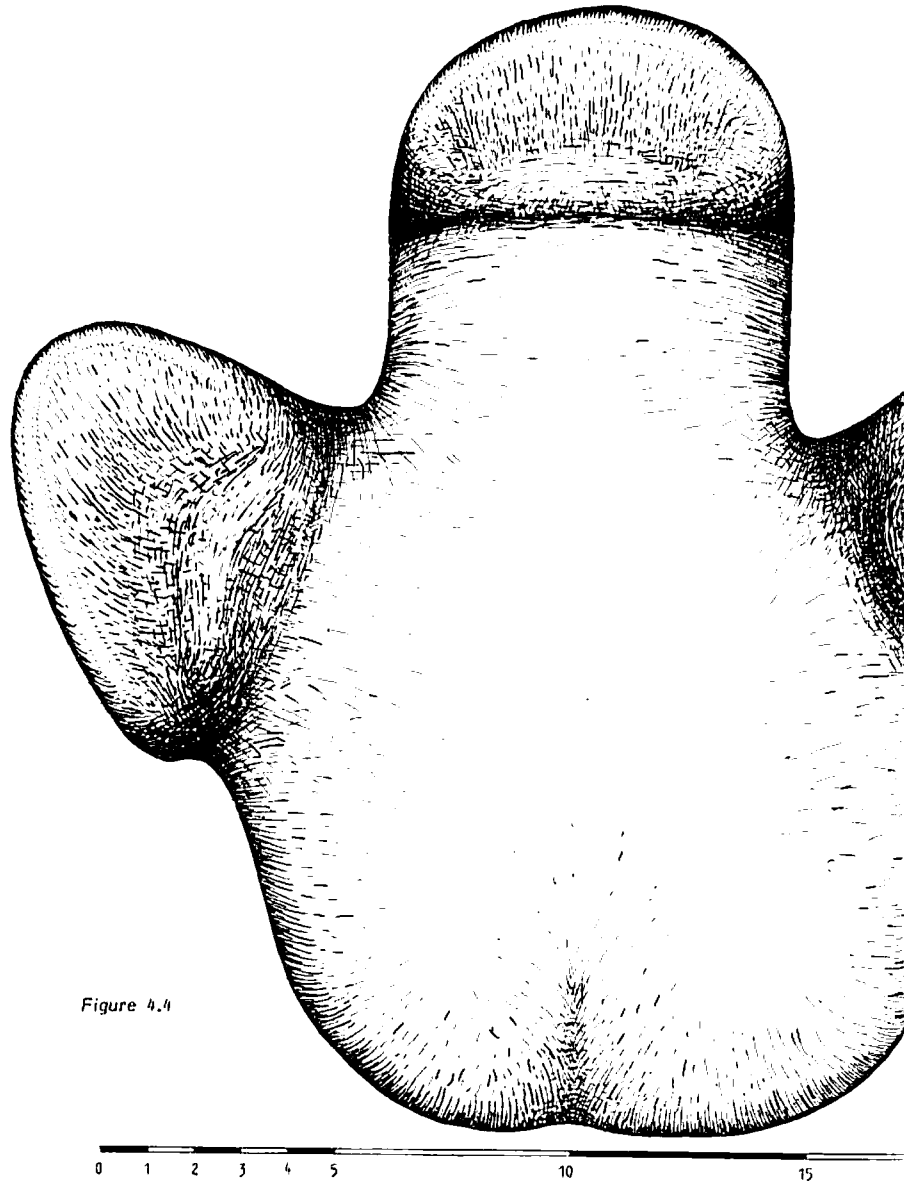


Figure 4.4

in chapter 6.3, here only the ageing aspects of the growth of the calves will be treated. All growth curves of the eight cow and calf pairs that were found at least once together (the date of birth can be estimated with some accuracy), were used to draw the shaded zones in figure 4.1, that indicate the variation of the four footprint measurements against the time after birth. The shaded zone is an approximation based on the available points. For comparison a growth curve of the print width of the Indian rhino (*Rhinoceros unicornis*), based on measurements from zoo animals, is included in figure 4.1 (References in the figure).

While the calf is still young and accompanies the mother the curves are steep and the band is rather narrow. In this stage a track of a calf can be aged rather accurately with the help of this figure. But after independence the curves flatten and the variation is considerable, making it impossible to age tracks accurately on the size only. Nevertheless tracks of this age are still easily recognizable as being from a young animal. These young animals have not only relatively small prints, especially small in the width of the front hoof and the print, but they have also a different appearance. The hoofs, especially the side hoofs, have a rather slender form, with sharp thin edges, which are very smooth and regularly curved. The plantar surfaces of the hoofs are flat with only very faint indications of ledges or lobes (see the stereophotographs of series 460 in figure 3.10, series 140 in figure 3.24, and series 146 in figure 3.27).

As a further aid in the ageing of the tracks of young rhinos, several growth-stages have been drawn to scale in the figures 4.2 and 4.3, based on the best casts available in the collection. The drawing of the foot of the newborn calf is an enlargement to scale of the drawing given by Bartlett (1873). The two-weeks and three-month old prints are from series 100, the 9-month (see also the stereophotograph of this cast in figure 3.27) and the 33-month prints from series 400. In figure 4.4 a drawing of one of the larger prints (male 610) is given for comparison.

#### 4.2 - Age classes

While the age of very young animals can be estimated to a few months on the size of the footprint, for older animals only broad categories can be indicated. For several of the longer series similar growth curves have been made, and a regression analysis performed on the data, but no growth rate for older animals could be obtained. The variation is too large and the points are located too far apart to give realistic outcomes in a regression analysis. Anyhow growth appears to be very slow after the first two or three years. No differences could be seen in size between early and late sets of the same series. This indicates that animals with very wide front hoofs and prints must be fairly old.

Comparing figure 4.1 and figure 4.5 shows that at the age of about three years the maximum print sizes are still much lower than the maxima for the adult animals. This means that the foot must grow considerably in later life, but it is not known whether this is a very gradual process related only to age, or whether there is increased growth during certain life stages. Obviously a wide front hoof and/or a wide print indicate advanced age. Other things that suggest advanced age are peculiar shapes of the hoofs and a pronounced profile of the plantar surface, with thick edges and lobes. Very irregular shapes of hoofs, like the front hoof of series 810 (see the drawing of the front hoof in appendix A), suggest very old age or even senility.

An indication at what size of print adulthood is reached can be found in those series of females known to be adult, because they gave birth to a calf. The lowest values found among these females were tentatively regarded as the lower limits of the range of the adult animals. Moreover none of these eight females had the characteristic appearance of a young rhino, all their prints were either considerably larger, or showed one or more peculiarities in the form of the hoofs.

All series were classified to age considering the size and the shape, as has been described above. Three categories were recognised: Juveniles - all calves born during the research period; sub-adults - the juveniles after independence and animals born before the study period, but still showing youngish characteristics in size and shape and presumably not yet participating in reproduction; adults - all known females and the other series that showed characteristics suggestive of advanced age. Four adults were classified as "very old" because of the peculiar worn-down look of the hoofs. Most series were easily assigned to one of these categories and only

(opposite page)

Figure 4.4 - A foot of a large adult male Sumatran rhino, based on a cast in series 610 (see also the stereophotograph in figure 3.28) for comparison with the figures 4.2 and 4.3.

four series (156,195,199,460) were intermediate. After further examination series 156 and 195 were added to the adult category and 199 and 460 were included with the sub-adults.

In figure 4.5 the variation in size for each of the categories is shown. There is considerable overlap between categories, with the exception of the front hoof which surprisingly shows only a minor overlap at 71 mm. Although this clear distinction is without doubt partially artificial, it could be useful as a field-characteristic to distinguish between sub-adult and adult rhinos. Anything over 71 mm is adult, anything under it is young.

#### 4.3 - Sex classes and sexual differentiation in footprint

For 8 of the 39 rhinos the sex is known; they were females accompanied by a calf during the study period. Others are suspected to be males, because they were not accompanied by a calf. Since a female Sumatran rhino nurses her calf for up to about 18 months and because it may take as long as three years before a female gets another calf (see chapter 6.4), any animal never accompanied by a calf during a period of at least three years, without interruptions in the records longer than 18 months, was assumed to be a male. Four series (610, 191, 296, 520) qualify in this category. Other rhinos could be tentatively classified as male or female according to such criteria as their distribution, occurrence and behaviour (see chapter 5.1.1 and 5.1.3). All 19 adult rhinos were tentatively classed as male or female. Two rhinos were classified with the 8 females and the other 7 rhinos of unknown sex were tentatively grouped with the 4 males.

The variations in the size of prints made by females and males are shown in figure 4.5. For all measurements the maximum values for the males are slightly higher than those for the females, indicating that the males' prints are generally somewhat larger. Print size is no more than an indication of sex, but this factor can be considered with other evidence.

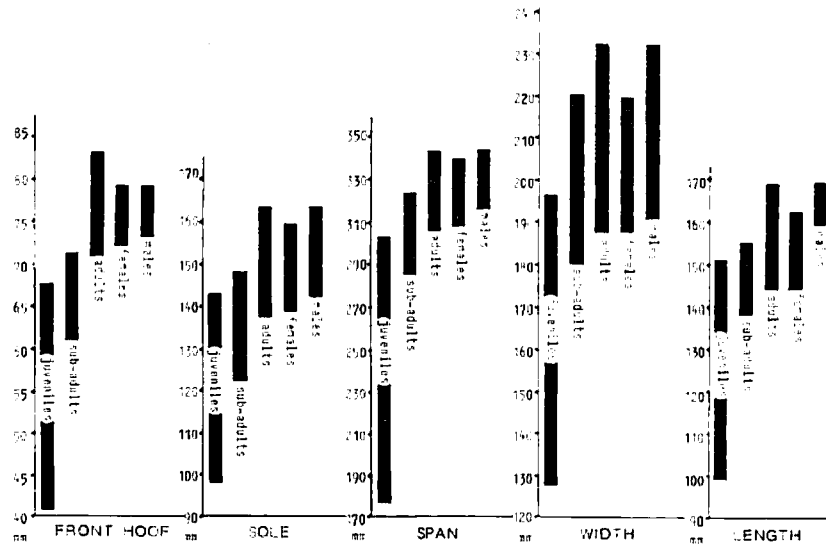


Figure 4.5 - The variation in the standard measurements for the different sex and age classes.

No apparent differences were found in form of the prints between the male and the female series, but it appeared that the females often have a more irregular print, with one or more of the hoofs having an aberrant shape or position. Also the side hoofs are often exceptionally long and most of the examples of changes in length of these hoofs (see chapter 3.5.4) were found among the females. The males have a more regular symmetrical print, with rather broad and regularly shaped hoofs. Probably the physiological stress of pregnancy and lactation influences the growth of the hoofs, resulting in a more irregular growth and form of the foot.

Examples of "typical" male and female footprints are shown in the stereophotographs of females in series 440 (figure 3.14) and 700 (figure 3.25) and of males in series 610 (figure 3.26) and 191 (figure 3.26). On the other hand male 296 (figure 3.25) has a very irregular print and showed a substantial change in size of the side hoof (it is also possible that this animal is in fact a female, but that it failed to reproduce or that the calf did not survive). The prints of female 840 (figure 3.24) and male 610 (figure 3.26) are almost identical in shape, flat with broad rounded hoofs. The prints of the female are clearly smaller, but the similarity in shape was such that initially they were not separated until female 840 turned up with a calf, while the animal making the larger prints was still travelling alone.

## CHAPTER 5 - DISTRIBUTION AND DENSITY

In this chapter the spatial and temporal distribution of the rhinos in the study area will be discussed. Basically two different ways of analysis have been used. Firstly all identified tracks of each rhino have been mapped. From these maps it is possible to compare the distribution of the different age and sex classes, changes in distribution over time and total ranges of individual animals. The average densities of rhinos in the study area was calculated from the spatial distribution of the various individuals. From the number of fresh tracks found by the patrols on each section it was possible to discover the parts of the study area most used by rhinos, and how often certain places such as salticks and wallows, are visited.

In the following chapters the term 'range' will be used for the area over which the tracks of one individual rhino were recorded. To calculate the size of this range a polygon was drawn joining the outermost records on the individual distribution map (see chapter 5.2). The area over which each rhino extends its daily activities over a long period is regarded as its 'home range'. Obviously the range of each rhino, as shown by its tracks may be only a part of its home range, but the extent and location of the latter may be estimated by looking at the size of the range, the direction of the tracks and the frequency of occurrence in the study area.

Some rhinos, mainly males, use a part of their home range more heavily, for which part the term 'core area' will be used. The rest of the home range, which is only occasionally visited by the rhino, is called the 'peripheral area'. The term 'centre' of the home range is used for the approximate geographic middle of the estimated home range. Most rhinos use specific routes to go to the saltlick, and these parts of the home range are called 'corridor' to the saltlick. Since a female nursing a calf appears to occupy a different area from those she occupies at other times, the home range of a female is split in a 'breeding' and a 'non-breeding' home range.

After each expedition all tracks found were mapped, together with collection numbers, dates and other relevant information. Throughout the process of sorting casts rough maps were made of individuals' movements. After the sorting a final map was made for each rhino including all records from the entire study.

### 5.1 - Distribution of the age and sex classes

The maps presented in figures 5.1 to 5.7 show the distribution of all individuals in a simplified form. Tracks are indicated by a symbol for each individual, and where a track was followed another symbol is placed every 500 metres. Separate maps were made for the different age and sex classes. For females two maps were made, one showing the ranges while they moved alone and another map for the period they were accompanied by a calf.

The first six maps (figures 5.1 to 5.6) show the actual locations of animals, while the seventh map (figure 5.7) shows the approximate centre of the various home ranges and the salticks visited by each rhino.

#### 5.1.1 - Distribution of the females and their calves

Finding tracks of a rhino accompanied by a young calf was always an exciting and joyous moment, and particular attention was paid to those parts of the study area where nursing cows were known to reside. It soon became clear that females with calves have a different distribution pattern compared to other individuals. Usually they were found in the vicinity of a saltlick which they visited relatively frequently. Tracks of the same cow and calf pair were generally found in a number of places on one expedition, and when fresh tracks were found there were often also old tracks in the same place, indicating repeated passage. Surprisingly often the nursing female's tracks were not of the well-known individuals, but appeared to be new in the area. When cow and calf separated the calf normally remained in the same area, but the cow seemed to leave the area.

Comparing the distributions of the same females for the periods with (figure 5.2) and without (figure 5.1) calf reveals considerable differences in their ranging behaviour. In the period that they are without a calf, the female rhinos are found relatively seldom, usually in the higher

parts of the study area, away from the bigger rivers. If they come lower it is usually for a quick visit to a saltlick. But with a calf they are much more frequently found at lower altitudes and from their abundant tracks it can be concluded that they make relatively frequent visits to the salticks (see chapter 5.6).

The non-breeding females appear to prefer the ridges and there is very little overlap in range between different individuals. The non-breeding ranges of the females are well separated from each other and they seem to be evenly distributed over the area. Non-breeding females only come together near the salticks, but actual overlap was minimal, because each rhino uses a specific corridor to the lick and usually does not deviate from this path. The range of rhino 195 (probably female) does not overlap with any of the other females (see figure 5.6).

A breeding female with a calf appears to shift its range to an area close to a saltlick. Then they are found frequently in the lower parts of the study area, where the salticks are located. The breeding ranges of the cows show considerable overlap near the salticks and several times tracks of two different cow and calf pairs were found very close together at about the same time.

When comparing the distributions of the females with calf (figure 5.2) with the distributions of the calves after separation (figure 5.3), it is apparent that the calves remain in or close to the area where they wandered with the cow. The cow after separation presumably retreats to its non-breeding home range, higher on the ridges. The calf remains for some time (at least 2 to 3 years) in the area where it was found together with the cow, in the lower parts of the study area, close to the salticks. Usually the area over which it wandered with the cow is larger than the area it occupies in the first years of independence, but once independent it also seems to explore adjacent areas probably for the first time. The ranges of the independent calves show considerable overlap. In several instances tracks of two or three calves were found within a few hundreds of metres from one another, using the same trails. It could be that in some cases these calves were walking together or were following one another's track, but they certainly do not associate for longer periods, or tracks of the same groups or couples would have been found more frequently together.

The following examples will clarify and illustrate the general observations made above. Female 440 was found twice before giving birth and four times after separation from the young, and her tracks during these periods were found exclusively on the trail leading north from saltlick 1. Mostly the tracks followed the trail closely, indicating that the animal was moving deliberately to the saltlick. From her wandering tracks found further north it was concluded that this animal usually ranges east of the most northern extension of the study area, but regularly visits saltlick 1.

On the four occasions when this female was found with calf 400, it was not only travelling along the northern route, but also east and south of saltlick 1, almost as far as camp Aceh. Each time the pair visited the saltlick, but from different directions and they did not return in the same direction but moved on to new areas. Their course was usually meandering, often leaving the main trails and wandering through the forest. Several times they descended to the Mamas river, and occasionally swam for a short distance, but they never crossed over to the west side of the river.

Similarly female 700, a visitor to saltlick 2 was found three times before the birth of her calf, and always in the northwest corner of the study area, on a route leaving the study area. She consistently followed the same route every time, never deviating one step from the trail. With her calf she was found twice away from this route, approaching the saltlick from a different direction. Both these females appear to have the main parts of their non-breeding home ranges outside the study area, entering only to visit a saltlick. Accompanied by calves they spend much more time in the study area, presumably to remain in the vicinity of the salticks.

Records for Female 840 show a different pattern. This animal was found four times without calf, walking around west of camp Aceh (Jalan Sudirman area) and upstream of saltlick 3, outside the study area. Once she was found on the route along the Mamas, going to saltlick 1. Travelling with her calf (rhino 800) she was never found in the Jalan Sudirman area, although this area is patrolled every expedition, but only around salticks 1 and 2, apparently using saltlick 1. This female's non-breeding home range seems to overlap a fair part of the study area, from where it frequents saltlick 1. With calf her, too, appears to concentrate her activity around the saltlick, and the breeding home range is probably located along the Sungai Markus because the tracks came from that direction.

The records for the fourth female (444) in the northern part of the study area are very incomplete. She was only found a few times east of camp Aceh, on expedition 6 accompanied by a small calf. No casts could be made of the calf and the pair was never encountered again. During the 14th and later expeditions a young rhino (445) turned up in the same area, and could well have been the young of 444. The female has never been found at a saltlick, but because calf 445 visited saltlick 2, it was assumed that 444 goes there too.

The two females from the central part of the study area (515 and 155) show identical patterns. Without their calves they were seldom found, and only near the western boundary

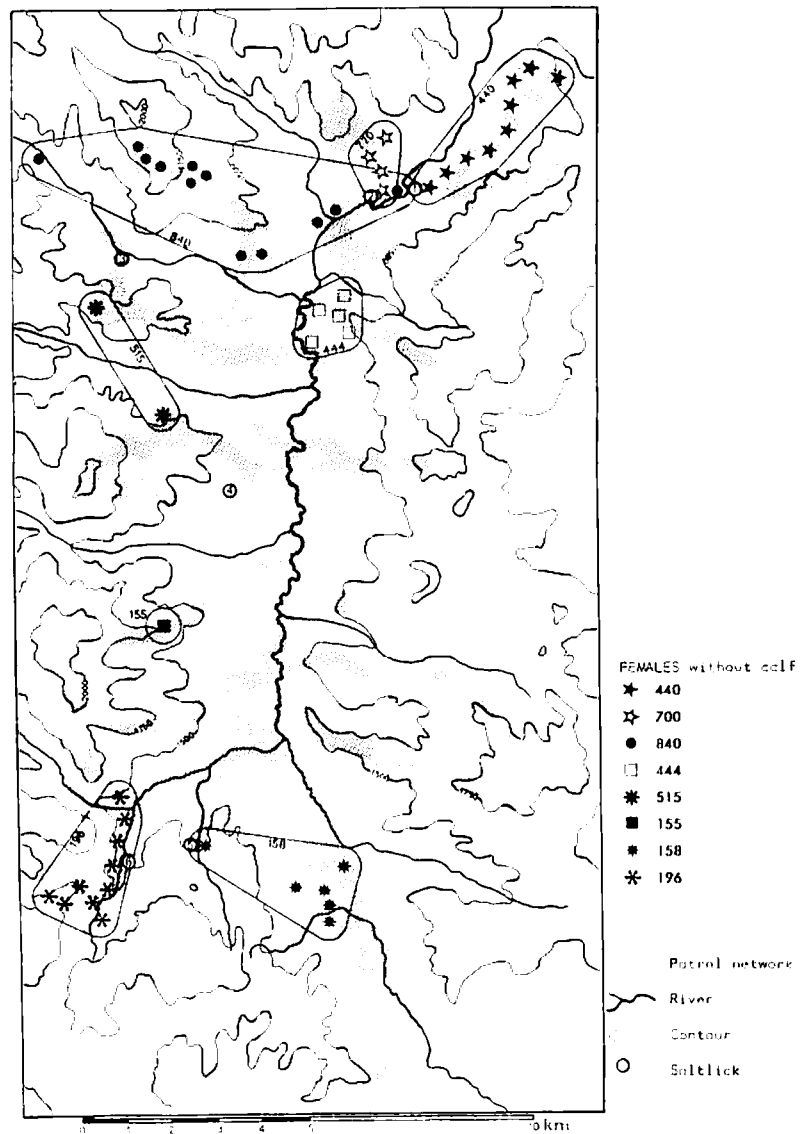


Figure 5.1 - Distribution of the breeding females in the period that they were without calf

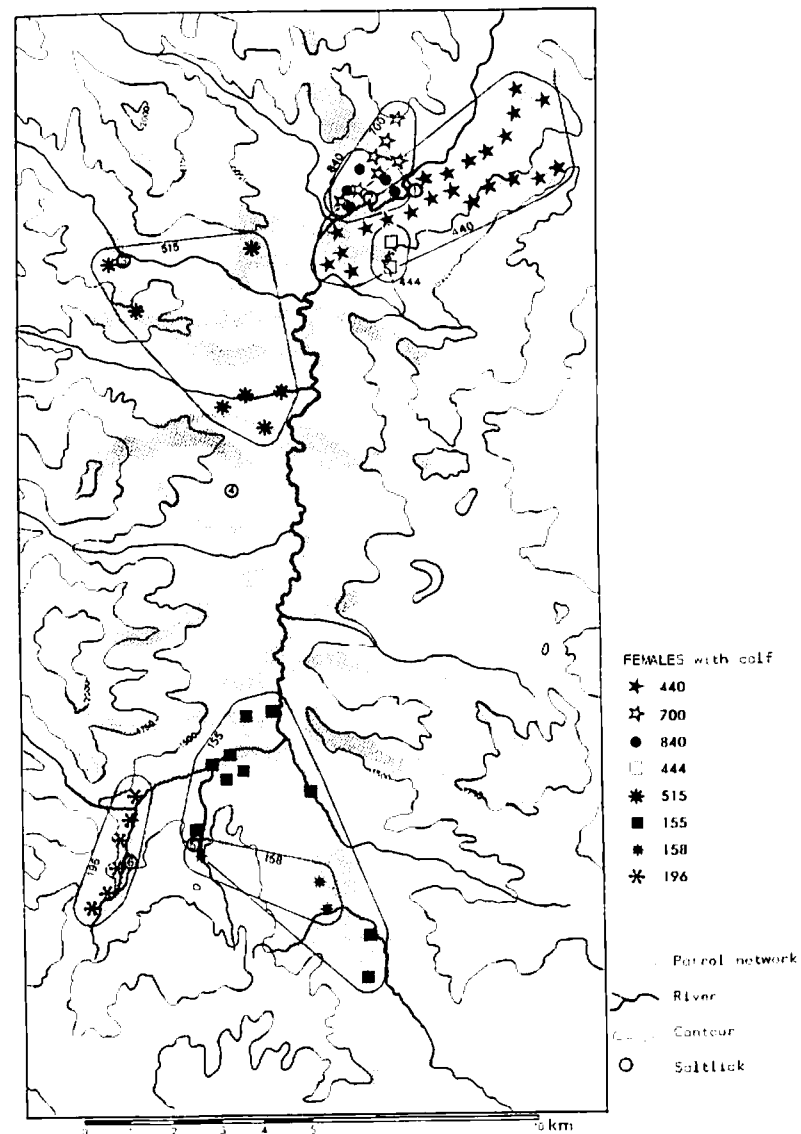


Figure 5.2 - Distribution of the breeding females in the period that they were with a calf

of the study area, but with calf they were found over a large area. Female 515 and calf 410 visited saltlick 3 and wandered over the area between that saltlick and the Mamas river. Female 155 and calf 130 frequented saltlick 5 covering an area between that saltlick, camp Pawang and camp Lukluk. Again both females appear to have their non-breeding ranges largely outside the study area, but with a calf they come down to the valley and remain in an area adjacent to the saltlicks.

Two females were found in the south. Female 196 and calf 200 were found fairly frequently, but only close to saltlick 6. They appear to originate from the mountains west of that saltlick. The records of female 158 and calf 138 are rather scanty. They visited saltlick 5 and were otherwise only found on the watershed between Mamas and Silukluk. The female presumably has a non-breeding home range in an area north of camp Lukluk, crossing the study area on the way to saltlick 5. The breeding home range is probably also largely outside the study area, possibly south and east of saltlick 5.

Calf 400 was rarely found after independence, and then only on the northern trail to the saltlick 1, and also a little further south on the west bank of the Mamas, where the cow was never found. Calf 100 was found late in the study and was still dependent at its conclusion. The young sub-adult 840 was only found around saltlicks 1 and 2 where it was also found with its mother 800. Young sub-adult 445 ranged over a rather large area, east of camp Aceh, an area it had probably also wandered with the cow.

By far the most complete records are available for the independent calf 410. After it left the cow its tracks were found on almost every expedition and generally more than once on an expedition. Its range overlaps considerably with the breeding range of its mother and most of the tracks were found along the ridge between saltlick 3 and the Mamas (Jalan A. Yani area). From the number of tracks it appeared that the animal made very intensive use of the area, walking up and down through the area. Once tracks were found, usually fresher tracks were found a few days later in the same place or nearby. This animal was regularly recorded in this area for a period of about three years, till the end of the study.

Calf 130 was after it left its mother found west of camp Pawang, along the lower Sungei Pinus and at the saltlick 5, but it was also found once at saltlick 6, where neither it nor its mother had ever been recorded before. In this case the home range of the young sub-adult appears to be located between the breeding and non-breeding ranges of the cow. Once independent calf 138 was found at saltlick 5 and further north, whereas with the cow it had appeared to reside south and east of the saltlick. Calf 200 was found on the mother's route from the west to saltlick 6, but also further downstream along the Sungei Pinus.

After separation all calves spent the first few years in roughly the same area they had wandered over with the cow. But the home ranges of the young sub-adults do not overlap completely with the breeding ranges of the females. They no longer visit some areas they had used with the cow and range into new adjacent areas, previously unknown to them.

Apart from the 8 pairs described above we found tracks of a few unassociated young rhinos, apparently born during the period of the study. This indicates the presence of still other females in the area. Based on the estimated dates of birth and the estimated breeding interval (minimal about 1500 days - See chapter 6.4) some suggestions can be made regarding the identity of the mothers of these young.

Young sub-adult 134 was found in the same area as calf 200, but since the birth interval between the two is only 630 to 880 days, it is highly unlikely that both calves had the same mother. Rhino 134 was presumed born in the second part of 1978 or early 1979, so it should have been accompanying a cow at least on expedition 15 and 16 and possibly on expedition 14, but no tracks of calves were found then. There are only two rhinos known to visit saltlick 6 from the south or west - 181 and 192. Rhino 181 cannot be the mother because this animal was found without a calf on expedition 16, but tracks from rhino 192 were found only on expeditions 13 and 14; this animal could have been the mother of 134. It was remarkable that on the 14th expedition fresh and old tracks of rhino 192 were found at saltlick 6 and also old tracks at saltlick 5, indicating that the animal had visited this place twice in a short span of time and apparently wandered away from her normal route. The distribution of the tracks of other females suggests that females might move down to the saltlicks some time prior to the birth of the calf.

Young sub-adult 135 was assumed born at about the same time as young 134, and from its tracks it seems that this animal probably visits saltlick 4 from the south. On the very first expedition a set of unidentifiable double tracks were found there, but no very small prints. This may have been a female with an older calf, already one or one and a half years old. Young 135 could be the next calf of this unknown female, because there would be at least a 1500 day interval between the births. This calf must have been accompanying a cow at least during expeditions 15 and 16, and probably also on the 14th expedition. Rhinos known to range that area include adult 195 and adult 106, but rhino 106 is unlikely to be the mother, it was found only once and is probably only an occasional visitor to the area. Rhino 195 was found frequently

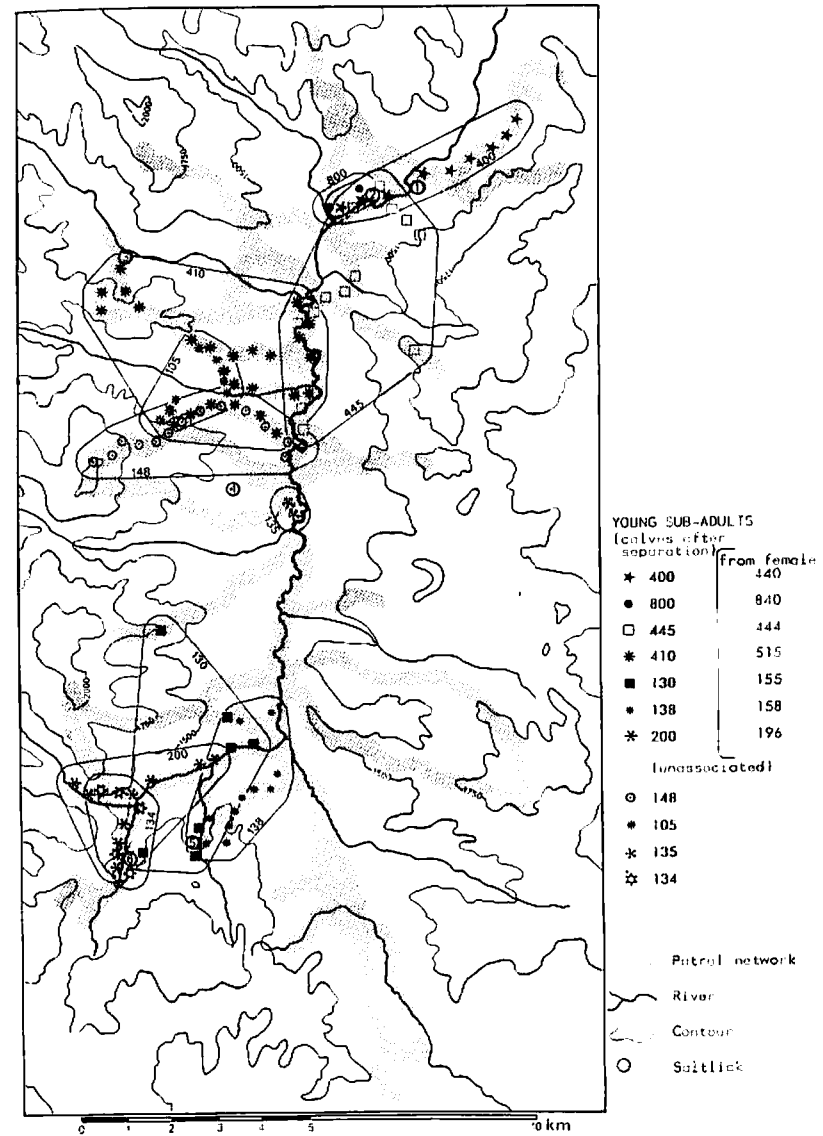


Figure 5.3 - Distribution of the calves born or presumed born during the period of the study, after they became independent from the female. The distribution of the older sub-adults, apparently born before the period of the study, is shown in figure 5.4



between the 8th and 11th expeditions and there is one unreliable record from the 17th expedition. It probably has its home range in the area north of the Sungai Pinus, from where it visits saltlick 4. With a calf it might reside in the area southwest of the saltlick, along the Sungai Niko, and be easily missed by the patrols. Sub-adult 146 could very well be the previous young, because it is found in the same area. Based on the above arguments the rhinos 192 and 195 are tentatively grouped with the females when appropriate.

Young sub-adult 148 was only found on the 16th expedition, when it entered the area over the top of the mountain west of camp central, walked down along the trail to the Mamas and returned along the same route. From the size of its tracks it was estimated as having been born in the first half of 1977, so would probably be travelling with its mother on the 10th and 11th expedition and probably also on the 9th or 12th. None of the rhinos known to reside in the study area seems a suitable candidate for mother. The most likely explanation is that young 148 and its mother normally reside west of the study area, possibly visiting saltlicks further up the Sungai Badak, and that the young animal made a short excursion into the study area, following a big game trail.

The fourth unassociated young (105) was found twice on the 17th expedition. Its prints were very small for an independent rhino and it was concluded that it was born in early 1979 and had left the mother only recently. Because it was found in the same area as calf 410, it seems likely that this is another calf of female 515. The cow was found only once on the 14th expedition, before this calf could have been born. If female 515 is the mother to both calf 410 and calf 105 the breeding interval would have been between 1000 and 1100 days.

### 5.1.2 - Distribution of the sub-adults

The distribution of those animals that were classified as sub-adults (which in this chapter does not include the calves that were born during the study) is shown in figure 5.4. The first thing that strikes the eye is the absence of this category from the southern half of the study area. In the northern half these smallish prints, called "mini" in the field, were found throughout the study period, but in the southern half they were absent until the three calves born there became independent. The reason for this can only be guessed, but it might have been caused by rhino poaching that occurred in this area until the start of this study (see chapter 5.1.4 and appendix C).

In the northern half of the study area prints of sub-adults were found frequently, more regularly than the larger prints of the adults. Their ranges include both high and low land and there is considerable overlap. In general the ranges of these older sub-adults seem to be larger than the ranges of the independent calves. Tracks of two sub-adults were found on both sides of the Mamas river. For all other rhinos in the northern half the Mamas appears to be an important boundary and they were never found on both sides except very close to the river.

The saltlicks 1 and 2 are each visited by one sub-adult - 446 and 820 respectively - and saltlick 3 and 4 by two sub-adults each - 140, 460 and 146, 199 respectively. From the distribution of the calves after separation it is clear that young sub-adults remain in a rather restricted area, close to where they were nursed, for at least two to three years. It could be that during the whole sub-adult phase the rhino only very gradually extends and shifts its range, and that the older sub-adults will still be found in the area where they were nursed. This lends added weight to the suggestion made previously that rhinos 146 and 195 could be young of the same cow, because they occupied roughly the same area. From their ranging patterns it seems likely that rhino 446 could be the progeny of female 440, rhino 820 of female 700 and rhino 140 of female 515. The tracks of sub-adults 460 and 199 were intermediate in size between sub-adult and adult when first found (see chapter 4.2) and are probably older than the rest of the sub-adults, and might be even earlier progeny of one of the females mentioned above.

### 5.1.3 - Distribution of the males and other adults

Only four of the adults can be identified with any certainty as males (see chapter 4.3). The ranges of these four males are shown in figure 5.5. Since there are known to be 8 or possibly 10 females in the total number of 21 resident adults, it can be expected that some of the other adults are males too, if we assume a roughly equal sex-ratio. The ranges of all unsexed adults are shown in figure 5.6.

Male ranges are extensive, much larger than those of the non-breeding females. They extended over both the lower and higher parts of the study area. Male ranges show considerable overlap and males wander over a wide area.

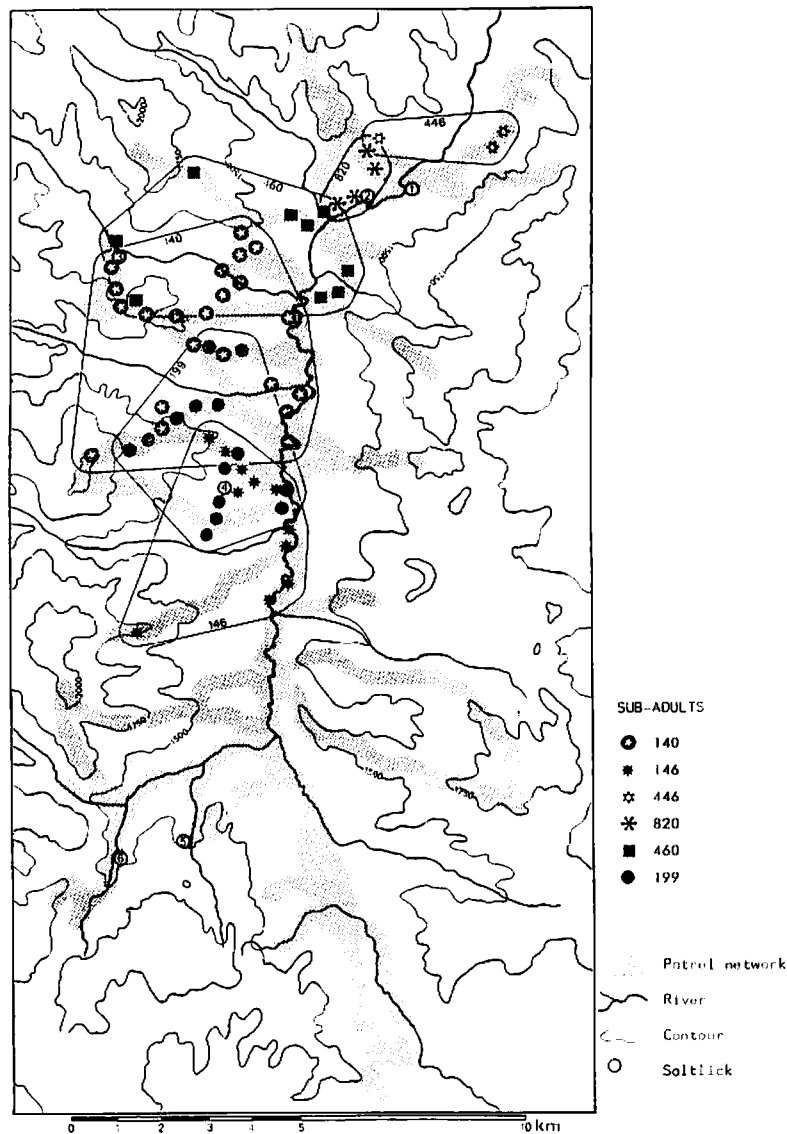


Figure 5.4 - Distribution of the older sub-adults, already independent at the start of the study

Male 520 is the most regularly recorded rhino. His tracks were found on most expeditions and often more than once in different locations. It appears that his home range covers a rather large area west of the Mamas, overlapping much of the study area. Like male 520, the other northern male - 610 - visits saltlick 3, but his range lies more to the north. The ranges of both males overlap, but male 610 appears to have a fair part of his home range outside the study area, and therefore the overlap is probably less than suggested in map 5.5. Male 610 was usually found north of the Batu Ikat river, and only on one occasion further south, near the Badak river, where male 520 is most often found.

Of the other adults in the northern half of the study area, two - 106 and 810 - seem typical of very old animals, with peculiar asymmetric prints, and both were found only once. These are probably only occasional visitors to the area, probably coming to one of the saltlicks. The tracks of the other two rhinos - 110 and 880 - were found over a large area, but there was no firm evidence that they were males, although their ranging patterns suggest this. Rhino 880 occupies an area east of the Mamas. It probably uses one of the northern saltlicks, although its tracks were never actually found there.

Rhino 110 (this rhino has a very characteristic print) shows a remarkable distribution. It was found once on the top of the mountain west of camp Central and twice more around saltlick 1 and on route thence, passing the saltlicks 2 and 3. Probably this rhino normally resides west of the study area, from where it undertakes a long journey to saltlick 1, bypassing two other saltlicks. Because all unsexed adults in the northern area have large home ranges and occasionally wander far from the centre of their home range, like the known males, they are all grouped with the males when appropriate.

The two males in the southern area - 191 and 296 - were found less frequently. Both visit saltlick 6 and probably have a large part of their home range outside the study area. Male 191 has a relatively large range, but most of this is due to one single trip the animal made from the Silukluk area, along the Tenang river, up and down the Mamas for a few kilometres and further up the Pinus river to the saltlick. More usually it approached the saltlick from the south or east, and the centre of its home range is probably south of the study area, between the Silukluk and saltlick 6. Male 296 was also found at saltlick 6 and close to the watershed between the Mamas and Silukluk. The tracks indicated that the centre of its home range is located northeast of the Silukluk, and it crosses the Silukluk area on its way to the saltlick.

Of the other five adults that were recorded in the southern half of the area, two - 195 and 192 - are probably females (see chapter 5.1.1). Another - 194 - was a regular visitor to the study area during the first two years of the study, but later vanished. The direction of its tracks suggest that it resides northeast of the Tenang river, and passes through the study area on its way to saltlick 5. The other two animals are occasional visitors, rhino 181 comes to saltlick 6 from the south and rhino 156 has been found a few times in the Silukluk and Tenang areas. Since the distribution of tracks of these three animals did not give sufficient information to sex them, all three were tentatively grouped with the males.

#### 5.1.4 - The overall distribution pattern

The distributions of the individual rhinos, as described in the previous chapters, clearly show that each rhino has a fairly well defined home range that includes a saltlick. Figure 5.7 shows the home ranges of known individuals. For some individuals the range is well known, for others it can be deduced from occasional tracks and direction of travel; for a few animals there is too little information to deduce anything other than an approximate locality for the animal's home range. Most rhinos were actually recorded at one of the saltlicks. Some were found nearby or walking towards a lick. The saltlicks are also shown in figure 5.7.

From the distribution map (figure 5.7) it seems that rhinos were absent from the area east of the Mamas in the central part of the study area, apart from north of camp Central and in the Silukluk area where a few rhinos were found in the mountains east of the Mamas. Most individuals were found west of the Mamas-Silukluk valley (30 of 39). In fact the area east of the Mamas was visited by rhinos, but good tracks were never found. Old faeces were occasionally found, but rhinos seem to use the area infrequently.

Although the area east of the Mamas is rather steep, it is not unsuitable for rhino, and there are well-developed rhino trails on all the major ridges, as elsewhere in the study area. But the trails were obviously very little used, overgrown at places, and the wallows had not been used for a long time. The trail system indicates that the area was used regularly by rhinos in the recent past. Their disappearance in recent years is doubtless caused by trapping on the Alas side of the mountains. Rhino traps were found close to camp Pawang in 1975 (see appendix C) and old signs of poaching were numerous on the slopes facing the Alas valley. Only in the north of the study area are rhinos safe east of the Mamas, because the escarpment there is extremely rugged and steep.

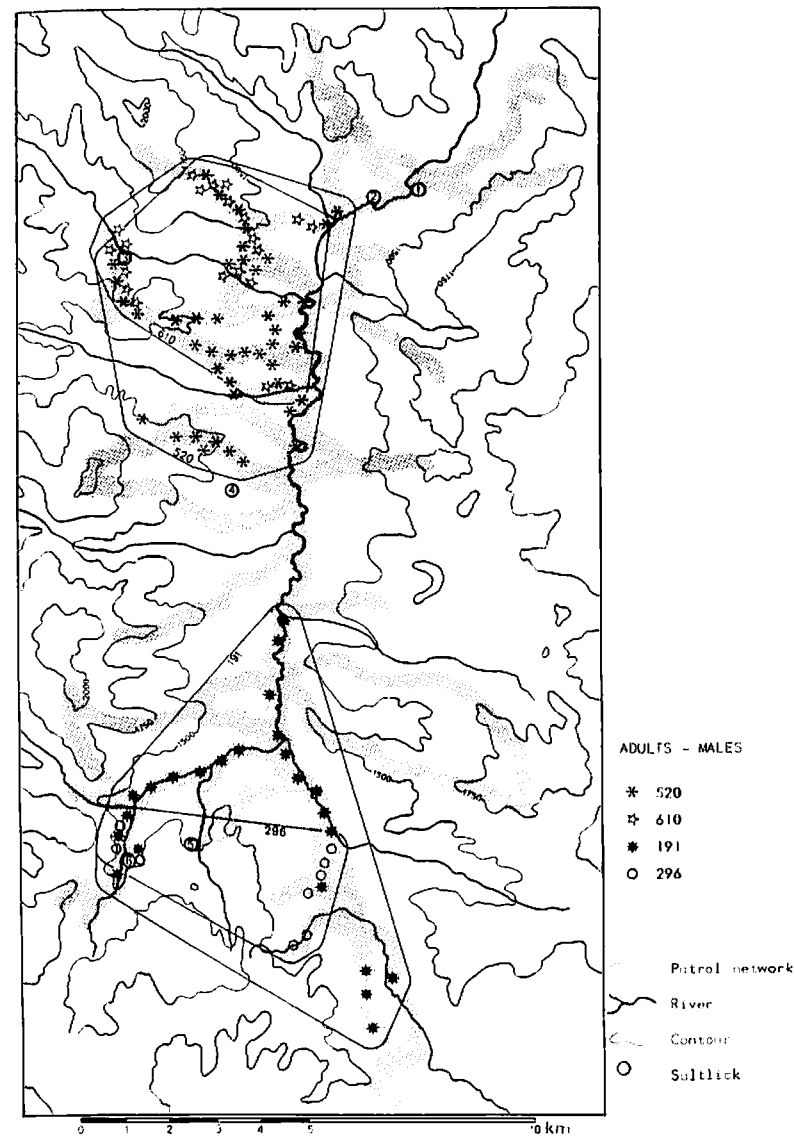


Figure 5.5 - Distribution of the adults, identified as males

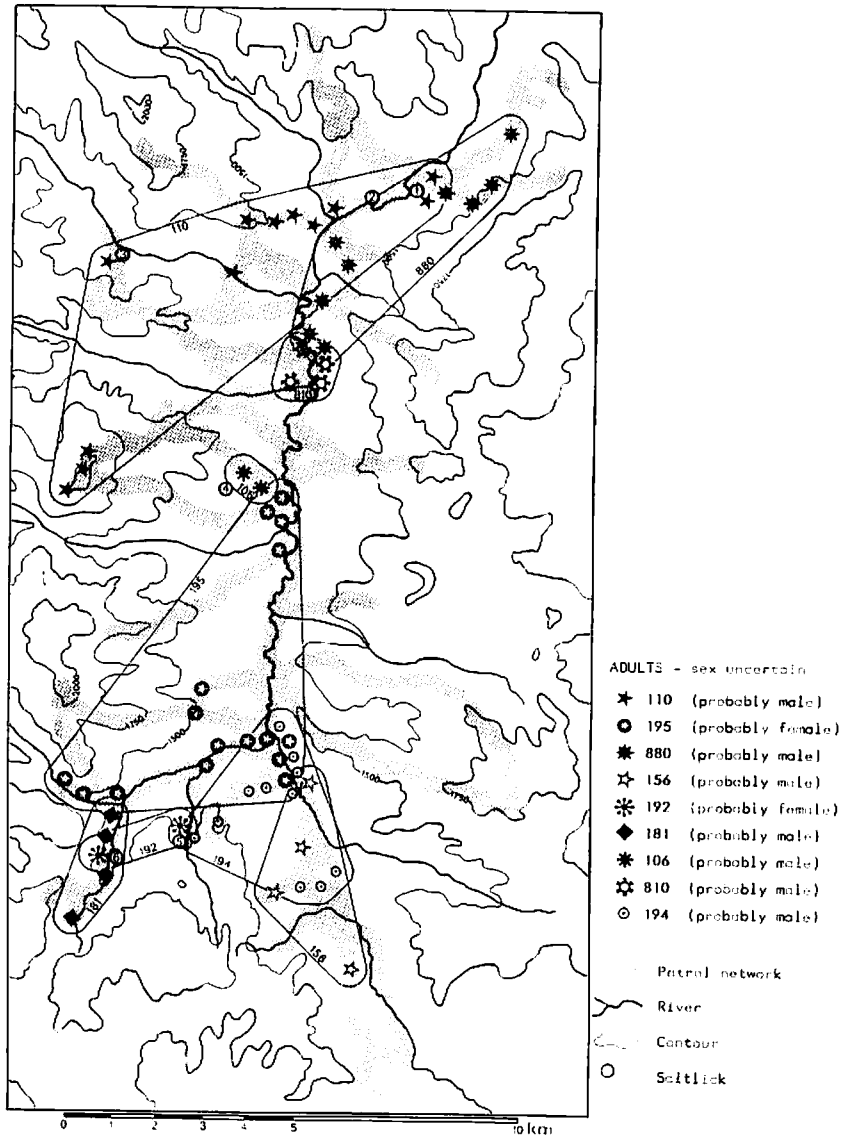


Figure 5.6 - Distribution of the unsexed adults. Two are probably females, seven are probably males

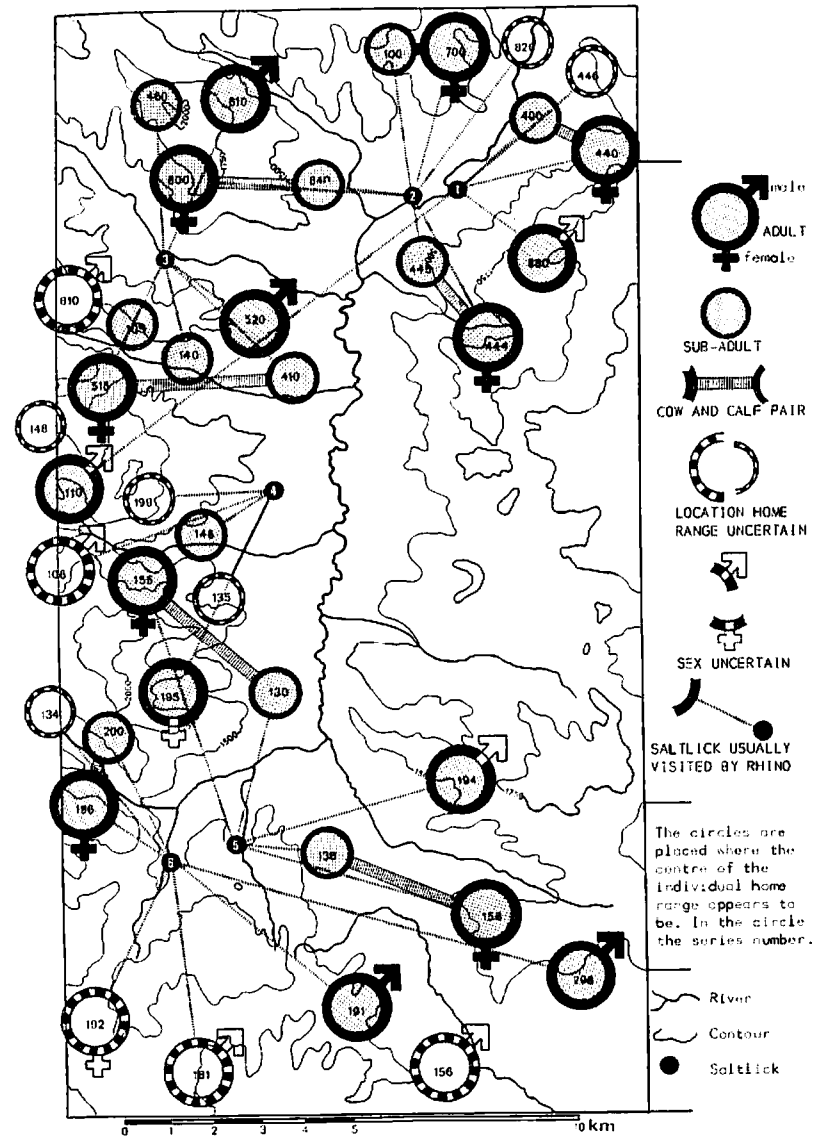


Figure 5.7 - Distribution of all identified rhinos. The circles are placed at the assumed centre of the home range

If we compare the northern and southern halves of the study area, taking the Sungai Niko as boundary, some differences in the distribution of individuals are apparent. Sub-adults are absent from the southern area and the total number of rhinos seems to be less there. 23 individuals were using the area north of Sungai Niko but only 16 were found in the south. These differences in numbers are probably also attributable to poaching. On the ridges south of the study area and in the area around saltlick 6, rhino trapping was practised for many years and as recently as 1974, and a fair number of rhinos must have been killed there. This could also explain the absence of sub-adults in this area. Females with calves and young rhinos remain close to the saltlicks and since traps are often placed on the big trails leading to the licks, they probably run a greater risk of being killed than the other rhinos, which go there less frequently.

The saltlicks appear to play an important role in the life of the rhino. The calves are born and raised in the surroundings of the saltlicks, and stay in the neighbourhood for some years. All rhinos pay regular visits to a particular saltlick, often travelling long distances to reach it. Tracks of 30 of the known individuals were found at saltlicks and only four individuals were never recorded close to a saltlick. Most animals seem to regularly visit one saltlick and only a few rhinos were recorded at more than one lick; in most cases these animals were males (see chapter 6.2). Travelling to or from a saltlick rhinos usually stick to one, but occasionally more, regular tracks; and in several cases rhinos visited a saltlick which was not the one nearest to the centre of their home range. The rhino home ranges serviced by each of the saltlicks overlap. It could be that rhinos normally visit the same saltlick throughout their lives and that most of the animals visiting a particular saltlick are related. The frequency of the visits to the licks will be further discussed in chapter 5.6.

For almost all the rhinos the Mamas river seems to be an important boundary. From the range maps in the figures 5.1 to 5.6, it is apparent that all but two animals (sub-adult 460 and sub-adult 446) are found exclusively on either the west or the east side of the river, although a few animals cross to the further bank but do not move away from the river. The other rivers and streams in the study area do not seem to act as a boundary.

The Mamas river is certainly not a physical barrier to rhino movements. Normally when a rhino descends to the river it enters the water, swims or wades to the other side, and often follows the river for some distance, crossing several times, but it almost always returns to the side from whence it came. Sometimes short visits are made to the opposite banks, but the animal generally quickly recrosses. A big river may be an important landmark for a rhino, determining part of the boundary of its home range (see also chapter 7.2).

The non-breeding ranges of the females all seem to be located at the margins of the study area, on the higher slopes of the mountains. This is also true for the ranges of most males and other adults. Only a few sub-adults have home ranges more to the centre of the study area. This is probably an artefact of the study area's location besides the Mamas river. This river forms the boundary of the home ranges of most rhinos, and therefore lies at the periphery of their extensive home ranges. If the study area had been centred on a major watershed, then it would probably have encompassed the main centres of distribution of the adult rhinos, but we would have found few tracks of young animals, which are found mainly at lower levels near the river.

Young and sub-adults range mainly on the lower slopes of the mountains, closer to the river, and to the saltlicks. The adults spend most of their time away from the licks, with the centre of their home ranges on the major ridges. The distributions of the non-breeding females and the males seem to differ. Tracks of the males were found frequently and virtually everywhere in the study area, in the higher and lower parts alike, and males have large home ranges that overlap extensively. Tracks of non-breeding females were rarely found in the study area and the non-breeding home ranges seem to lie on the higher parts of the ridges, with individual home ranges rather restricted and well separated from the ranges of other females. Centres of both female and male home ranges seem to be rather evenly distributed over the area.

Females seem to show a strong spacing mechanism. In non-breeding condition they use strictly separated home ranges, but with a calf they are less exclusive. The males do not avoid one another's home ranges, but it may be that there is only peripheral overlap of the extensive home ranges, and that the core areas are more clearly separated. Young sub-adults appear to occupy mainly the marginal parts of the home ranges of the adults, and gradually expand their range with time, gradually moving away from the lower slopes and saltlicks where they spent their infancy.

## 5.2 - Analysis of the individual ranges

To analyse the extent of individual home ranges detailed large-scale distribution maps were made for all the rhinos; a selection is shown in figures 5.8 to 5.11. The course and direction of each track is shown by the thick solid lines, and tracks made during the same expedition are, whenever possible, connected by dashed and dotted lines to indicate the presumed course of travel. Dashed lines indicate unidentified tracks if these are believed to have been made by the same rhino. The dotted lines connect successive tracks of the same rhino and indicate the animal's probable route. Wallows used by individual rhinos are indicated by solid circles.

Range size was measured by drawing a polygon enclosing all recorded tracks. Straight lines were used except where the Mamas river was known to form the boundary. There the approximate course of the river was used as the boundary line. If the direction of the tracks suggested that the rhino had ventured outside the polygon, this is shown by the short fat arrows.

The maps presented in figures 5.8 to 5.11, show the ranges of animals from different age and sex classes. No ranges are included for rhinos that were found only once or twice, animals found only in a small area on their way to a saltlick, or whose tracks were found only infrequently.

There are a few factors complicating the estimation of the size of the home range of the individual rhinos. The irregular and localised occurrence of the tracks of many of the rhinos in the study area, suggests that most animals spend only part of their time in the study area. The range of an individual as shown by its tracks recorded during the study therefore represents only a part of its home range, but it is difficult to estimate how large a part that is. For the estimation of the average size of the home range for each category the ranges of the most frequently recorded rhinos have been used.

### 5.2.1 - Female home ranges

As has been explained previously females in non-breeding state use different ranges to when they are accompanied with a calf. Females with calf were found comparatively often in the study area, usually close to a saltlick. Outside the breeding period the females were found much less frequently and on the higher slopes, where they have relatively small ranges, which do not overlap with those of other females.

Because of the limited number of records of non-breeding females, sizes of home ranges are difficult to estimate. But the range of a non-breeding female is certainly comparatively small, much smaller than the range of a male, otherwise the rarity of records of non-breeding females cannot be explained. The non-breeding home range is probably not more than 10 to 15 sq km, perhaps even less, with the female using a regular corridor to a saltlick.

Much more records are available for females with a calf. The home range of the pair is about 10 to 15 sq km, and adjacent to the saltlicks. Because of the shifts in home range in relation to the breeding cycle, the total home range of a female (throughout the breeding and non-breeding periods) is fairly larger, but only part of it is used at any time. For one well-known female the "overall" home range was about 20 sq km. For other females figures cannot be given, but all appear to have relatively small home ranges, clearly smaller than the males' home ranges (see chapter 5.2.3). The average home range of a female rhino was estimated to be 20 sq km.

When a female visits a saltlick, her tracks are generally easy to follow. Often her tracks to and from the lick follow a direct route. Occasionally a few short detours were made around the lick, but the animal's trails of approach and departure were easily found. Unlike males, females do not make extensive explorations in the environs of the lick; they simply ingest minerals and leave again. Non-breeding females seem to be very conservative in their choice of route to the saltlick, and they use the same route each time they travel to the lick. When accompanied by a calf they may approach the lick from several different directions.

The following examples will illustrate female behaviour. Three females - series 700, 440 and 196 - were found fairly often without calf, but invariably on a specific route to one of the saltlicks, and their ranges are illustrated in figure 5.1. The rhinos 440 and 700 used exactly the same routes to approach and leave the saltlick every time, generally not deviating more than a few steps from their previous track. Since all the records for these females follow one line their known ranges are very small (0.2 to 3 sq km). Female 700's tracks were found only in the last kilometre of the corridor the animal travelled to the saltlick.

Four of the females were found very seldom outside the breeding period, and their known non-breeding ranges are also very small (1 to 3 sq km). Female 158, found once at saltlick 5 and twice in the Tenang - Silukluk watershed has her home range probably north of the Silukluk river. Female 444, was recorded three times in a small area east of camp Aceh. Female 155

was found only once and female 515 twice, three kilometres apart. The ranges of all these females are shown in figure 5.1.

The only female that was found over an extensive area during the period when she was without a calf, is female 840. She ranged over an area of almost 12 sq km in the Jalan Sudirman area, west of camp Aceh, and up to saltlick 1. A map showing all the tracks of this female is shown in figure 5.9C. This rhino was found once outside the study area upstream from saltlick 3, once at saltlick 1 and further west along the ridge. Again it appears that a fair part of this range is made up of the corridor to the saltlick, and that a fair part of the home range is outside the study area. The centre of the home range of this rhino is probably located somewhere around the mountain top at the end of the patrol trail, but it is difficult to estimate the extent of the home range.

The scarcity of records for most of the non-breeding females makes estimation of the average non-breeding home range very difficult, but it is apparently a relatively small area, no more than 10 to 15 sq km, part of which covers the corridor to the saltlick.

During the periods when the same females were with a calf more records are available. When the females have a calf they come down to the saltlicks and remain in a rather small area adjacent to the lick. One female - 444 - was found only once with a calf. Four others - 700, 158, 196, 840 - were found only very close to the saltlick, and their breeding ranges apparently fall also outside the study area (see figure 4.2). Three females used the study area fairly extensively.

From records collected on four expeditions over almost one year the range of female 515 and calf 410 was found to cover almost 11 sq km (see figure 5.2). No indications were found that the animals had been far outside the polygon and the breeding home range is probably not very much larger.

The distribution of the tracks of female 440 and calf 400 are shown in figure 5.9B. This pair was found on four successive expeditions and their tracks could be followed for relatively long distances. Their range covers a longitudinal area of over 9 sq km on the slopes east of the Mamas. The tracks of this pair were mainly found travelling to or from saltlick 1, but once they were found walking south along the slope and within a few hundred metres of the saltlick. Going to the saltlick they used several different routes, not only the route which the cow used regularly before the birth. The tracks indicate that the range is probably more extensive to the north and northeast but the animals were frequently found in the study area and the range shown in the map probably covers most of the animal's actual home range.

Female 155 and calf 133 were found on five successive expeditions, four times with fresh tracks. Their total range might be somewhat larger than the figured area of almost 13 sq km (figure 5.10B), but not much, because the animals were frequently found in the study area.

Based on these three examples of rhinos whose breeding ranges largely overlap the study area it can be concluded that a female rhino with a calf, has a home range of 10 to 15 sq km, adjacent to a saltlick.

For female 155 the 'overall' home range was substantially larger (15.9 sq km) than her range with young (12.9 sq km). For other females the total range is only slightly larger than the breeding range. Female 155 was found five times in succession with her calf, but outside this period she was found only once at the western boundary of the study area, about 5 kilometres north of the centre of the breeding range. It seems that this female, when not nursing, travels mostly outside the study area and that it migrated several kilometres south to nurse its calf. Its home range may therefore be as large as 20 sq km, but the animal uses only part of it at any one time.

Similarly female 515, seems to reside at the periphery of the study area, when not with calf. Other females, like 840 and 196, show smaller range shifts, and their total ranges may be smaller. The home ranges of the females are considerably smaller than those of the males, which can be 25 sq km or more (see chapter 5.2.4). The average home range of a female rhino, breeding and non-breeding together, is estimated to be about 20 sq km.

In this context it is worth considering the distribution of adult 195, as shown in figure 5.10C. As this rhino may be a female and the mother of calf 134, this rhino probably visits saltlick 4, because it was never found at the southern saltlicks, although it was often found nearby at Sungai Pinus. Its range is more than 20 sq km, but this can be attributed to one single track found close to camp Central and saltlick 4. All other tracks of this animal were found along or close to the Sungai Pinus. It could very well be that this rhino resides normally along the ridge north of the Sungai Pinus, travelling a rather long corridor to saltlick 4. After the birth she may have migrated to the area south or west of this saltlick; an area that was not very often patrolled. In general the pattern of distribution shown by this animal does not contradict the pattern described above for females, and this rhino could indeed be a female.

## 5.2.2 - Home range of the calves after weaning

In chapter 5.1.1 we saw that the calves, after having separated from the mother, remain in the area where they were nursed for two to three years, and gradually extend their range by venturing into adjacent areas. These young subadults have a home range of about 15 sq km, with a corridor to a saltlick.

One of the calves - 100 - was still with the cow at the end of the study. For four others - 200, 400, 800, 138 - only scanty records are available, but for three young subadults good sets of tracks were found over their first few years of independent life. By far the most frequently recorded young subadult is rhino 410, calf of female 515 (see figure 5.9D). Fresh tracks of this rhino were found on six of the seven expeditions made after it became independent. Its range covered almost 14.5 sq km, but most of the tracks are located in the eastern half of the range. It was found only once at saltlick 3 and it apparently does not use the big trail leading down from the ridge, but takes a more southern route to the lick; a route it probably used with its mother.

The home range of this rhino should probably be extended somewhat to the southwest and might be a little over 15 sq km. The western and less used part of the home range is formed by a corridor to saltlick 3, following the Sungai Badak, before turning north to the saltlick.

Another young subadult - 445, calf of female 444 - was found on the opposite side of the Mamas using an area of 11.6 sq km (Figure 5.9E). Although the eastern side of the Mamas was less regularly patrolled, this rhino was found on three successive expeditions, once over a rather large area. Although records are fewer than for calf 410, the home range of this rhino is probably not much larger than the range shown in figure 5.9E.

In the southern half of the study area one of the young subadults - 130, calf of female 155 - was found ranging over an area of 9.6 sq km (Figure 5.10A), on both sides of the Sungai Pinus. Its range would become considerably larger (almost 15 sq km) if an unreliable record on the high mountain top north of camp Pinus is included. It is remarkable that this rhino was found on one occasion at each of the southern saltlicks. On that expedition one of the rare visitors to the Sungai Pinus saltlick - rhino 192 - was also found at both licks, so it could very well be that calf 130 followed the older trail of rhino 192 to the other lick.

Young subadult 400 was also once found at saltlick 2, whereas with its mother it had always visited saltlick 1, and never crossed the Mamas (see figure 5.9B). This suggests that young subadults are exploratory and venture into new areas, thus gradually extending their range. This could also explain the sudden appearance of a new young subadult - 148 - on the 16th expedition (see figure 5.3), in an area that had been regularly patrolled before. The rhino came over the mountain top west of camp Central and descended to the Mamas along one of the big trails. After a few short detours close to the river it returned the same route and left the study area over the mountain top.

## 5.2.3 - Home range of the other subadults

Six rhinos were classified as subadults from the size and form of their prints. Records for most of these are scattered over time as well as in space (see the table of occurrence in figure 3.2B). The fact that their tracks were not found on every expedition but at infrequent intervals made identification of the tracks more difficult. The tracks were often also found at scattered locations over a large area, as can be seen in figure 5.4. In general the older subadults appear to have large ranges, 20 sq km or more, consisting of a small well-used core area and an extensive and less-used peripheral area. The average home range of an older subadult rhino is estimated at 25 sq km.

The most regularly recorded subadult is rhino 140, whose distribution is shown in figure 5.8C. Its range in the study area is 18.7 sq km, and it probably extends further in northern and western directions. A concentration of tracks was found east of saltlick 3, while in the eastern and southern part of the range the records are more scattered. This rhino's range seems to include a core area east of saltlick 3, surrounded by a wider zone, which the animal uses only occasionally. Rhino 140 was found less regularly than adult male 520, who uses the same area, and probably spends more of its time outside the study area than does rhino 520. The home range of rhino 140 is probably larger than the range shown in figure 5.8C, and might be as much as 20 to 25 sq km.

Another subadult - 460 - was occasionally found in the same area. It was encountered at long intervals and the locations are scattered (see figure 5.4). Its range of 12.6 sq km probably only covers a peripheral area and its core area may be outside the study area, probably

further west. West of Camp Central two more sub-adults were found, using saltlick 4. Both show the same type of distribution as rhino 460, and both apparently have the centres of their home ranges at or beyond the western boundary of the study area. The range of rhino 146 covered an area of 10.3 sq km (see figure 5.4).

The range of sub-adult 199, an animal found only twice near camp Central, is shown in figure 5.11A, mainly to show that this rhino visited the saltlick twice within a few days. Sub-adults 446 and 820 are poorly known. They visit the northern saltlicks, but were only found once or twice, so that nothing can be said about their home ranges. They probably reside north of the study area.

In summary it can be said that sub-adults appear to have large ranges, consisting of a core area and extensive and less-used peripheral zones and one or more corridors to a saltlick. In essence the ranges of older sub-adults are more similar to the ranges of males than to those of females; this may indicate that most of the recognised sub-adults are in fact young males, but there is no other evidence to support this assumption. If sub-adult females have ranges comparable to the ranges of the non-breeding adult females, comparatively small areas higher on the slopes, they are less likely to be found. Some of the rarer sub-adults, like 446 and 820, may in fact be females, but it is also possible that they are only occasional visitors to the study area. During the whole study 12 calves were born, but only 6 older sub-adults could be recognised; this apparent rareness may arise from a distribution of some of the sub-adults that is similar to the distribution of non-breeding females and from the difficulty of distinguishing between the tracks of different individual sub-adults.

#### 5.2.4 - Male home range

As has been explained in chapter 5.1.3, the rhinos that were thought to be males, have extensive ranges, especially compared to those of the non-breeding females. A few males are among those rhinos most frequently encountered in the study area. Their home ranges appear to consist of a core area (where their tracks are most frequently found), surrounded by a wide zone that is less frequently visited. Male home ranges are large, 25 sq km or more. Males visit saltlicks, but usually do not travel only on one specific corridor, they often stay close to the lick for some time, foraging in all directions. Occasionally other saltlicks may also be visited. The average home range of a male rhino was estimated to be 30 sq km.

Of all the rhinos the tracks of male 520 (see figure 5.8A) were by far the most frequently encountered throughout the study. This rhino was found during 13 of the 17 expeditions, and often more than once, with fresh tracks on 9 expeditions. This rhino's home range seems to overlap almost completely with the study area.

The range over which this series was found is almost 24 sq km, west of the Mamas river to saltlick 3. The direction of the tracks indicated that on the west and south-west side the rhino had been outside the supposed boundary of the range. This rhino was most frequently found in the centre of its range or near the saltlick, and its total home range is estimated to be between 25 and 30 sq km.

Most tracks of male 520 were found along the ridge between the Sungai Badak and the Sungai Batu Ikat, in the Jalan A. Yani area, and on the trail leading down from this ridge to the saltlick. But apparently this rhino also follows other routes to the saltlick. The Mamas and some of the smaller tributaries to a lesser extent, seem to serve as boundaries. On several occasions the rhino turned back at the Sungai Badak or the Sungai Batu Ikat, but in other instances these rivers were crossed and tracks were found on both sides. It appears that the core area of the home range covers the eastern two-thirds of the ridge between camp Acoh and saltlick 3. All tracks found in the west of the range led more or less directly to the saltlick, while in the eastern half the rhino travelled in various directions.

The range of the other northern male, rhino 610 is shown in figure 5.8B. It is only 15.7 sq km and completely overlaps the range of 520, but the tracks seem concentrated in the north and especially in the north-western corner (Jalan Sudirman) and at the saltlick. The tracks to and from the saltlick lead to the west and this rhino was once found south of the Sungai Batu Ikat, when it followed the big trail from the saltlick to the Jalan A. Yani and proceeded almost to the junction of the Sungai Badak and the Mamas.

Male 610 was less frequently encountered than male 520 and the core area of its home range appears to be north of saltlick 3, partly outside the study area. If the centre of the animal's home range is situated almost on the boundary of the study area, we can expect that there is another 10 to 15 sq km of its home range outside the study area. The home range of male 610 would then be similar to the home range of 520, between 25 and 30 sq km.

Although the ranges of both males seem to overlap completely, the core areas (the areas which the animals use intensively) appear to be separated. Male 520 has only been found once along the Jalan Sudirman, while male 610 only once ventured east over the Jalan A. Yani. The two rhinos are only regularly found using the same areas at saltlick 3 and along the Sungai Batu

Ikat. Rhino 610 has a very large and characteristic print, that can even be recognised in the field, and the Jalan A. Yani was the most intensively patrolled area. If this area is regularly visited by this rhino its tracks would certainly have been found there more than once. From the saltlick male 610 walked along the very well-worn trail uphill, probably following a track of one of the sub-adults (140). Rhino 610 travelled east, not following the main trail, till it almost reached the Mamas and returned along the Sungai Badak.

For the two males resident in the southern half of the study area only the distribution map of series 191 is given. For the distribution of male 296 see figure 5.5. In the study area this rhino has a small range of only 8.6 sq km, presumably largely formed by its corridor to saltlick 6, over the watershed between the Mamas and Silukluk rivers. The centre of its home range is believed to be north of the Silukluk river.

The distribution of male 191 is shown in figure 5.10D. With a range of 28.7 sq km it has the largest range of all the rhinos resident within the study area, but almost all of this range can be attributed to one extensive tour recorded on the 4th expedition, when rhino 191 followed the Tenang river downstream and along the Mamas for a few kilometres. The animal then returned and followed the Pinus river upstream to the saltlick. The animal apparently moved rapidly, because tracks were of about the same age all along the route. About 10 days later fresh tracks of the same rhino were found in the Silukluk area, very close to where it started its tour. The whole round measured at least 22 kilometres. Later this rhino was found once more in the Silukluk area and several times at saltlick 6, generally coming and going in southern or eastern directions.

Although the evidence is far from conclusive, the location and direction of the tracks indicate a home range in the triangle between the Tenang, Silukluk and Pinus rivers, with the core area probably somewhere near the southern boundary of the study area. That an animal can cover an area of this size in one rapid sweep suggests that the estimated total ranges of the males, as based on series 520 and 610, are probably still too small and that other males may also travel farther afield. If rhino 191 were to make similar trips south to the Sungai Kompas area, its total range could be something in the order of 50 to 60 sq km. Indeed males may wander over such large areas during their entire adult life, but for the duration of the study an estimated male range of 30 sq km seems appropriate.

Typically males seem to make long excursions into areas that are otherwise rarely used. None of the females showed such behaviour (see chapter 5.2.1). Both males in the northern half of the study area were frequently found at saltlick 3, but both were also found very close to saltlick 2 and male 520 probably also visited saltlick 4 (see also chapter 6.). Males may regularly visit two or more saltlicks.

The main habit of making quick sweeps through the peripheral parts of their home ranges may explain the appearance of those rhinos that were only found once or twice in the study area. The most notable example is rhino 810 (see figure 5.6). The highly characteristic footprints of this rhino were found only once in a well-patrolled area at the Mamas river. This rhino must occupy a home range almost entirely outside the study area, but probably made a quick excursion westward after visiting a saltlick along one of the side-rivers. The same could be argued for series 106 (see figure 5.6), another loner found once close to camp Central. The behaviour of these two animals suggest that they are males.

Similarly rhino 110 has very characteristic prints and was found with certainty on three expeditions, over a large area (see figure 5.9A). Its range in the study area covers more than 22 sq km and it has the greatest linear extension, almost 11 kilometres. During the 13th expedition its tracks were found over a large area between saltlick 1 and saltlick 3. It apparently visited first saltlick 3, wandered downstream along the Batu Ikat river and proceeded north to saltlick 1. Here it wandered around extensively, visiting the saltlick at least three times in about one week and finally returned, following the Mamas and going on in the direction of the Jalan Sudirman.

Later this rhino was found once more at saltlick 1, again wandering about in the surroundings. Much further south it was found once on the top of the mountain west of camp Central. There is a doubtful record from near camp Central, that would almost double the animal's range if included. The long trek, visiting two saltlicks in succession, and the animal's behaviour, wandering about around the saltlick, indicate that this rhino is a male. The core area of its home range must be somewhere west of the study area, probably in the upper reaches of the Badak river.

The range of adult 194 is shown in figure 5.11B, because it is a good example of a rhino that apparently only passes through the study area on its way to a saltlick. Its tracks were found twice heading for saltlick 5 and twice at the junction of the Tenang river and the Mamas. The core area of this animal's home range must be more to the northeast, and this rhino may have made the unidentified tracks that were occasionally found along the entrance route.

Generally when males visited a saltlick, there were prints all over the place. On all trails leading to the saltlick there were tracks going up and down, and it was often very difficult to find out where the rhino had come from or where it went. Males apparently wander around extensively in the neighbourhood of a saltlick, following all major trails for some distance and coming back several times to the lick, whereas females approach and leave the lick directly.

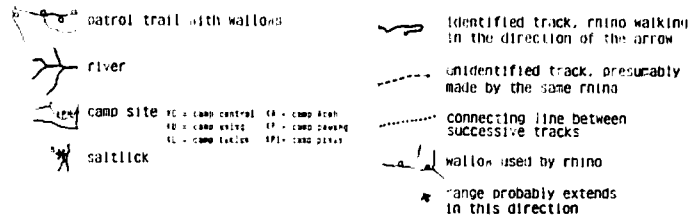
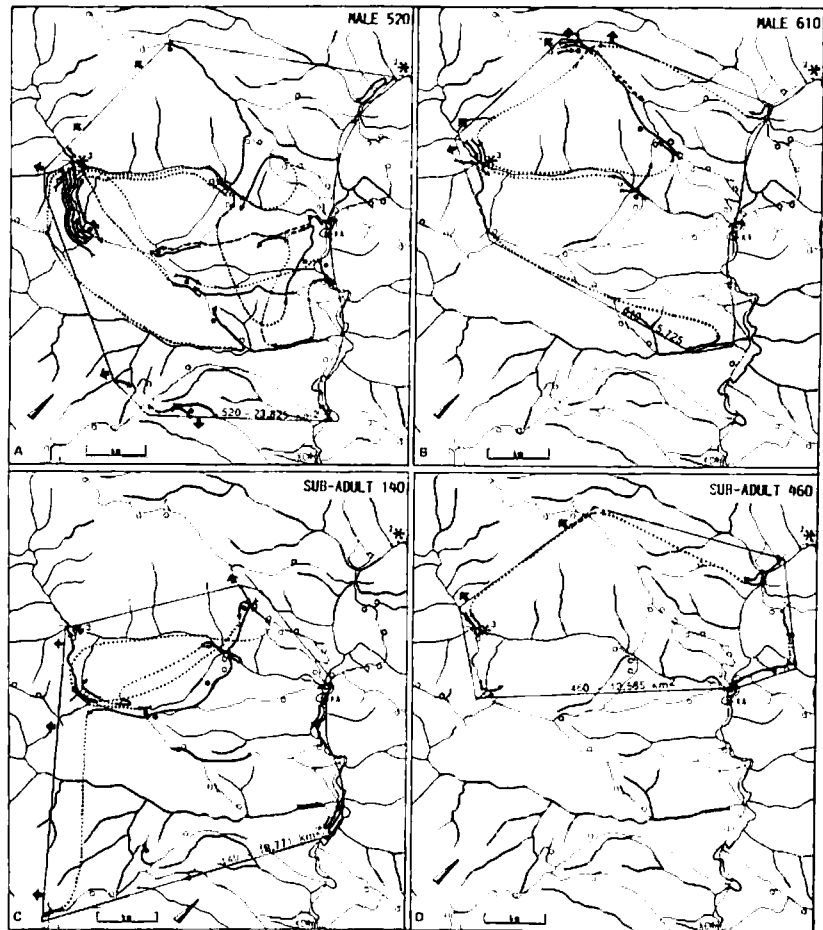


Figure 5.8 to 5.11 - A selection of detailed distribution maps of individual rhinos. The course and direction of each rhino track and the wallows used by that rhino, are shown.

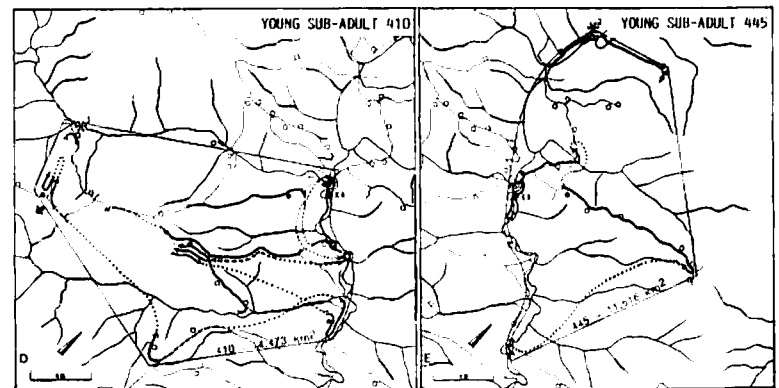
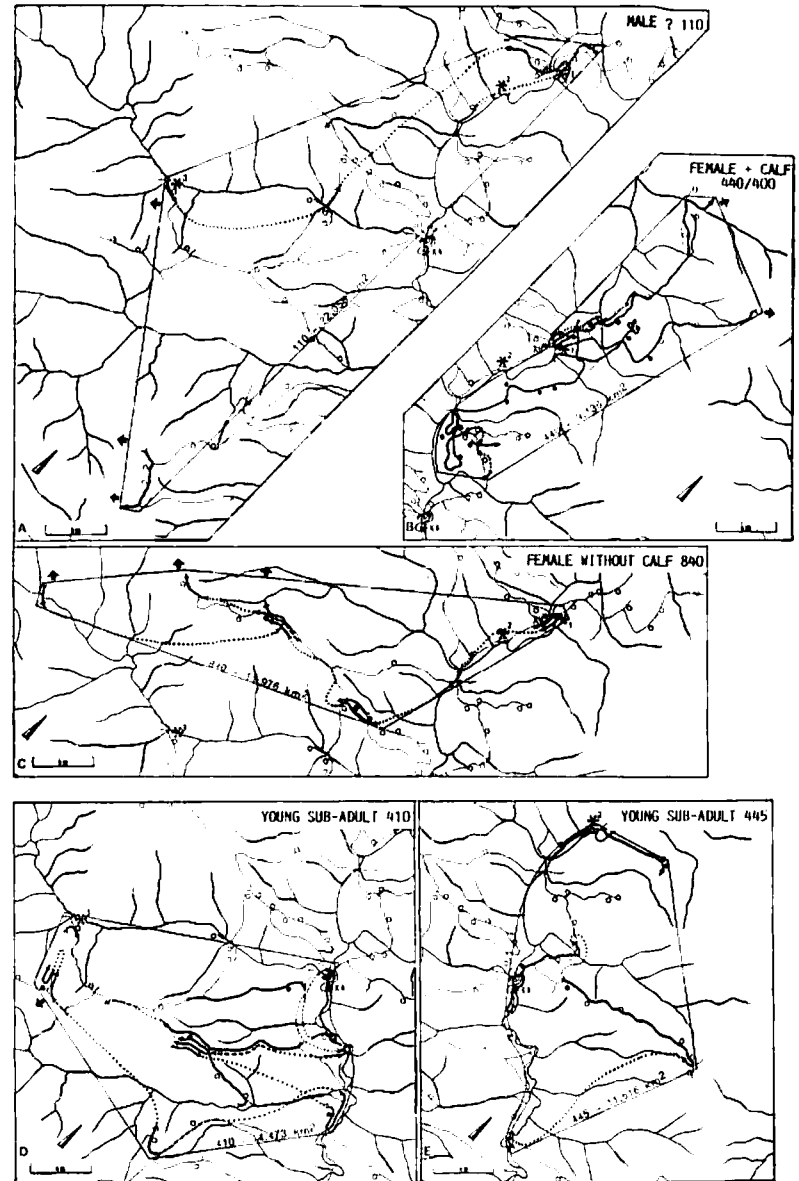


Figure 5.12 to 5.16 - A selection of detailed distribution maps of individual rhinos. The course and direction of each rhino track and the wallows used by that rhino, are shown.

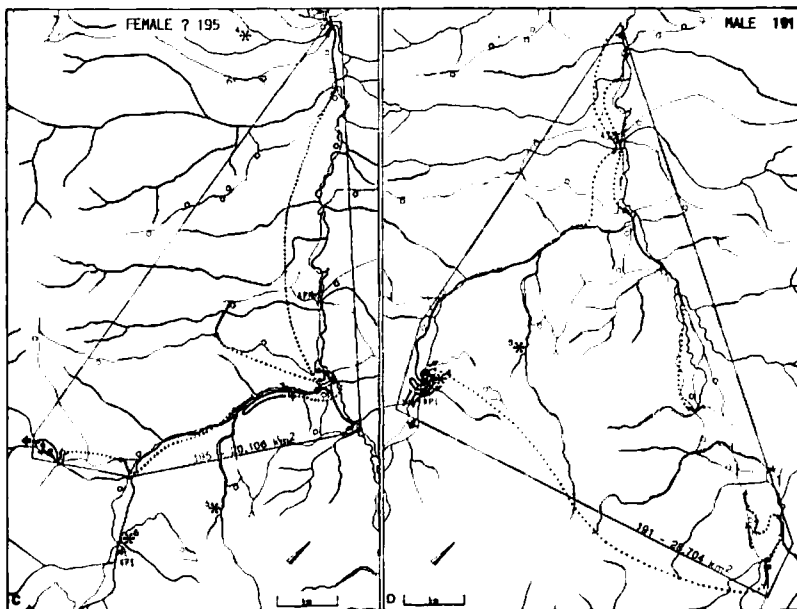
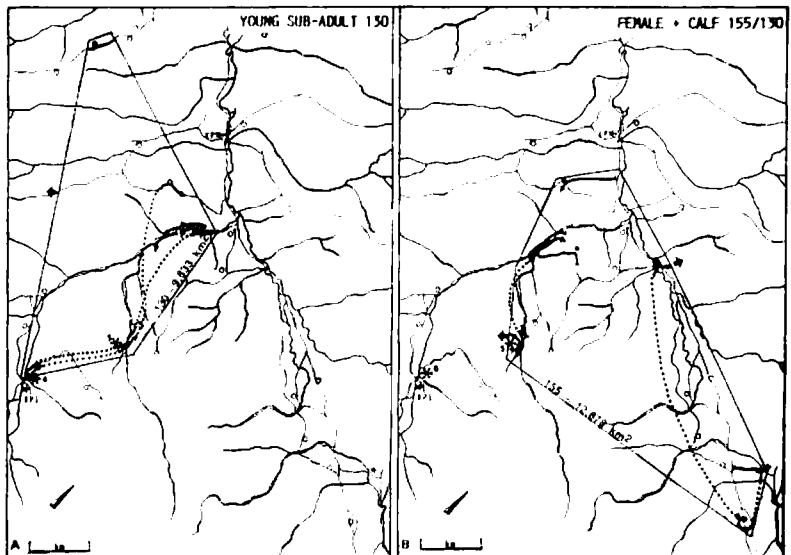


Figure 5.10

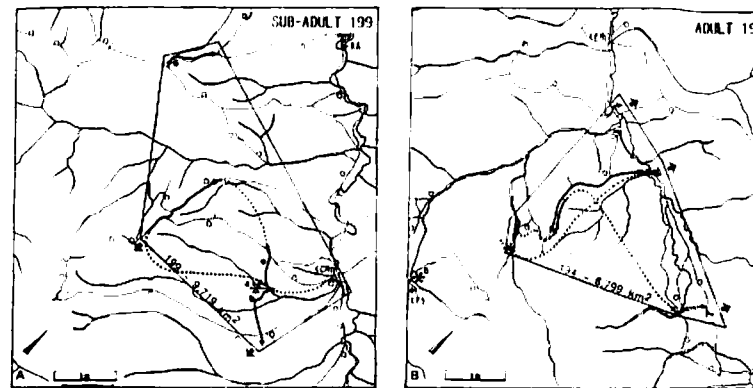


Figure 5.11

### 5.3 - Density of the rhino in the study area

The density of an animal population is a useful parameter for comparison with other areas and for management purposes. To study fluctuations in a population or for comparison of carrying capacities of different habitats it is sufficient to know relative densities, that is the ratio of one population to the other. For this study it was necessary to know the absolute density of the rhinos, that is the average number of rhinos per unit of area (Andrewartha, 1971), to be able to estimate the total rhino population in the Gunung Leuser reserve.

The number of rhinos in the study area could not be established by direct counts, because of the nature of the terrain. Limited visibility restricts the use of transects and direct observations as a means for calculating density (see chapter 5.3.3). Moreover the animals were shy and rarely encountered. Therefore the number of animals had to be determined from the tracks. From the distribution pattern of the inferred home ranges of all the individuals one can estimate the average number of animals present in a certain area. The number of identified individuals is the minimum number of animals present in the area. These figures can be used to calculate absolute density of the rhino in the study area.

The number of fresh tracks found in a certain area is proportional to the density of rhinos and can be used as a density index for comparing numbers of rhinos using different parts of the study area (see chapter 5.4). A fresh track count can be correlated to density and be a useful tool for censusing rhino (see chapter 10).

In the ensuing chapters a few methods are described for calculating the density of the rhino from the results of track analysis. By using the spatial distribution and extent of the home ranges of the individual rhinos a density of 13 to 14 rhinos per 100 sq km was calculated. Comparable figures were obtained from the number of identified rhinos, when the area covered by the expedition was regarded to be the area within one kilometre from the patrolled routes.

#### 5.3.1 - Density calculations based on distribution

By mapping the ranges of individual rhinos known to be present in a given area one can estimate the number of animals likely to be present, in a certain area. This is comparable to the territory mapping techniques used to count songbirds in the breeding season (van Lavieren, 1982). The use of a technique like this for the Sumatran rhino is complicated by the absence of distinct territories, by the considerable amount of range overlap and by the largeness of the home ranges, which often fall partly outside the study area. None of the existing techniques seems applicable to this situation (van Lavieren, 1982). To make the calculations one has to



delimitate a certain test area and estimate the probability of each animal being present in this area. The probability of an animal being present in the test area is considered to be proportional to the part of its home range that falls in the test area.

Based on this principle two different approaches were tried. In the first method a rectangular test area was chosen and it was estimated which part of each home range lies in the test area. In the second method all identified records were used, and the test area consisted of the area covered by all identified records. The part of the home range that lies in this area was found by dividing the range of each animal by the estimated average home range of the age and sex class. In both methods the sum of the fractions of the home ranges lying in the test area were regarded as the average number of rhinos present in the test area.

The records from which the individual ranges were determined were collected over more than five years, but gave a reliable picture of the distribution of the animals during the study. It appears that each rhino has a definite and rather stable range, at least over the few years of the study, except for temporary shifts in the ranges of the females (see chapter 5.1.1) and gradual shifts and extensions of ranges in sub-adults (see chapter 5.1.2). Through births the number of rhinos increased, and it is possible that in the same period a few animals emigrated or died, which would have gone unnoticed. In estimates of population density only those individuals were included that were recorded during the period of regular visits to the study area, up to the 16th expedition (the 17th and 18th expedition were made in later years). In the year before the 16th expedition (see figure 3.28) 33 of the 35 rhinos found up to the 16th expedition were still occasionally present in the study area, indicating that the accumulated records are a reliable representation of the distribution of the individual rhinos around the beginning of 1979. Only two rhinos (194 and 106) may have been lost from the population since the beginning of the study.

**Method I.** A rectangular test area was drawn on the map of the study area, covering the best known part of the study area. The size of this test block is 93.0 sq km. The outline of the test block is shown in figure 5.12. Subsequently the presumed home range of each rhino was sketched on the map, and an estimate was made of the fraction of the home range that lies in the test block. For this estimate not only the size of the area was taken into consideration, but also the intensity of use by the rhino. When the part of the home range lying in the test blocks was only occasionally visited, the estimate was lowered, but when the core area lay in the test block the estimate was increased.

For example if 0.25 of the home range of a rhino is estimated to lie within the test area, the probability of the rhino being present in the test block is 0.25. The sum of the probabilities of presence for all the rhinos, is the average number of rhinos present in the test block at a certain time, from which the density per unit area can be calculated. For those individuals whose home ranges are fairly precisely known estimation was not very difficult, but for others it is at best a guess. Uncertainties about the proper boundaries of the home ranges and about the way a rhino spreads its activities over the different parts of the home range, can cause bias in this method.

The result of this calculation is shown in table II, showing total figures and figures for each sex and age class.

**Method II.** This method was developed to eliminate some of the bias inherent in method I, which relies heavily on one's interpretation of the size and shape of the home ranges. In this case the known ranges, not the inferred home ranges, were used, and consequently the test area is the area encompassing all the identified records. To measure the size of the individual range a polygon was drawn around the records of one rhino (see the examples in figures 5.8 to 5.11) and the test area was constructed by overlaying the polygons of all the rhinos on a map. The size of the test area is 101.9 sq km, and it is shown in figure 5.12. Subsequently for each rhino the size of the range was divided by the average size of the home range for its sex and age class (see chapter 5.2 - males 30, females 20, older sub-adults 25, young sub-adults 15 sq km). The resulting fraction was regarded as the probability of a rhino being present in the test area and the sum of the fractions is the average number of rhinos present at any given time.

For example a male with a range of 8.57 sq km would score  $8.57/30 = 0.286$  for its probability of presence in the study area. In this method bias may be caused by an incorrect estimate of the average home range and differences in intensity of use of different parts of the home range. Moreover the polygons are only crude approximations of the rhino's ranges. The results of the calculations are shown in table II below.

Table II: Density of rhinos in the study area, based on the spatial distribution of the individual rhinos.

= Number of rhinos per 100 square kilometres.

	Method I	Method II	Identified individuals (chapter 5.3.2)
Males + presumed males	3.7	3.9	
Females + presumed females	4.1	3.8	
Older sub-adults	2.8	2.1	
Young sub-adults	3.8	3.1	
TOTAL	14.4	12.9	11.3

The densities calculated by both methods do not differ substantially, either for total density or for the different age and sex classes. As a further check the total area covered by the home ranges of all individuals was estimated. Around the centres of the home ranges of the individuals, shown in figure 5.7, circles were drawn proportional in size to the average size of the home range. The rhinos with doubtful home ranges were excluded. The total area covered by these circular home ranges was 285 sq km, used by 32 rhinos, which gives a minimum density of 11.3 rhinos per 100 sq km. This figure compares well with the densities shown in table II, especially since a number of rhinos known to have part of their home ranges in this area, were not included.

The results of all these calculations depend very much on the estimates of the average home ranges for the different age and sex classes. But since detailed records are available for several rhinos, over a period of several years, these estimates must be regarded as reliable. Therefore a density of 13 to 14 rhinos per 100 square kilometres can be regarded as a fairly accurate estimate for the upper Mamas study area.

The rhino population in this part of the Gunung Leuser area is probably still at an almost natural level. In the southern part of the study area poaching had gone on for some time and several animals were killed there in the years preceding the study. In the year before the start of the study a few rhinos were killed in the area around camp Pawang. This was probably the first case of poaching in the upper Mamas area, and elsewhere in the study area the rhinos have probably never been hunted. The scarcity of rhinos around camp Pawang and the relative low numbers of rhinos in the southern part of the study area are certainly a result of poaching pressure, and we can expect that the natural population density of the rhino prior to the poaching was slightly higher.

Rhino hunting has eliminated the rhino in the fringe areas of the Gunung Leuser reserve, and this also may have reduced the numbers of rhinos in the central parts, with animals migrating to these 'open areas'. If so it was probably mostly older sub-adults, which would emigrate and may then have fallen victim. This may be one reason for the relatively low number of older sub-adults in the study area.

It is difficult to say to what extent the upper Mamas is representative of the rest of Gunung Leuser or of other areas where rhino are found or used to be found. In altitude the area is intermediate. Nowadays rhinos are rarely met at lower altitudes in Gunung Leuser, but the well-developed trail systems, now abandoned, indicate that formerly there was a sizeable population of rhinos. The same is true for some of the higher parts of Gunung Leuser. The upper Mamas could be favoured by rhinos because of the relatively shallow gradients, and because of the presence of several saltlicks; indeed it may support a higher density of rhinos than steeper areas, farther away from saltlicks. Therefore it seems appropriate to use a slightly lower estimate for other areas - 10 rhinos per 100 square kilometres - to estimate natural density of the Sumatran rhino.

### 5.3.2 - Density calculated from the number of individuals per expedition

The number of individuals that can be identified from tracks found during a survey can be regarded as a count of the minimum number of animals that were present in the area during the time of that survey. This method has been used to estimate the size of the rhino populations in Ujung Kulon, Java (Schenkel & Schenkel-Hulliger, 1969) and Endau-Rompin, Malaysia (Flynn & Abdullah, 1983). Differences in size of the prints and minimum distances between individuals with identical prints were used to estimate the minimum number of rhinos present in the area under study. To calculate density the size of the area that was sampled has to be measured. Schenkel and Schenkel-Hulliger (1969) assumed that their records covered the whole reserve.

while Flynn and Abdullah (1983) reckoned that their method detected all rhinos within 2 km from the patrol routes. No arguments for the choice of this distance were given.

When a track is found the animal responsible has already moved on to somewhere else in the area. By counting tracks one counts animals that are spread out at the time of the count, over a certain area around the points where the tracks are found. Since tracks remain visible for a limited time only, the animals will still be fairly close to the place where the track is counted. So one may argue, as Flynn and Abdullah (1983) have done, that the counted tracks represent the animals that are within a certain average distance of the tracks. How far that distance should be depends on the animal and on the average terrain conditions, and it is only by applying the method in an area with a known density of the animal that one can find the correct figure.

Because track count techniques are very useful for census of rhino, they have been applied to the Mamas study area, where the density of the rhino has been estimated to be 13 to 14 rhinos per 100 sq km (see above). Each expedition was regarded as a separate survey, and to count the number of animals whose tracks were found, the results of the plastercast analysis (see figure 3.28) were used, as well as a simulated track count using only the width of the print. The latter is comparable to the methods used by Schenkel and Schenkel-Hulliger (1969) and Flynn and Abdullah (1983). The area surveyed was calculated (1) as a 4 km wide transect, i.e. a 2 km wide strip on either side of the patrol route, as suggested by Flynn and Abdullah (1983), and (2) as a 2 km wide transect, i.e. a 1 km wide strip on either side of the patrol route. With the 4 km transects results showed an unrealistically low densities, compared to the known 13 to 14 rhinos per 100 sq km. For the Mamas study area a 2 km transect was more appropriate. An example of a 2 km transect, i.e. a 1 kilometre strip enclosing the whole patrol network (185.1 sq km) is shown in figure 5.12, and examples for single expeditions are shown in the figures 10.1 and 10.2.

In chapter 10 these different methods are compared to develop a useful method for censusing rhino populations. The use of print width only for identifying individuals can only be useful in populations with a very low density, where the individuals are widely scattered. For an area like the Mamas it is unsuitable as too few individuals can be identified with certainty. Using a 1 kilometre strip on either side of the patrol route and the results of the plastercast analysis, the densities calculated were fairly close to the figures known from analysis of the animal's spatial distribution. Even with a 1 kilometre strip width the average densities calculated are slightly below the density estimated from other methods and it may be that a slightly narrower strip is more appropriate, for instance 800 metres. However a 1 kilometre strip on either side is more convenient for working with, and gives density estimates that are 'on the safe side'.

Population estimates from different expeditions varied considerably, and one should allow for a rather large margin of error, when using this method to estimate the density of the rhino. The densities calculated from the results of the 'good' expeditions (see figure 10.3) varied from 5.5 to 13.3 animals per 100 sq km, with an average of 9.6 rhinos per 100 sq km. On the later expeditions (10 to 17), with more experience in tracking and casting, we calculated an average density of 11.3 rhinos per 100 sq km. The poorest results were obtained on the 5th expedition, which gave a density of 1.1 rhino per 100 sq km. For reasonably accurate results whether must be favourable, and the survey team experienced.

### 5.3.3 - Density calculated from the number of direct observations

Counting animals observed along a transect, is one of the more common methods of estimation of density or population size. The total of the patrols made in the study area can be regarded as one wound transect, and the number of direct observations of rhinos is the counted number of animals. To calculate the strip width of the transect the mean sighting or flushing distance at the moment of detection can be used, as in King's census method (van Lavieren, 1982).

Direct observations of rhino - i.e. the animal being seen or heard - were very rare. In total rhino were seen on only four occasions and another six times rhino were heard snorting and crashing off through the forest after being disturbed by the patrol group. The estimated distance at which the animal was first seen or heard varied from 10 to 40 metres, an average flushing distance of 30 metres. The width of the transect is 60 metres, twice the average flushing distance. Throughout the study a total of 3976.1 kilometres were walked, during which 10 direct observations of rhino were made. So ten rhinos were counted in an area of  $3976.1 \times 0.06 = 238.6$  sq km, or 4.2 rhinos per 100 sq km.

This figure is substantially lower than the densities calculated by other methods above. Limited visibility in the forest allows rhinos to retreat unnoticed. The flushing distance of a rhino is certainly larger than the maximum distance at which a rhino can be spotted in the type

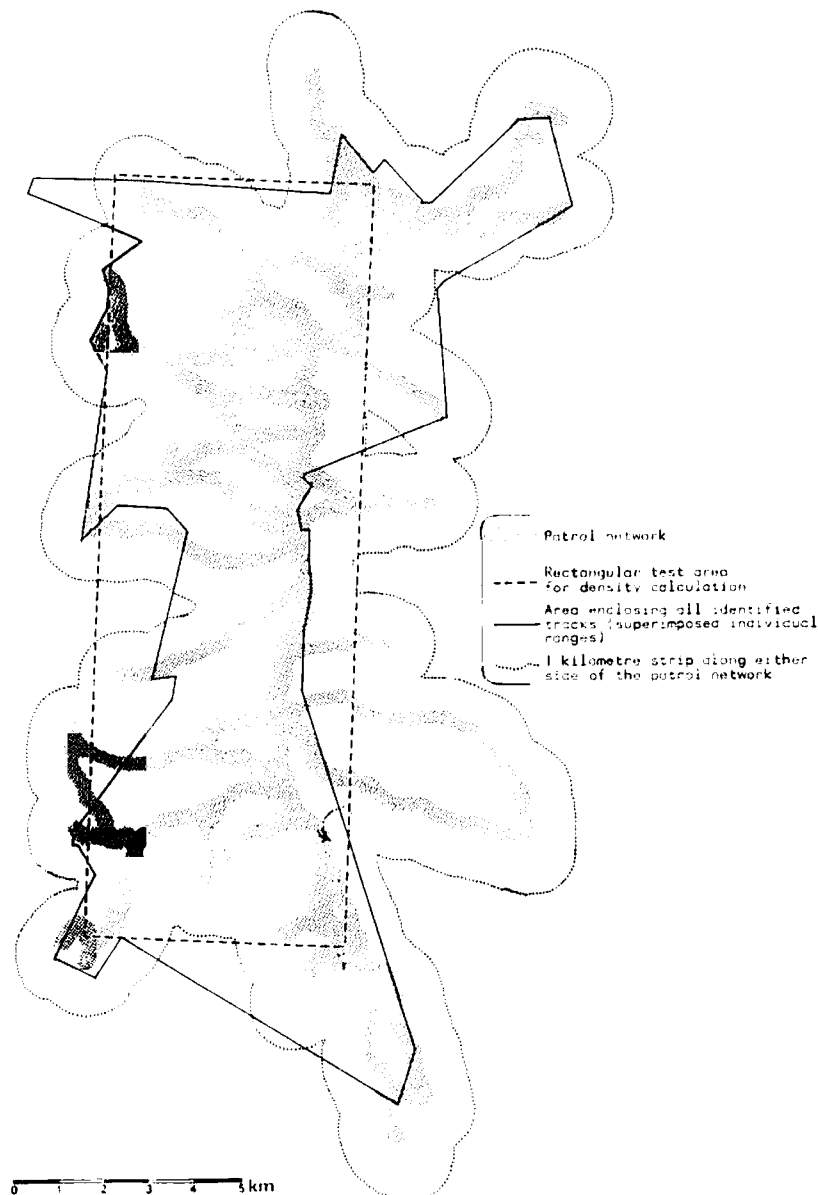


Figure 5.12 - The different delineations used to compute the size of the test area for calculation of the density of the rhino in the study area

of forest that covers the Mamas area. Even an elephant standing motionless at about 30 metres is hard to discern. Rhinos can be heard over larger distances, but if they don't start in alarm, they can be overlooked even at fairly close range. Several times very fresh tracks were found of a rhino that had doubled back on the trail and it is possible that the rhino had heard or smelled the patrol group and turned tail. Because of the difficult terrain patrols used only big game trails where rhinos spend only a relatively small part of their travelling time (see chapter 7.2), and it might be that they do so mainly at night. This may also explain the low number of encounters.

Relying on direct observations for studies of rhinos which have acute scent and hearing is not appropriate in a habitat where man's senses are seriously handicapped, and leads to an underestimation of the density of the population.

#### 5.4 Comparative occurrence in parts of the area

Because the frequency of rhino visits can be calculated from the number of fresh tracks, special records were made of fresh tracks throughout the study. Fresh tracks are those made since the last rain and they are usually easily distinguishable from old tracks. By determining the number of hours between the last rains and the time of the patrol, one can calculate how many tracks were made in a certain period of time or how often a rhino visited a certain place or area. These calculations were made for all sections of the patrol network, to study frequency and patterns of use of the trails by various rhinos. The accumulated data gave some idea of how much different sections and altitudes were used, the frequency of the visits to saltlicks and the amount of use of each lick. For use of wallows see chapter 7.3.2.

During the fieldwork period a few simple experiments were tried to preserve tracks by covering parts of the trails with plastic sheets. These experiments were only partly successful, see below.

##### 5.4.1 - Counts of fresh tracks

The age of the tracks was estimated in the field, based on the condition of the track, the soil and the prevailing weather conditions in the period immediately prior to the patrol. We also recorded whether or not the track was affected by rain. Tracks not affected by rain were called fresh, all other tracks were called old. Generally it is easy to decide whether a track is fresh or old, especially when the trail is followed for some distance. A fresh print has a smooth surface and any soil particles that have fallen into the print are still loose. Even a short shower of light rain leaves clear marks in the clay surface and causes the small soil particles to stick to the print surface, and sediment is left in the deeper parts of the print. Single prints can sometimes remain fairly fresh if they are sheltered from the rain by thick vegetation, but following the track for some meters will generally show the experienced observer whether it is fresh or not.

Since fresh tracks must have been made in the period between the last rainfall and the time of encounter it was important to keep careful daily records of the duration and intensity of any rainfall. It appeared that the rainfall was usually rather uniform over the study area, especially when it rains hard and long. A few times, mainly in periods of relatively dry weather, local showers occurred, but these can be determined from the moisture on the soil and vegetation.

For each section of the patrol network the time between the end of the last rain and the patrol time was calculated. Sometimes there had been no rain between two patrols, and the time between the patrols was taken. The dry period was summed for each section and this was called the observation time, the period when all fresh tracks must have been made. The longer the observation time the higher the probability of finding fresh tracks in that section. The longer the section the higher the probability that a rhino will have crossed the section at some place and left a fresh track.

For comparison between sections the fresh track counts were converted to the same units of time and distance. For convenience a year (= 8760 hours) and the average length of the sections (0.775 km) were chosen as units and the frequency of passing was calculated, i.e. the number of times a rhino is likely to pass through that area in a year. The complete formula is:

$$\text{Frequency of passing} = \frac{\text{Number of fresh tracks} \times 0.775 \times 8760}{\text{Length of the section (km)} \times \text{observation time (h)}}$$

The divisor of this formula is also called the km.h score, and is used in chapter 10 and figure 3.5 for comparison of the results of the different expeditions. If an animal's chance of passing through the study area is constant throughout the period of the study (and there is no reason to believe that there were seasonal or other changes in degree of use of the trail), the number of fresh tracks found on an expedition is proportional to the km.h score (the sum of the km.h cores of each section patrolled on that expedition). The km.h score can be seen as a measure for the intensity of the patrolling. The more sections were patrolled and the longer the periods of dry weather, the higher the km.h score and the higher will be the number of fresh tracks one may expect to find.

The number of fresh tracks per section was counted from the expedition maps. All fresh tracks were included, even those that could not be identified. Females with calf were counted as one, as were tracks of the same rhino recorded at more than one place on the same section. If the rhino had passed over a section on several occasions or in different directions, as for instance when it had travelled to and from a saltlick, this was counted as two. The number of fresh tracks for all expeditions together varies considerably between the sections. In many (40%) of the sections a fresh track was never found, while the highest count was 13 at one of the saltlicks. The average for the whole study is 1.65 fresh tracks per section.

There are considerable differences between the total observation times for the sections, because of the differences in intensity of the patrolling and because of the variability of the weather conditions. The sections between the camps score highest while many of the outlying sections score very low, because they were visited least and often only after rain the night before and little time was spent studying tracks along the way. The lowest observation time was 18 hours (for an outlying section of the most northern trail), and the highest value was 3187 hours, or almost 19 weeks (for a section between camp Central and camp Fawang). The average observation time for all sections was 862 hours, or almost 36 days. Because the number of fresh tracks per section is low (84% had 3 or less), despite the accumulation of the results from 17 expeditions, the results are subject to a large amount of stochastic variation. Therefore the sections with the shortest observation time have been omitted. A lower limit of 300 observation hours was chosen for each section, because then most of the isolated high values for the frequency of passing were eliminated (includes 49 of 206 sections).

##### 5.4.2 - Frequency of use of the game trails

The frequency of passing for each section, except those with less than 300 hours observation time, is shown in figure 5.13. In a large number of sections the frequency of passing is low, especially in the middle of the study area. In these sections fresh tracks are seldom found, less than 10 or 20 times per year. But there are also sections that score much higher, where one may expect or find more than 50, or in some cases more than 100 fresh tracks per year.

The highest values are found around the saltlicks, and there seems to be a concentration of low values along the Mamas and on the lowest sections of the trails west of the Mamas. But two to three kilometres west of the Mamas there seems to be a concentration of moderate and high values. At this place the ridges begin to rise steeply, which might explain the animal's preference for trails along the foot of the mountains. Rhinos crossing from one side of the mountain to the other seemed to prefer this route which avoids too much climbing.

The high number of fresh tracks found on the watershed between the Tenang and the Silukluk rivers may be explained by its location between two marshy areas. The rhinos seem to avoid these open places and concentrate in the narrow strip of forest between.

The average number of fresh tracks for all sections with more than 300 hours observation time is 22.3. In 55% of the cases the rhino travelled along most of the section; in the other cases it only crossed the trail or followed it for a short distance. This means that each year about 13 rhinos will pass over a section or part of it, or about one rhino per month. On the main trails leading to the saltlicks a rhino will pass about once every fortnight. About one rhino per month and one or two elephants per year is apparently enough to keep the game trails open. More frequent useage of the trails to the saltlicks keeps trails free of vegetation or litter and such trails are often deeply worn.

These figures show how effective trapping can be for hunting rhino. Traps are placed on the main trails, usually a few in succession. If the traps are properly made and triggered a rhino is not likely to escape them if he uses the trail. Occasionally traps may be triggered by other game, but a rhino poacher can expect to make a catch about every month with a set of traps placed close to a saltlick in an area like the Mamas. Over a period of just a few years poachers can kill all the rhinos using the saltlick, and exterminate the animals completely from a rather large area (see also appendix C).

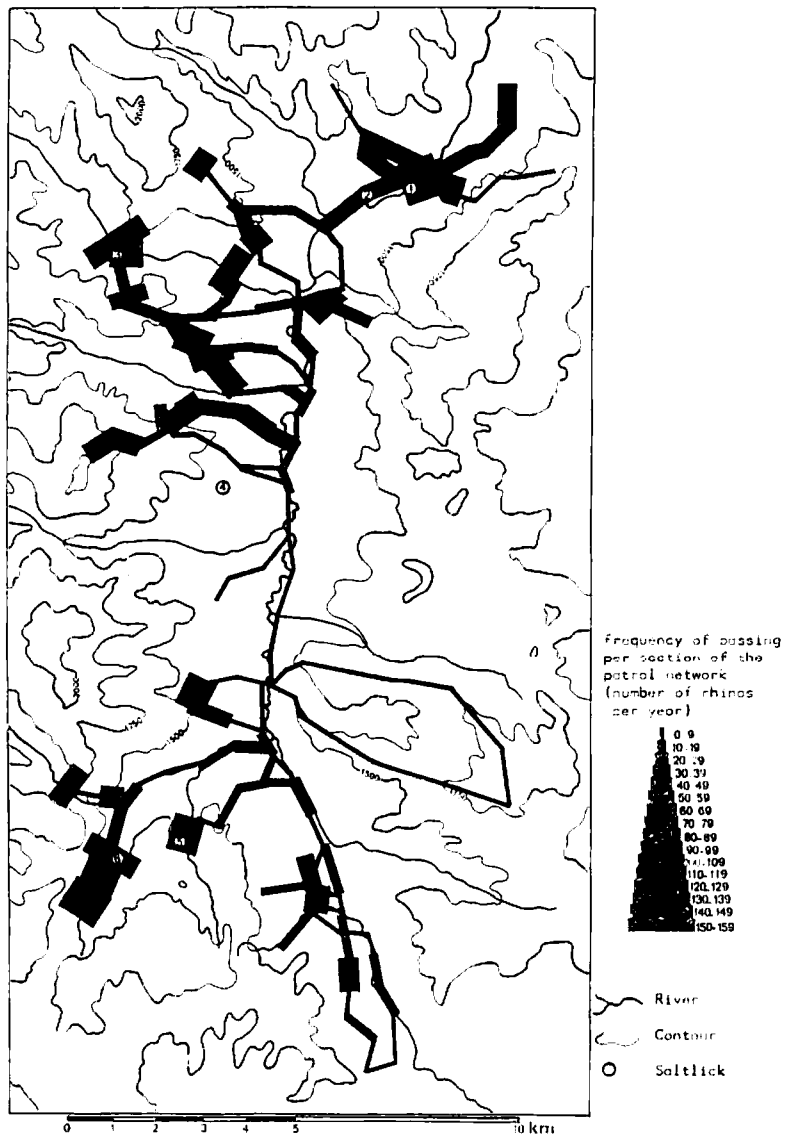


Figure 5.13 - The frequency with which the rhinos use each section of the patrol network, calculated from the fresh track counts. The broader the band the more frequently a rhino will travel that section of the patrol network. Sections that were not patrolled frequently are omitted. For the explanation of the method see chapter 5.4.1

#### 5.4.3 - Comparison of different areas

In chapter 5.1.4 we saw that less animals used the southern half of the study area than the north. The average frequency of passing has been calculated for both parts (taking the mouth of the sungai Niko as boundary), and shows a considerable difference. Omitting the sections with less than 300 observation hours, the average for the 73 southern sections is 15.9, while the average for the 82 northern sections is 28.0 fresh tracks per year. The lower number of rhinos in the south and the less frequent use of the game trails are probably a result of poaching in the Pinus area.

Because the boundaries of the sections were chosen to follow the contours of 1200 (the lowest point in the study area), 1400, 1600, 1800 and 2000 meters altitude, it is possible to compare the rhino's use of different altitudinal zones. For zones with saltlicks the average frequency of use was calculated twice, once including and once excluding the data from sections immediately near saltlicks. The two sections above 2000 metres and most sections above 1800 metres were omitted because of short observation time. The results are shown below in table III.

Table III : Average frequency of passing per altitudinal zone. (between brackets the number of sections)

Altitudinal zone	frequency of passing excl. <300 hours observation time
1200 - 1400 m excl. saltlicks	14.6 (88)
incl. saltlicks	18.6 (95)
1400 - 1600 m excl. saltlick	28.0 (38)
incl. saltlick	33.7 (44)
1600 - 1800 m	10.8 (13)
1800 - 2000 m	15.7 (3)
TOTAL excl. saltlicks	17.9 (142)
incl. saltlicks	22.3 (155)

There are differences in rhino use between the zones, especially between the two lower zones. With or without the saltlick data the average frequencies of passing are markedly higher in the second zone, which could be seen as an indication that rhinos prefer the zone between 1400 and 1600 metres. The next zone, 1600-1800 metres, seems to be less favoured, but the number of sections in this zone is low; if we exclude the entrance route sections from this category (there are very few resident rhinos in this part of the study area), the average frequency of passing is 17.9 (8 sections)

Since the Mamas river is an important boundary for most of the rhinos (see chapter 5.1.4), the lowest section (1200 - 1400 m) was divided into three parts: - the sections along the Mamas, the sections on the ridges, and the Tenang - Silukluk area (excluding saltlicks). The Tenang - Silukluk area showed a similar amount of use (15.5 rhinos per year) to the whole southern half. The sections along the Mamas averaged 10.2, a relatively low value, but the sections on the ridges had an average of 20.0, much higher than the river-sections.

Therefore the difference between the two lower altitudinal zones is due not so much to preference for altitude, but the rhinos choosing to use the trails along the Mamas river less frequently than the trails over the ridges. They could be deliberately avoiding the river, but this seems unlikely. Rhinos generally walk for only a short distance along the river before going back up the slopes (see chapter 5.1.4). So are generally only recorded in one or two sections at the river, but on the ridges rhinos often follow the big trails for a long distance and are then logged in several sections in succession. The low frequencies of passing scored on the sections along the Mamas river is probably not due to rhinos avoiding this area, but the fact that they wander away soon from the main trails here.

Rhinos show less preference for altitude than would appear from the figures in table III, but still the values for the 1400 - 1600 metre zone are the highest of all. It appears that the rhino has a slight preference for this zone, at least compared to the higher zones. The game trails are certainly best developed in this zone. Lower on the ridges trails are often narrower and less open and at higher altitudes they are often fragmented. The juicy undergrowth, the rhino's favourite food, appears more prolific at the mid-altitudes in the Mamas area.

### 5.5 - Other methods to record the use of the trails

Two other methods were used to count the number of rhinos that pass over the game trails. Thin plastic sheets were placed over the soil, to prevent rain washing away the tracks. At a place where the trail was well-developed, preferably with some obstacles left and right, the loose top layer of soil was removed and the soil was loosened. Then a piece of plastic sheet - about 75 cm wide and 1 metre long - was laid over the prepared ground, fastened with twigs, and camouflaged with some litter.

On the next visit the plastic was lifted and plastic and soil were inspected for impressions of rhino hoofs. The tips of the hoofs pierced or stretched the plastic and left faint impressions of the hoofs in the soil surface. Because the stride of a rhino is about 75 cm, each passing rhino can be expected to leave at least one impression on the plastic. But it is difficult to see whether two impressions close to each other are made by different rhino or by the fore- and hindfoot of the same rhino. The impressions are often very vague, especially when the soil has dried out, and it is difficult to see how many animals have passed especially if there are several impressions on the plastic.

Plastic sheets can be laid quickly and they are not easily displaced by passing animals, but results are difficult to interpret. During the study plastic sheets were laid at 28 places in 17 locations throughout the study area. In total 119 rhino tracks were counted during the 12 388 days that the plastics were functioning, or about 3.5 rhinos per year.

A second method involved the construction of a plastic roof over a short section of trail, to shield it from rain. This requires much more plastic, but the results are better. It was hoped that identifiable tracks could be obtained, but that was never the case. A piece of thick plastic, about 2 m wide and 3 m long was suspended over a suitable section of trail and supported by oblique poles tied to nearby trees. The roof was placed three metres or more above the trail and the soil beneath was cleaned and loosened. It was rather difficult to find suitable places, where the soil was neither too dry nor too wet, and that would not be flooded during heavy rain. Sometimes the roof collapsed because of decay in the poles, but most were destroyed by passing elephants. Even when placed about 4½ metres above the ground the roofs were invariably torn down and the plastic trampled and torn by elephants. Rhinos seemed undisturbed by the roofs; their tracks showed that animals did not hesitate nor avoid the roof.

Plastic roofs were pitched at 16 different locations, but only a few functioned well for a long period. Many of the selected locations flooded during heavy rains, and few tracks remained visible till the next inspection. It is easy to count the number of tracks under the roof, and the results obtained from some of the better-situated roofs are probably fairly accurate.

A total of 58 rhino tracks were recorded under the roofs, which remained in situ for 4920 days. This means that on average 4.3 rhinos passed any given location in a year. The four best sites, roofs over a large trail over a ridge, gave results of 6.6 rhinos per year, or about one animal every two months.

From counts of fresh tracks (see chapter 5.4.2) an average frequency of passing of 13 rhinos per year was calculated, double the highest value found with the methods described above. But these plastic sheets cover only a very small part of the trail, while the fresh track counts covered whole sections of several hundreds of metres, including places like wallows and saltlicks, that are specially attractive for rhino. This and the deficiencies of the methods as described above must be responsible for the different results.

### 5.6 - Frequency of visits to the saltlicks

The saltlicks play an important role in the life of a Sumatran rhino, as will be clear from the previous descriptions of distribution and range. How frequently rhinos visit the different saltlicks was calculated from fresh track counts in relation to the observation time (see chapter 5.4.1). Of 39 rhinos in the study area 10 were never found at a saltlick. Three of these (105, 148, 810) probably use an unknown saltlick outside the study area and will not be considered further here. The other seven probably frequent one of the known saltlicks, and are treated with the rhinos known to visit the licks. For each saltlick the time interval between rhino visits was calculated by dividing the observation time (the number of hours between the time of the inspection of the lick and the last rain, for the duration of the study), with the number of fresh sets found at the lick. The results are shown in table IV below.

Table IV: Frequency of visits of any rhino to the saltlicks.

Saltlick	nos. of rhino using the lick (observed+suspected)	no. of times fresh tracks found	observ. time (in hours)	interval (days between visits)	frequency (visits to lick per year)
1	5+1=6	8	1576	8.2	44.5
2	4+2=6	5	1700	14.2	25.8
3	6+0=6	6	811	5.6	64.8
4	2+3=5	1	(discovered on 17th expedition)		
5	5+1=6	2	564	11.8	31.1
6	7+0=7	7	1565	9.3	39.2
Average for all saltlicks				9.3	39.5

Use of saltlicks by rhinos varied little between licks, but saltlick 3 seemed to be the most popular, while lick 2 was least favoured. The results at saltlick 2 are certainly biased by the fact that it lies in the centre of several warm springs and potential licks. Several times fresh tracks were found bypassing saltlick 2 en route to some other lick close by, and these tracks were not included in the count. In fact the whole complex of licks and springs was visited more frequently than lick 2 alone. On average one rhino visits a saltlick every 9 days or so, an interval that compares well with the frequency with which animals were recorded travelling the trails close to the saltlicks (where one may find a rhino about once per fortnight - see chapter 5.4.2), considering that there are several trails going to each saltlick.

Visits to saltlicks by each sex and age class were analysed separately, and females were considered for both the period with and without calves. For each individual the observation time (during which it might have visited its usual saltlick) was calculated and a count made of the number of times its fresh tracks were actually found. Observation periods and numbers of fresh tracks were totalled and for each age and sex category the average interval in days between rhino visits was calculated. The results are shown below in table V.

Table V: the frequency of visits to a saltlick of an individual rhino.

	female + calf	non-breeding female	sub-adult	male
No. of rhinos	8	8	11	10
No. of fresh tracks	6	7	6	9
Total observation time (hours)	3292	7462	8531	11943
Interval in days	22.8	43.8	59.2	55.3
Frequency per year	16.0	8.3	6.2	6.6

The interval between male's visits to the saltlicks may be too high, because there are a number of animals presumed male that are only rare visitors to the study area. The average interval for the four males that were regularly encountered is much lower, 26.2 days, similar to the figure calculated for a female with calf. The two best known resident males (520 and 610) visit saltlick 3 more frequently. On three occasions fresh tracks of male 520 were found at the lick, with an interval of 11.3 days between visits. Fresh tracks of male 610 were also found, and both males together used the saltlick with an average interval of 13.3 days.

It appears that resident males regularly visit the saltlicks, and females with calf make more visits to the licks than do other rhinos. A breeding female visits the saltlick once every three weeks or so, while a non-breeding female goes there on average only once every six weeks. Sub-adults use the saltlick even less frequently, only about once every two months or so.

## CHAPTER 6 - THE LIFE CYCLE

Very little is known about the life cycle of the Sumatran rhinoceros, and even the more recent field studies have added little to our knowledge on mating, reproduction, growth, development etc. Prior to this study there were no basic data on gestation period, period of nursing, age of first breeding, longevity, breeding interval etc. But there was consensus on the fact that the Sumatran rhino is a slow breeder, with single calves being born at intervals of several years (van Strien, 1974).

One of the more remarkable details in all the older reports of the Sumatran rhino is that evidence of calves was seldom found. Also during the more recent surveys of Borner in Sumatra and Flynn in Malaysia the tracks of young calves were rarely met. Borner (1979) estimated that 4 - 5 calves were present in the Sungai Pinus - Sungai Kompas area during his three-year study, but he gives no details on date and place. In all the other areas that he visited, covering most of the known rhino areas of Sumatra, only in the Kerinci-Seblat area in central Sumatra did he find tracks of a calf. In a six year field study in the Endau-Rompin area only three cow and calf pairs were recorded (Flynn & Abdullah, 1983).

During the present study many tracks of cows with calf were found, but it cannot be said that they were common. Finding a track of a young calf was still an exceptional and happy event. It was probably only because of our methods of intensively patrolling a large area including several saltlicks, that so much evidence of calves could be gathered. Often extra patrols were made in areas where a calf had been found before.

In this chapter various population parameters relating to breeding and reproductive success will be discussed.

### 6.1 - The sex ratio of the population

Of all the rhinos that have been captured, dead or alive, and have been reported in the literature, the great majority were females (van Strien, 1974; Borner, 1978), but it was generally believed that this apparent imbalance of the sex ratio was caused by selectivity of the capture methods. Borner tries to explain this by assuming that males have exclusive territories around wallows, saltlicks and focal points of the main trails, where traps are usually built, so that at such sites only one male is likely to be captured, but several females.

This view is not supported by the results of this study. The territories of males are large and overlap considerably, and more than one male may use the same saltlick and trails, although the core areas of their distribution are probably well separated. Males range over larger areas, and probably make even more frequent visits to saltlicks than do females. The explanation of the fact that males are apparently more difficult to catch is probably a combination of distribution and character. The rhino traps are usually operated for a long period on regularly used trails in a rather restricted area. Males range over large areas and spend probably less time in any one place, while females appear to limit their activities, in and outside the breeding period, to relatively restricted ranges. Females regularly use the same trails, which is certainly the case when going to a saltlick (see chapter 5.1.4), while males might be more alert and wary, used as they are to explore unfamiliar ground. Of the 10 times a rhino was seen or heard during the study, 7 were of animals later identified as females, 1 was a juvenile and only 2 were males; on both occasions male 520. This could indicate that males are more alert and more difficult to approach.

The sex ratio among the adult animals identified in the study area seems to be fairly even. Of the 21 adults, 8 were known to be females, and 4 were classed as males. Of the rest 2 were thought to be females (see chapter 5.1.1) and 4 males, because of their distribution and ranging patterns (see chapter 5.2.4). This gives a ratio of 10 females to 8 males, while another three adults, occasional visitors to the study area, were also suspected of being male.

The adult sex ratio of populations of the Indian rhino and of the African rhino species is about even or with a slightly higher number of females (Laurie, 1978). The males of these species are usually territorial and fierce fighting between rival males is common, which may account for the lower number of males in some populations.

### 6.2 - The mating system

Most reports in literature so far indicate a short-lived bond between male and female, but several older authors have stated that Sumatran rhinos live in more or less permanent pairs (van Strien, 1974). Borner (1979) assumes exclusive territories for dominant males, and Kurt (1970) voices the opinion that females have rather small permanent territories, while males wander

around in search of females in oestrus. Both opinions are mainly intuitive and not based on substantial evidence.

This study has been able to add little to the understanding of the meeting and mating habits of male and female Sumatran rhinos. But everything points to a short-lived bond between male and female, because tracks of two animals moving together, other than cow and calf, were extremely rare. Several times tracks of different individuals were found along a trail or at a saltlick, but in most cases it was clear that they had visited separately; one of the tracks was clearly older, or came from a different direction. On some occasions it is possible that some rhinos visited the lick together or met there.

Only once during this study were tracks found that showed undoubtedly that the animals had walked together. The animals were later identified as male 610 and sub-adult 460, one of the larger and less frequently encountered sub-adults. Both had descended the ridge from the west at the junction of the Mamas and the Sungai Markus. After a short circuit they returned in the same direction. Later tracks of this pair were found at saltlick 3. The tracks were of about the same age, but it was not clear whether the animals had visited together or not. Also at the top of the Jalan Sudirman two rather similar tracks, that could not be identified with certainty because of their bad quality, were found crossing the trail. Here again it was not certain whether the animals were there together or separately a short while apart. So it could be that the animals were travelling together, or that one followed the other closely, from the saltlick to the Mamas, a distance of about 5 kilometres. This meeting certainly did not lead to a successful pregnancy, because rhino 460 was found again on the 16th and 17th expeditions, about 500 and 800 days later, without a calf.

In the previous chapters it has already been explained that males have much larger ranges than females, and that they have a tendency to make quick excursions over rather long distances. Non-nursing females on the other hand seem to have rather restricted ranges on the higher slopes. With a calf females remain close to the saltlicks in the lower parts.

There also appears to be a difference between males and females of behaviour at the saltlicks. Males wander all over the area surrounding the lick and often leave such a confusion of tracks that it was sometimes very difficult to determine where the animal had come from or gone to. But when females visit a saltlick their tracks are generally easy to follow. They often make a few short tours around the saltlick, but their trails are direct and usually clear; they seem to visit the lick and then leave its immediate surroundings.

Males apparently hang around the saltlick, presumably investigating the neighbourhood, while females only make a quick visit to the lick and leave again, consistently returning by the same trail. A male explores the area around the lick, possibly to find a scent trail of a potential mate that has been there shortly before. There are indications (see chapter 5.6) that some males make more frequent visits to saltlicks than others. For instance male 520 visited a lick on average once in 11 days.

The importance of the saltlicks as a contact place, is further illustrated by the visits that males sometimes make to saltlicks other than the ones they regularly use. Males 610 and 520 regularly use saltlick 3, but were both found very close to saltlick 2, and male 520 probably actually went there, but there in the confusion of tracks it was impossible to be completely sure. Twice male 520 was also found close to saltlick 4, and it could be that he occasionally inspects this lick. Visiting more saltlicks will certainly increase the chances of picking up the track of a potential mate and increase chances of encounter with other rhinos.

### 6.3 - Birth of the young

From the size and shape of the footprint of very young rhinos the approximate date of birth can be extrapolated, as has been shown in chapter 4.1. The smaller the prints and the more often a calf was found the more accurate this extrapolation will be. For all calves the growth curves were compared visually with figure 4.1 to determine the approximate time interval during which birth occurred. The results are shown in figure 6.1. The scale runs from August till July, because no births were thought to have occurred during these months.

The number of births varied considerably from year to year. In 1975 and 1980 apparently no calves were born, while probably 6 of the 12 calves that were found were born in 1976. In the following three years, 1977 to 1979, each year a few births occurred, most of them in the second half of 1978 and in 1979. From the data collected during this study it seems that most births occur from October till May. The period with little or no births, June till September, coincides with the long dry season (see figure 2.4), and it seems that most calves are born in the periods of heaviest rainfall.

The gestation period of the Sumatran rhino is unknown (van Strien, 1974). One would expect it to be shorter than for the other rhinoceros species, because of the animal's smaller body-size. The other rhinoceroses have gestation periods of around 16 months, and are about twice the weight of a Sumatran rhino. There is one unreliable report of a gestation period of

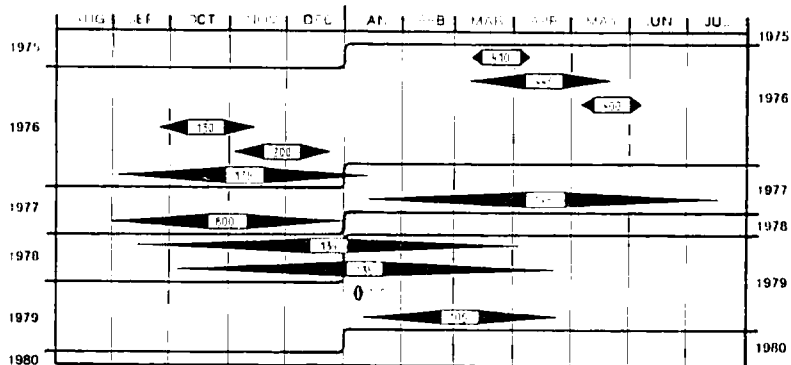


Figure 6.1 - The approximate time interval during which calves were born in the study area. Each bar indicates the time interval during which the calf was presumed born, based on the growth curves of the foot and on the occurrence of the tracks of calf with cow.

around 7 months for a Sumatran rhino (Bartlett, 1873), but usually the gestation period is estimated to be between 12 and 16 months.

In this study we could gather no information regarding the gestation period. No female was found together with another adult rhino prior to giving birth. There are only two records of females about one year prior to giving birth, but both were walking singly and none of the males was nearby.

#### 6.4 - The breeding interval

The duration of the study was too short to record two successive calves known to have the same mother. Therefore there are no precise records regarding the interval between two successive births, but a minimal interval can be measured from the periods that females were recorded without a calf.

Female 700 was found wandering alone over a period of about 1055 days before giving birth to calf 100. Female 840 was found for the first time 500 to 600 days before giving birth, and female 440, after having separated from her calf, was found regularly over a period of at least 500 days. In all cases the intervals between individual records were so short that no calf could have been born and raised during that period. Adding the nursing period of 180 to 540 days to these figures gives a minimum period between births of 1000 to 1600 days, or 2.7 to 4.4 years. Female 444 was found again 1550 to 1600 days after giving birth, but unfortunately was not recorded in the intervening period. In theory she could have had another calf in this period. Female 700 was found more often and certainly did not have a calf in the three years before calf 100 was born, moreover it is unlikely that this was her first calf, because this rhino has a large foot with strong profile, suggestive of fairly old age. If this is not an exceptional case, the normal breeding interval will be four years or longer.

In chapter 5.1.1 kinship has been suggested between the calves 105 and 410 and between calf 135 and an unknown young (146?) found on the first expedition. If this is true the breeding intervals are respectively about 1050 and 1500 days, about 3 to 4 years or more. All evidence points to the breeding interval being considerably longer than the 2 to 2½ years that cover gestation (8 to 14 months) and the ensuing nursing period (16 to 18 months). In the Mamas study area a female Sumatran rhino normally only breeds again a considerable time after she has separated from her calf. It may be that this long interval between births is caused by poor quality of the available food, and that a female rhino needs a long period to recover and to build up enough strength for nursing another calf.

In this respect the Sumatran rhino differs considerably from the Indian rhino (*Rhinoceros unicornis*), where the calves remain with their mother for three to four years, and only leave her shortly before the birth of the next calf. The breeding interval for that species in Chitawan, Nepal, is comparatively short, on average 34 months or 2.8 years (Laurie, 1978).

#### 6.5 - Development of the calf

The new-born calf is about 60 cm high, 90 cm long and weighs around 25 kilograms, and it is for the first few days probably hidden by the mother in vegetation while she browses (Bartlett, 1873). On one occasion tracks of a very young animal were found, estimated to be not more than 15 days of age (see chapter 4.1). This infant (calf 100 from female 700) was found very close to siltlick 1 and may have been born there. The other calves found during the study were two months or more when they were found for the first time.

In the first months of life the calf remains very close to the cow. The small prints of the calf are then often obscured by the cow's prints, walking behind the calf. Several times it was only after a track had been followed for some distance that it was discovered that there was also a small calf accompanying the cow. Many times the calf was found to have walked in front of the cow for a long distance, but sometimes the cow led.

On one occasion we met cow 440 and calf 400, then about 5 months of age, in the forest. After the first alarm the rhinos walked away. After some moments of silence the cow came running back and passed us closely. The calf did not follow and while running the cow sprayed copiously with urine and defecated several times. When alarmed young calves apparently take cover, while the cow tries to divert the attention. To avoid further disturbances no search was made for the hidden calf.

Older calves wander away from the cow, and both tracks form intertwining lines, alternating liveering for several meters and coming together again. After some time the calf is found to walk alone and the cow is generally no longer present in the area where it nursed the calf (see chapter 5.1.1). But it might be that there is still a loose bond between cow and calf, because three times after separation tracks of a cow and her calf were found together in the same place. From the age of the tracks it seems that they were not there together, but it could be that one was following the other's trail and that they occasionally still meet.

As has been explained in chapter 4.1 and shown in figure 4.1, the cow and calf separate after about 500 days (480 - 540 days). At the time of separation the foot of the calf is still markedly smaller than the adult foot, and it is reasonable to suppose that the animal's overall size and bulk will also be less than the adult's. Comparing the growth curves shown in figure 4.1 and the foot dimension for the age and sex classes as shown in figure 4.5, it was found that the median values of the calf's footprint at separation were about 85 percent of the median values for the adults.

If the same percentage can be applied to the other body dimensions, the height of the animal at separation would be about 85% of the adult's shoulder height (125 - 135 cm) or about 105 to 115 cm. The weight would be  $.85^3$  x adult weight (800 - 1000 kg) or 500 to 600 kg. Growth must be close to one kilogram per day during the period of nursing, if the calf is to grow to more than 500 kg in about 500 days.

#### 6.6 - The sub-adult phase

After separation growth levels off. In the first year or so of independence there is still noticeable growth of the foot, but later the growth is hardly visible and much less measurable. A few calves were found for about two years after becoming independent, and their footprints were still clearly those of a young animal, smallish and without distinctive features. Several other rhinos found with similar footprints were called sub-adults. They were presumed born prior to the start of the study. Some of these were found for four or five years, and in that period they appeared to have grown only very little. Looking at the whole series of casts sometimes a slight increase in size appears to be visible, but in the standard measurements there is no detectable increase. The individual variation between the casts is many times more than the supposed increase in size.

Different sub-adults showed appreciable differences in size, some were very similar to the calves shortly after separation, others were larger and in size and character were similar to the tracks of the adults. This indicates that the sub-adult period is probably longer than the longest period - 5 years over which they sub-adults could be followed in this study. It could well be that the sub-adult phase lasts for 6 or 7 years or even longer. Probably the Sumatran rhino does not reach sexual maturity and age of first breeding until 7 or 8 years old at least.

The sub-adults form a fairly elusive group. Not only are their prints difficult to identify, but most were found over long intervals of several expeditions, and scattered over a large area. The small sub-adults - the calves in the first few years after separation - have small and clear-cut ranges, but the larger sub-adults appear to range over large areas. In their first two or three years of independent life a Sumatran rhino lives in a relatively restricted area, usually close to a siltlick and in the lower part of the valley. Later they become more and more exploratory and range over vast areas, probably trying to find themselves a vacant range between the established adult ranges.

At the end of 1982/early 1983 a sub-adult rhino visited the Kotambe Research Station a few times (A plastercast was made by Dr. H.D. Rijksen). This station is at least 20 kilometres from any of the existing rhino areas and the only previous record of a rhino there dates from 1971. Occasionally rhino are also reported from other places, far from the known centres of rhino distribution. It might be that these wandering individuals are mainly sub-adults, like the one in Kerambe, forced to explore new territory to establish a home range when the main rhino areas are already 'full'.

## CHAPTER 7 - DAILY ACTIVITIES OF THE RHINO

In the following chapters we will look at the daily activities of the rhino. Many of these aspects of the rhino's life have been described in detail by previous field surveys (Borner, 1979; Flynn, 1978; see also van Strien, 1974). A major shortcoming of the use of indirect evidence of animal movements for the analysis of the daily activities is the difficulty in estimating the age of the tracks or other signs. It is usually possible to tell if tracks and other signs are very fresh, no more than a few hours old, from the freshness of mudsmears, scratches on bark, trampled plants etc. But these very fresh tracks were rare and usually it is difficult to be more precise in dating than to say for instance 'last night', 'previous day' or '2 to 3 days ago'.

With older tracks it is even more difficult to make an estimate of their age. Under the moist conditions of the tropical forest, drying and discolouring of mud, faeces, scratches and bruises on plants, can be very slow. Mudsmears known to be several days old were found to be still wet and appeared freshly made. The wounds on broken and snapped twigs can remain moist and light-coloured for days or even weeks, so that they appear to be freshly damaged. Moreover there are great local differences: a track can appear very fresh in one place, and several days old only a few meters further on.

On the few occasions when a rhino was met, it was usually a complete surprise. Although we were following fresh tracks, there was nothing to indicate that the rhino had passed only minutes before. In one case it was even judged from the discolouring of the faeces that the track was probably two days old, yet we met the rhino only a few hundred metres further on. In other cases we followed what seemed to be very fresh tracks very cautiously in the hopes of seeing a rhino, but after some time it became obvious that the track was at least many hours or even days old.

### 7.1 - The system of trails

One of the characteristic aspects of a rhino area, at least in the mountains, is the existence of an extensive network of wide, clear and well-used game trails. The trails generally follow the rivers and the ridges, forming a huge network for easy travel, and used not only by the rhino, but also by other forest animals and man. Very little clearing is needed to follow a rhino trail and on the bigger trails one can easily walk 15 to 20 kilometres in a day. When a trail has to be cut in difficult terrain like the upper Mamas, one can not expect to travel more than 5 kilometres per day and often less. It was only because of the existence of the rhino trails that such a large area could be surveyed in the time available. See figure 2.5 for the location of the trails that formed the patrol network.

Trails are generally better developed in the larger valleys and on the main ridges. The trails along the major rivers like the Mamas and some parts of its tributaries are well developed and cross the river frequently to cut off bends in the river. Where the trail crosses the river the banks are generally eroded by heavy use. At a few places along the Mamas the trail crosses a low spur, here the trail has worn away a narrow trench, to 4 metres deep at the centre. These deep cuts are caused by heavy animal traffic. On steep slopes rain washes out the trails, but nowhere is soil erosion serious.

The trails along the bigger rivers often branch, with side trails going to alternative crossing places or vanishing into the vegetation. At the foot of a main ridge there are sometimes well defined side trails leading up to the ridge. The trails along the smaller streams are much less developed. As long as the streambed is flat the animals follow the stream, but cutting off the largest bends. Where the streambed is steeper the trail leaves the stream, but occasionally minor trails cross the rivulet.

Where the banks of the Mamas are steep the trails go up the slopes, generally following a spur between the river and a small side stream, to reach more level ground, after which the trail continues more or less parallel to the river. North of camp Acoh the trails leave the river for a few kilometres, because the Mamas enters a narrow steep-sided valley. Where the valley broadens again the trails descend again to the river until camp Uning. Just north of this camp the Mamas enters a deep gorge and the trails rise again and follow the edges of the gorge.

The trails on the ridges are even better defined than those along the river, probably because of the drier and harder soil and the less vigorous undergrowth. On every spur and ridge there is a trail, but those on the main ridges of the watersheds are the best developed. These trails are between 40 and 100 cm wide and are generally worn with use. On the trail the soil is bare with a little moss. The vegetation alongside the trail is meagre, and most of the saplings and trees are bent, broken or otherwise damaged by animals passing.

As one would expect the trails follow the easiest route, avoiding unnecessary gradients. They circle small peaks on the ridges and on steep gradients, more than about 15°, they zigzag