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CONTRIBUTIONS TO THE ECOLOGY AND SOCIOLOGY OF THE JAVAN RHINOCEROS (*RHINOCEROS SONDAICUS* Desm.)

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Dr. U. Rahm

Basel, den 16. April 1985

Prof. Dr. G. Backenstoss
Dekan

to

my parents

SUMMARY

A field study of the Javan rhinoceros (*Rhinoceros sondaicus* Desm.) was carried out in Ujung Kulon National Park, Java (Indonesia) between February 1978 and May 1980. The aim of the study was to obtain information on the size and structure of the population as well as on the ecology and social organization. This information was obtained principally by following the tracks of individual rhinos and recording the traces of their activity.

1. On two censuses carried out in 1978 and 1980 the number of rhinos was estimated between 46 and 53 (mean 49.5) in 1978 and between 47 and 57 (mean 52) in 1980. This corresponds to an annual population increase of 3.8 % in that period. The census results are low estimates of the population size. On the base of an average density of 0.47 - 0.51 rhinos/km^2 in the study area, the size of the population in Ujung Kulon was estimated to be 70 rhinos in 1980. The sex ratio among adult rhinos was 0.64 : 1 (♂/♀). In 1980 about 17 % of the rhinos were juveniles or subadults.

2. The Javan rhino's diet is characterized by a high species diversity. 190 foodplant species were recorded, 179 of which were dicotyledones. The four principal food species were *Spondias pinnata*, *Amomum* sp., *Leea sambucina* and *Dillenia excelsa*; together they constituted approximately 44 % of the quantity of food eaten. The rhinos ate mostly leaves, young shoots and twigs. Seasonal variations both of the proportion of some species in the diet, and of the total quantity of food consumed were observed.
   Most of the plants eaten by rhinos stood in unshaded locations. The rhinos preferred to feed in vegetation types without tall trees: gaps created by fallen trees and shrubland without trees. Their preference for these vegetation types is most probably to be explained by the better average quality of foodplants growing in unshaded locations. Rhinos rarely fed in vegetation types in which the quantity of available food was small.

3. In spite of their preference for feeding in vegetation types without tall trees, rhinos are probably dependent upon the occurrence of forest in their environment. Forest provides protection against solar radiation; water supply is subject to smaller fluctuations inside forest than outside; forest trees are the source of many saplings eaten by rhinos. The optimal habitat of the Javan rhino, with regard to vegetation types, therefore appears to be a mosaic of glades interspersed with patches of forest. This kind of habitat is widely distributed in Ujung Kulon.

4. The movement pattern of rhinos was characterized by stays lasting from a few days up to three weeks in an area of high food density before they shifted to another. Solitary rhinos and cows with calves covered distances between 1.4 and 3.8 km per 24 hours. Higher movement rates were occasionally recorded in cases where rhinos shifted from one ecological place (e. g. an area of high food density) to another.

5. The rhinos were predominantly solitary. Permanent associations existed between cows and their calves. Temporary associations, lasting no more than several days were observed between a cow/calf pair and a subadult individual as well as between a male and one or two females. The latter were interpreted as associations between a bull and an oestrous female. The length of the association suggests that mating is preceded by a courtship phase.

6. Home ranges of females were 2.6 - 13.4 km^2 in size; home ranges of males 12.5 - 21.0 km^2. The size difference between male and female home ranges must probably be seen in connection with different reproductive strategies of the sexes.
The home ranges of females overlapped each other considerably, while the home ranges of males, determined in this study overlapped each other only marginally. This indicates that these males were intolerant among each other and avoided the areas occupied by the others. Comparison with other rhino species suggests that a dominance hierarchy exists among males, and that the males, whose home ranges were determined, were of high social status.

7. Various measures for the conservation of the species are discussed. Continued protection of the species, research on the vegetation of Ujung Kulon and the feeding ecology of the banteng and the translocation of a group of rhinos to other suitable reserves are recommended.

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CONTENTS

1. INTRODUCTION

The plight of the Javan rhinoceros (*Rhinoceros sondaicus* Desm.) has been attracting world-wide attention since the early sixties. Once widely distributed over South and South-East Asia its numbers have dwindled at an increasingly alarming rate due to hunting pressure and the claims laid on its habitat by man. By 1967 only a few individuals remained in the nature reserve Ujung Kulon on the island of Java and possibly some in areas of Indochina where they would however have been severely threatened by the war. Thus the Javan rhino had the dubious distinction of being the rarest mammal species on earth. Since 1967, thanks to the implementation of efficient guarding and management of the population in Ujung Kulon, poaching has been stopped and the number of Javan rhinos has begun to increase again.

1.1 Aims of the study

The present study of the Javan rhinoceros originated from a proposal made by Prof. R. Schenkel. In 1967 and 1968 Prof. Schenkel together with his wife conducted a field study of the Javan rhino (Schenkel and Schenkel-Hulliger 1969a). The study, made possible through a generous financial grant by Prof. R. Geigy, was carried out in a frame of cooperation between WWF/IUCN and the Indonesian government. Schenkel and Schenkel-Hulliger developed methods of research as well as a method by which a reasonably accurate estimate of the number of rhinos remaining in Ujung Kulon could be obtained. Further they studied various aspects of the ecology and behaviour of the Javan rhino. At the same time these authors devoted considerable time to the reactivation of the guarding and the management of the reserve. In conclusion of his study Prof. Schenkel asserted that several important questions concerning the biology of the Javan rhino remained to be answered. His experiences on trips to Ujung Kulon after 1968 convinced him that the results of his field study required confirmation as well as extension and deepening. This became important in defining the aims of the present study. The areas of investigation were determined both by a scientific interest in the Javan rhinos biology as well as by an interest in obtaining information pertinent to the management and conservation of the species. I tried to gain insight into the following aspects:

1. Size and structure of the population.
   Besides continuing to estimate the size of the population by the method developed by Schenkel and Schenkel-Hulliger I tried to develop an alternative method. Information was gathered on other population parameters such as age structure, sex ratio, birth and death rates.

2. Feeding ecology.
   The aim was a deepening of the investigations already begun by Schenkel and Schenkel-Hulliger on food and habitat preferences of the Javan rhino as well as the availability of food and habitat types in Ujung Kulon.

3. Spatial organization of the population.
   I intended to determine the size of home ranges of individual rhinos as well as their location relative to those of other rhinos. A further aspect was to determine whether some rhinos maintain territories.

4. Movement patterns.
   I examined the distance individual rhinos moved and the patterns in which they moved around their home ranges.

5. Social organization.

In addition I gathered all information available on other aspects of the Javan rhinos ecology.

1.2 Previous knowledge and former distribution of the species

1.2.1 Previous knowledge

The earliest written records of the Javan rhinoceros date from the time of the Chinese T'ang dynasty (618 - 906 AD) (Sody 1959) where the export of rhino horn from the island of Java is mentioned. In the 13th century Marco Polo saw rhinos on Sumatra and from his description of them having only one horn it may be assumed that they were R. sondaicus (Polo 1982). A Javan rhino is depicted on a relief dating from the 12th or 13th century in Angkor-Vat (Brentjes 1978). From the end of the 16th century on Javan rhinos were mentioned with increasing frequency in books and reports of travellers, hunters and government officials. At the beginning of the 19th century Cuvier suggested that there might be two different species of Asian rhinoceroses (Hookmaker and Visser 1982) and, in 1822, Desmarest described the Javan rhinoceros for the first time as a separate species and gave it its scientific name (Desmarest 1822).

Little information on the Javan rhino's way of life can be found in older literature (for a review see Sody 1959), although it is an invaluable source of information on their former distribution. In 1933 Hazewinkel and in 1935 Franck published their observations on the biology of the Javan rhinoceros, the former rather from a hunter's than from a biologist's point of view. From 1932 on Hoogerwerf began to take an interest in the Javan rhino population of Ujung Kulon and visited the reserve repeatedly before, during and for some time after World War II. Most of these visits were only of short duration however, the two longest lasting two and three months, and Hoogerwerf did not carry out a systematic research program. He published his observations in several reports on his trips to Ujung Kulon and later summarized his vast knowledge of the reserve and its wildlife in a large monograph (Hoogerwerf 1970) several chapters of which are devoted to the rhinoceros. The first scientific study and first study of longer duration was the one begun in 1967 by Schenkel and Schenkel-Hulliger (1969a) mentioned above. The two authors continued their visits to Ujung Kulon in subsequent years and have proposed various measures for the management of the species (Schenkel et al. 1978, Schenkel and Schenkel 1982).

1.2.2 Former distribution and habitat

Until about 150 years ago R. sondaicus was widely distributed over South and Southeast Asia, although the numbers may already have been low in some areas at that time (Schenkel and Schenkel-Hulliger 1969a). In the western part of their range Javan rhinos occurred in Assam, Bhutan, the Sundarbans and possibly in SW China as well. Further eastward they have been reported from Tenasserim (Burma), southern Thailand, Kampuchea, Laos and Vietnam and in the south from Malaysia, Sumatra, West and Central Java (Loch 1937, Sody 1959, Groves 1967, Rookmaaker 1980) (see figure 1.1). Their range never seems to have extended into northern Burma and Thailand nor to East Java, because of a lack of suitable habitat (Groves 1967). It is remarkable, however, that no records exist of their presence in the central regions of Burma and Thailand, where evergreen forest is found. Thus the distribution in recent historical times appears to be discontinuous. It is conceivable that large human populations developed in early historical times around the fertile valleys of the Irrawaddy and the Chao Phraya, which led to the extinction of rhinos in those areas. On the other hand separate subspecies have evolved in each of the three subpopulations — Rhinoceros sondaicus inermis in the western, R. s. sondaicus in the central and R. s. annamiticus in the eastern (Groves 1967, Groves and Guérin 1980; the subspecies were distinguished on the base of cranial and dental measurements) — but no subspecies have evolved on the island of Java and Sumatra

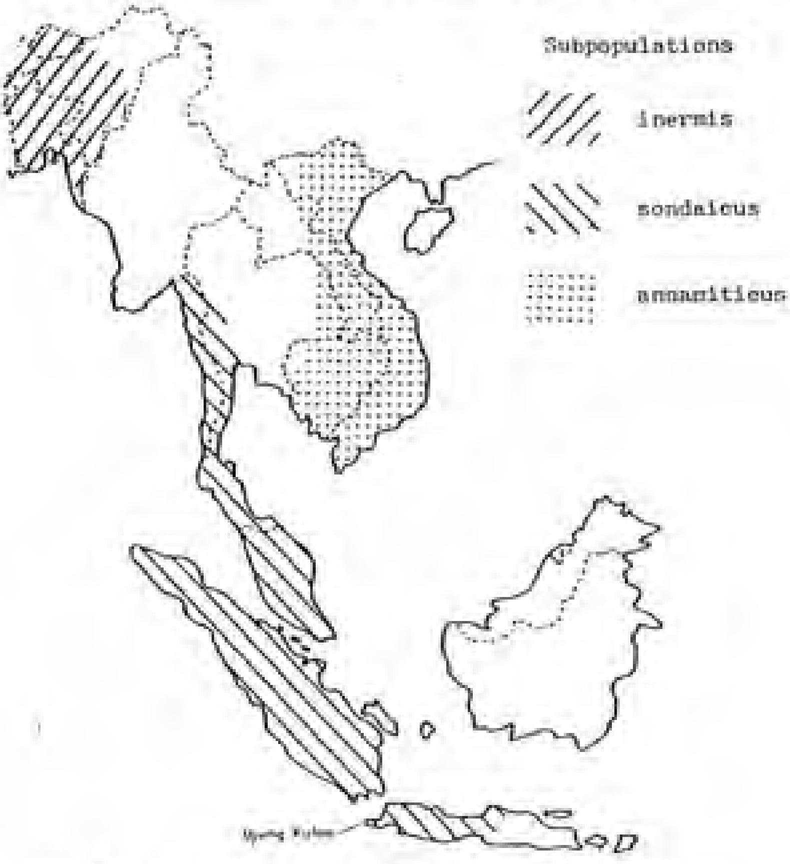


Figure 1.1 Distribution of Rhinoceros sondaicus in recent historical times.

although these have been separated from the mainland since 8'000 years at least (de Lattin 1967). This suggests that the three subpopulations may have become separated long before competition with man became an important factor in eliminating rhinos from certain areas.

Very little can be found in the literature concerning the original habitat of the Javan rhino. Most older authors noted its occurrence in "forest" without giving any closer details. Its distribution coincides in fact with that of evergreen forest in areas with high annual rainfall and some rainfall in all months. Only once has its habitat been described as "high grass jungle" (Thorn, in Sody 1959). Rhinos always seem to have been fond of the vegetation growing on plantations and in man-made jungle clearings. In Java they were even considered quite a pest and twice — 1747 - 1749 and around 1820 — the government paid a bounty for every rhino killed (Sody 1959). Javan rhinos seem to be more adapted to the lowlands than to mountainous areas. In those regions where they occurred sympatrically with the Sumatran rhino (Dicerorhinus sumatrensis), a tendency could be observed for the latter to inhabit the mountains, while the Javan rhino inhabited the lowlands (Groves 1967). Where Javan rhinos occurred alone, however, they were found on mountains as well (Sody 1959, Groves 1967).

1.3 Ujung Kulon

1.3.1 Location

Ujung Kulon National Park is situated on the western tip of Java (Indonesia) (Figure 1.1). The administrative unit of the park includes Ujung Kulon peninsula, the G. Honje* mountain range east of the isthmus, P. Panaitan on the Krakatau archipelago in the Sunda Strait and some smaller islands off the north and east coasts of the peninsula (figure 1.2). Rhinos occur only on the peninsula and up to a few kilometers east of the isthmus.

1.3.2 A brief history of Ujung Kulon

It is not known how long Ujung Kulon has been inhabited, but the existence of several villages on the peninsula in the 19th century has been recorded by various authors (Hoogerwerf 1970). Probably the most important of these, thanks to its safe anchorage and situation on an important trade route, was Djungkulon on the north coast opposite P. Peucang. It may be assumed that the inhabitants practiced wet rice agriculture in the plains and shifting agriculture in the hilly areas of the interior (I found low earth ridges crossing each other at right angles in the alluvial plain east of Citadahan. These may have been former boundaries of rice paddies). In the report of an expedition carried out in 1853 the "...fertile soil, where palms and indiarubber trees thrive in their thousands, where a superabundance of honey and beeswax may be collected..." is mentioned (Hoogerwerf 1970). Veth (1912) later wrote about the former export of large quantities of indiarubber. The forest was exploited for timber used in construction of housing and boats.

* For an explanation of Indonesian geographic terms and their abbreviations see Appendix III.

Figure 1.2 Location of Ujung Kulon National Park (after Blower and Van der Zon 1977)

In 1883 the volcano Krakatau erupted and the resulting tidal wave and volcanic ashes destroyed settlements and crops. Though some of the villages were rebuilt after the catastrophe, the area was evacuated around the beginning of this century by the authorities because of rampant diseases and the depredations of tigers.

Possibly the real reason was to facilitate the institution of a nature reserve (Hoogerwerf 1970). Both the Netherlands Indies Society for the Protection of Nature and a hunting society petitioned the government that Ujung Kulon be set aside as a reserve with organized protection, but this was denied and it was only in 1921 that the area was made a nature reserve, where all hunting and trapping was prohibited. No measures to protect the area were taken, however, and poaching continued through the following years, mainly because of a lack of funds to pay for a guard organization. In 1937 the status of the reserve was changed to that of a game sanctuary, a status permitting some limited and controlled exploitation. The aim was to obtain funds for management and protection through the lease of hunting rights. In the same year a guard system with permanently occupied posts and regular patrols was drawn up. Large areas were cleared to provide grazing grounds for the banteng population.

In the turbulent period after the war poaching increased considerably. Nature reserves came under the administration of the forestry department, but in spite of the interest taken by the Indonesian government in the protection of the reserve and the Javan rhino, sufficient funds were lacking - other matters were more pressing for the young nation - and the poaching of rhinos continued. The serious situation drew the attention of WWF/IUCN, and Prof. Schenkel and his wife were sent to Ujung Kulon to find the ways and means of saving the probably last remaining population of Javan rhinos from extinction. It is due to their efforts, the continued committment of the Indonesian government and the financial support provided by Prof. R. Geigy and WWF between 1967 and 1980 that an efficient system of management has been instituted and the poaching of rhinos reduced to virtually nil (with one exception in 1969 (Schenkel pers. comm.)).

In 1977 a plan for the future management of Ujung Kulon was submitted by a team from FAO (Blower and Van der Zon 1977). Finally in 1980 Ujung Kulon became a national park and its boundaries extended to include the Krakatau archipelago.

1.3.1 Climate

Ujung Kulon has a "monsoon and trade-wind littoral climate" (Strahler and Strahler 1983), which is characterized by high annual precipitation, precipitation in all months and monthly variations resulting in a dry and a wet season. The annual range of temperature is very slight. On the average the wet, or rainy season lasts from October to April with winds blowing predominantly from west to northwest and high precipitation in all months. From May to September dry winds blow from the southeast and there is usually little rain. The amount of precipitation and the length of seasons may vary considerably from year to year. In some years there may be lots of rain during the normally dry months and conditions remain similar to the months of the wet season. In other years very little or even no rain at all may fall during the months of the normally wet season and an extended dry season may result (Schenkel and Schenkel-Hulliger 1969a, Hoogerwerf 1970, Hommel 1983). Figure 1.1. shows the precipitation measured on P. Peucang from August 1978 to May 1980 and the monthly averages from measurements made over a period of 57 years at Tg. Layar. The pattern of rainfall in the years 1978 – 80 followed more or less the long-term average. Rainfall measurements taken at Tg. Layar and on P. Peucang are not representative for the whole area of Ujung Kulon as there may be considerable local variation. According to Hoogerwerf (1970) less rain falls in the eastern part of the peninsula. The length and course of seasons is however similar throughout Ujung Kulon.

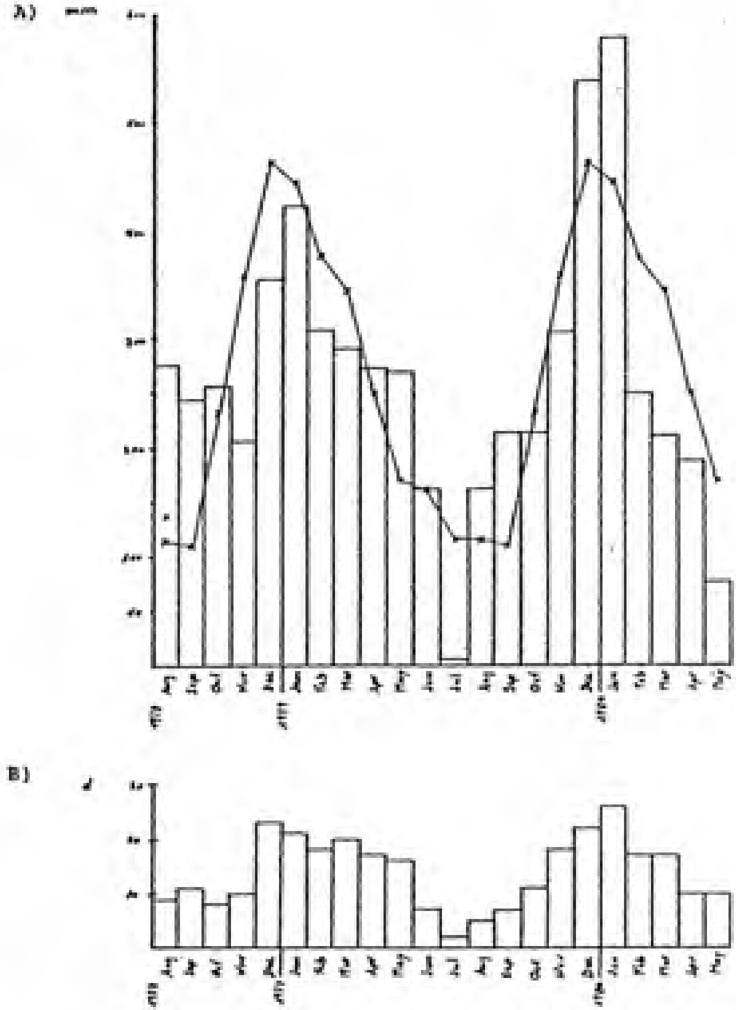


Figure 1.3 Precipitation

A) Monthly precipitation on P. Peucang Aug. 78 - May 80 (columns) and monthly averages (x——x) 1885 - 1941 at Tg. Layar (from Vogel 1979)

B) Number of days per month with precipitation (P. Peucang). Aug. 78 - May 80

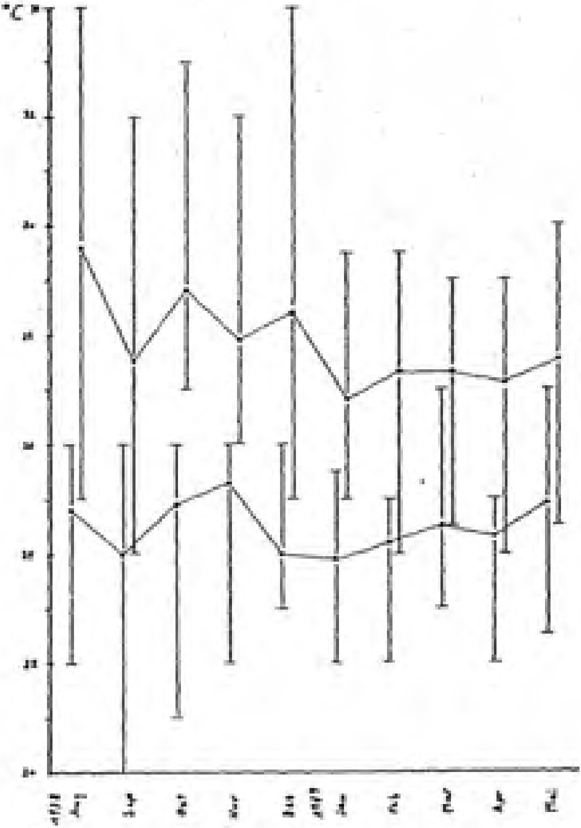


Figure 1.4 Means and ranges of daily temperature minima and maxima per month (P. Peucang)

The temperature was measured in the forest on P. Peucang about 50 m from the guard post. The average daily minima and maxima for each month are shown in Figure 1.4. The smallest daily variation of temperature was 1° C, the largest 10° C.

Humidity measured at the same location as temperature, was 95 % and higher throughout the rainy season and on days with rainfall during the dry season. During periods with no rain in the dry season it could drop to 90 %. Outside the forest — on grazing grounds, in shrubland etc. — humidity is much lower; as low as 65 % during the dry and 75 % during the rainy season (Halder 1975). Temperatures do not seem to be higher outside the forest than inside.

1.3.4 Topography

Ujung Kulon is a roughly triangular shaped peninsula connected to the rest of Java by a narrow isthmus which is about 1.5 km wide at its narrowest point. The size of the area has been variously stated as 300 km^2 (Hoogerwerf 1970), 360 km^2 (Schenkel and Schenkel-Hulliger 1969a) and 411 km^2 (Koesnadi 1981). Calculations made on an official scale 1 : 50'000 map showed that 300 km^2 is the most correct approximation; the actual size lies within 10 km^2 of this figure. This includes the area of the peninsula and the area east of the isthmus up to the trail Karangranjang - Cikawung and the park boundary leading from that trail to the coast at Legonpakis.The rhinos range extends eastward over the trail, but on the other hand the area near Legonpakis is not visited by them at present. 300 km^2 may therefore be considered a good approximation of the size of the area frequented by rhinos.

The most prominent topographical feature in Ujung Kulon is G. Payung whose highest peaks lie at about 500 m a.s.l.

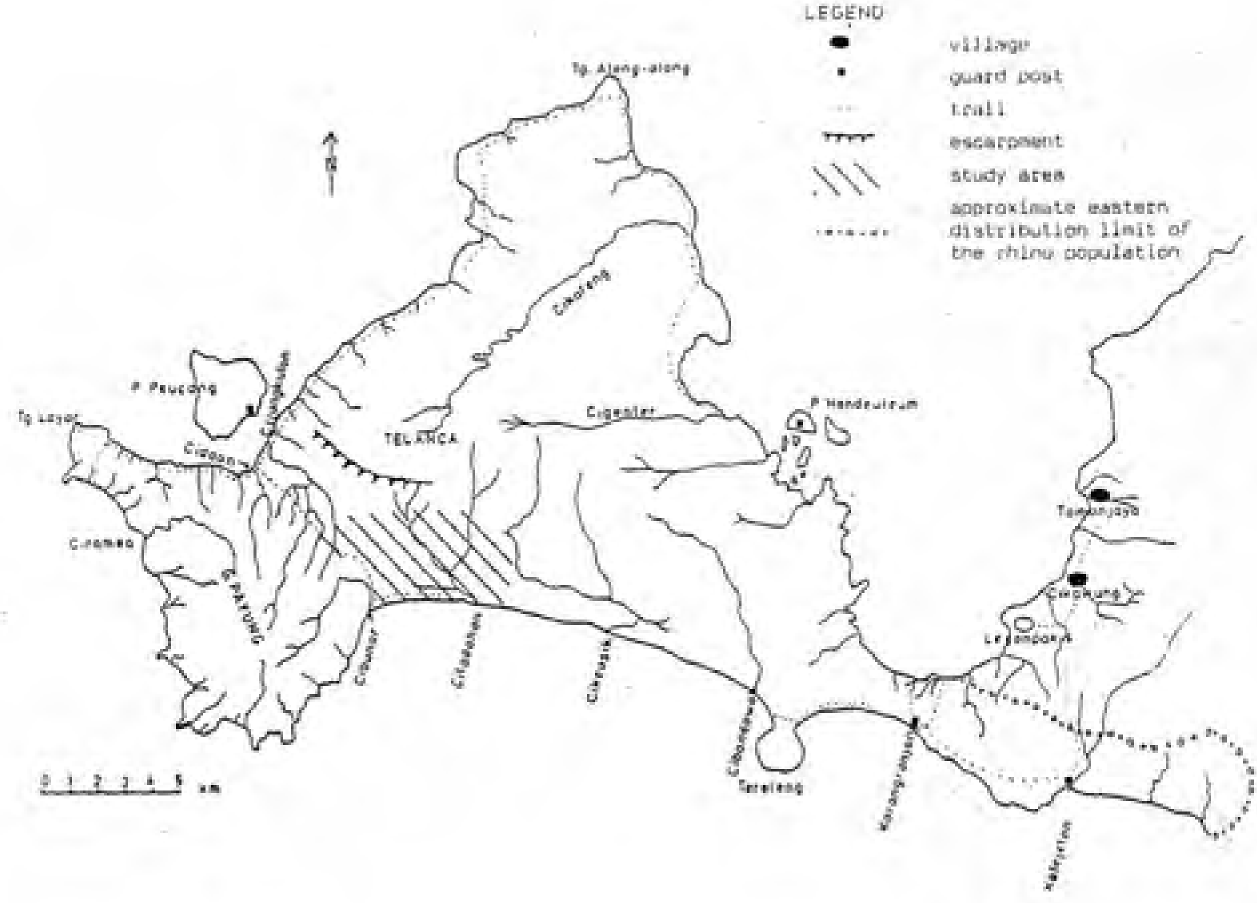


Figure 1.5 Ujung Kulon peninsula (based on Schenkel and Schenkel-Hulliger 1969a; Schenkel

(Figure 1.5). The slopes of this mountain are very steep in most places and the numerous streams have cut deep ravines. To the northwest a broad spur leads down to Tg. Layar. The central area of the peninsula is formed by the Telanca plateau which in the area of highest elevation reaches 150 - 200 m a.s.l. Towards the east and south it falls off gently becoming progressively more dissected by streams and rivulets and evolves into a series of low hills. In the north the descent to the coastal plain is steeper and on its western side the plateau ends abruptly in a steep escarpment. Between Telanca ad G. Payung lies an alluvial plain, about 2 - 3 km wide, that stretches from the north to the south coast. Fringing the central plateau to the north and east and G. Payung to the north and west lies a narrow coastal plain formed by erosional action (Hommel 1983). Along the east coast lies a strip of mangroves and permanently inundated saltwater swamps. Inshore from these as well as around Tg. Alang-alang and Nyur in the north and in the area of the isthmus large areas are inundated during the wet season. A raised sand bar of calcareous sandstone runs along the south coast (Hommel 1983). Between Citadahan and Tereleng, as well as around Karangranjang the sandstone has been weathered by the wind and the sand blown up into dunes that may reach a height of 40 - 50 m in some places. Several lines of dunes running parallel to the coast can be distinguished. Between Cibunar and Citadahan and east of Tereleng where the influence of the surf is predominant the sandstone layer has been truncated and forms a platform. A more detailed description of Ujung Kulon, its landscape forms, geology and soils may be found in Hommel (1983).

Water is usually abundant in Ujung Kulon and besides the streams shown on the map small rivulets are found everywhere. There are no major rivers but some of the streams are wide and deep and navigable by canoe near their mouths. As the dry season progresses smaller rivulets dry out and in very long or extremely severe dry seasons water, with a few exceptions, is found only in major streams (Schenkel and Schenkel-Hulliger 1969a). Because of the lack of current, salt water flows into the estuaries and lower courses of these streams and the water may become brackish.

Two permanently inhabited guard posts - Karangranjang and Kalejetan - are situated in the area of the isthmus and further east. On the peninsula itself the only permanently inhabited place is the lighthouse compound at Tg. Layar, where about 10 - 15 persons of the lighthouse service live. These persons are not affiliated with the nature conservation department and have no guarding functions. Two more guard posts lie on the islands of Peucang and Handeuleum. There are no roads in Ujung Kulon; a few trails lead along the coasts and one trail from the grazing field at Cidaon to Cibunar. A few huts where guards or tourists can pass the night, but which are not inhabited otherwise, are scattered around the reserve. The nearest villages are Cikawung in the north and Cegog in the east. Legonpakis, an illegal settlement inside the boundaries of the park, was abandoned in 1980 and its inhabitants resettled elsewhere.

1.1.5 Vegetation

The vegetation of Ujung Kulon is very varied, ranging from primary forest on G. Payung to plant communities profoundly influenced by man's former activities and the effects of the Krakatau eruption in 1883. A remarkable feature is the very fine mosaiclike distribution of vegetation types in many areas of Ujung Kulon, so that along a transect the vegetation may change several times within 100 m. Descriptions of the vegetation have been given by Koesnadi (1961), Schenkel and Schenkel-Hulliger (1969a), Hoogerwerf (1970) and Halder (1975). A detailed study of the vegetation was completed only recently by Hommel (1983) in whose report descriptions of plant communities and a landscape ecological map can be found. I will present here a brief description of those vegetation types found in the areas where I studied rhinos and which will be referred to in the text, followed by a general description of how these and some other plant communities are distributed in Ujung Kulon. The names of these communities are according to Hommel.

1.3.5.1 Description of some important plant communities

Arenga obtusifolia community:
Forest dominated by the palm Arenga obtusifolia. A few tall dicotyledonous trees are usually present. Where the crowns of the palms form a continuous canopy, up to 95 % of the light may be absorbed before it reaches the ground layer (Schenkel et al. 1978) and consequently undergrowth can be very scarce. Where the palm canopy is more open, saplings and herbs are abundant.

Drypetes-Bambusa community:
Characterized by the tall, spiny bamboo Bambusa blumeana which may grow to over 25 m in hight. The undergrowth is moderately dense; saplings, palms, herbs and climbers are found here. Tall dicotyledonous trees and palms are present as well.

Schizostachyum zollingeri community:
Almost monotypic stands of the bamboo Schizostachyum zollingeri which grows to a height of about 4 m. A few tall trees are usually present as well, but saplings and climbers are rare.

Salacca edulis community:
Characterized by the spiny, stemless palm Salacca edulis which grows to a height of over 4 m. Usually a layer of tall trees is present. Saplings and climbers are rare.

Calamus Amomum community:
An extremely dense shrubland consisting of a nearly impenetrable tangle of rattans (Calamus sp.), small trees and saplings, bushes, gingers, climbers and other herbaceous vegetation. Locally gingers or the bush Eupatorium odoratum may dominate. Tall trees are scattered or grow in small clumps.

Dendrocnide-Eupatorium community:
A very variable shrubland dominated by the shrubs Eupatorium odoratum and Lantana camara. Saplings and climbers are abundant.

The latter two communities correspond to the "glades" mentioned by Schenkel and Schenkel-Hulliger (1969a). For the purpose of this study I made my own classification of vegetation types since Hommel's classification had not yet been made then. This classification is given in 4.1.3.1 together with the corresponding names according to Hommel's system.

1.1.5.2 Distribution of plant communities in Ujung Kulon

The vegetation of Ujung Kulon has been profoundly influenced by two factors: man and the Krakatau eruption. The former influence of man is evidenced by the vast areas of secondary growth. Much of the area in the interior was cultivated at some time, either permanently or temporarily (slash and burn agriculture) (see 1.3.2). The Calamus-Amomum, Salacca edulis and Schizostachyum zollingeri communities are all thought to grow on formerly cultivated areas (Hommel 1983). The eruption of Krakatau had two effects upon the vegetation: The huge tidal wave generated by the explosion of the volcano destroyed the vegetation of the low lying coastal plains of the north and east coast. Secondly, a deep layer of volcanic ash was deposited on the peninsula. This ash layer may possibly have prevented the establishment of tree seedlings in areas which were not covered by forest, i. e. those areas under cultivation, and thus impeded the normal successional development towards forest (Hommel 1983).

Primary rainforest is found only on the upper slopes of G. Payung down to about 150 m a.s.l. and on the highest parts of the Telanca plateau near the escarpment. Below this level it is replaced by a mosaic of varying composition. The two plant communties which are characteristic for Ujung Kulon, Arenga forest and Calamus-Amomum shrubland, form part of this mosaic almost everywhere. Due to its preference for growing on well drained sites Arenga forest is more common on G. Payung and the Telanca plateau than in the alluvial and coastal plains. In the eastern hills Arenga is confined to hilltops, while in the swamps of the coastal plains it does not occur at all. It may also be found on the older, interior sanddunes along the south coast. Further extensive tracts are found around Kalejetan.

Towards the central part of the alluvial plain the mosaic includes patches of the Salacca edulis community, while further eastward in the hilly areas the two bamboo dominated communities are frequent. Schizostachyum zollingeri is more confined to slopes, but Bambusa blumeana may be found on hilltops and in depressions as well.

Near the coasts this mosaic is replaced by other plant communities. On the beach ridge of the south coast the dominant vegetation is the Dendrocnide-Eupatorium community. Locally, on exposed sites near the shore along the south and west coast Pandanus tectorius grows in dense thickets. Along the eastern coast mangrove forest is found as well as Nypa fructicans in the salt-water swamps behind the mangrove belt. In the coastal plain along the north coast a young growth dominated by the tree species Ardisia humilis and Buchanania arborescens has grown on the sites of the former man-made grazing fields. Elsewhere in the coastal plain the vegetation has developed into a forest that has not yet reached a mature stage.

There are three small grazing areas — one near the mouth of the Cigenter and two between Cijungkulon and Cicadas — that are kept open artificially through periodical cutting and burning of the invading shrubs.

1.4 General methods

In this section I shall describe those methods chosen to achieve the aims of the study in view of the conditions under which research was carried out. Methods related to specific problems or sets of questions will be described at the beginning of each relevant chapter.

To achieve the aims of the study it was necessary to:

- Recognize individual rhinos.
- Gain insight into the activities of rhinos.
- Obtain information on the movements of individual rhinos.

1.4.1 Main difficulties and consequences

The principal difficulty of studying rhinos in Ujung Kulon is the extremely dense nature of many types of vegetation found there. Visibility is often very low. In Calamus-Amomum shrubland, for example, the distance from which rhinos can be observed lies on the average between 15 and 25 m, but frequently it is even less and sometimes below 5 m. At such a short distance the rhino will catch the observer's scent during his approach or shortly thereafter and flee. Thus even if rhinos could be observed for short periods, their behaviour would be strongly influenced by the observer.

> In the beginning I tried to approach rhinos and observe them directly. During the first four months of the study I approached rhinos on 17 occasions. On 9 occasions the rhino fled before I could see it, on 4 occasions I could see it only briefly and on the remaining 5 occasions I was able to observe the rhino for a period lasting between 11 and 47 minutes. Once the rhino slept while I was observing it and another time it had become alerted and stopped all activity except to listen and scent.

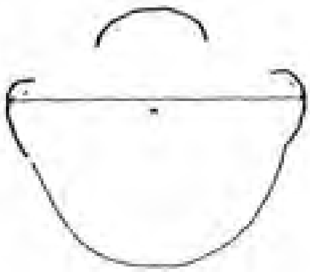
A further difficulty caused by the density of the vegetation is the impediment to movement it forms. Because of this and the abundance of spiny and thorny plants which get caught in the skin and clothe, progress is only possible with the aid of a bushknife. In extremely dense vegetation progress may be less than one half kilometer per hour. The exact determination of geographical location is difficult as well, because the available maps provide little detail and distant landmarks on which compass bearings could be taken are rarely seen.

Clearly direct observation would be a very unprofitable method of obtaining information, and consequently information has to be gathered through indirect observation, that is from traces left by rhinos. This method was applied extensively by Schenkel and Schenkel-Hulliger (1969a). I followed the tracks of rhinos which I could recognize individually (see 1.4.2) as long as possible. Research was concentrated on a selected and specially prepared study area (see 1.4.4).

1.4.2 Recognition of individual rhinos

Some recent researchers of free-ranging rhinoceroses in more open habitats have been able to recognize individual rhinos from their external appearance (Schenkel 1966, Goddard 1967, Schenkel and Schenkel-Hulliger 1969b, Owen-Smith 1973, 1975, Laurie 1978, 1982). Since Javan rhinos could be observed only

Figure 1.6 Footprint of the Javan rhino (after Schenkel and Schenkel-Hulliger 1969a)



w = maximum width between outer toenails

rarely and for short periods, this approach was not feasible. Individual rhinos were identified by the measurements of their footprints (Schenkel and Schenkel-Hulliger 1969a)*. The footprints of both fore- and hindfeet were measured with a measuring tape at their greatest width between the outer toenails (figure 1.6). A reliable identification is only possible if the variation between footprints of the same individual is small. It was found that the variation between

* Van Strien (1978) devised a method of identifying individual rhinos from plastercasts made of their footprints. This method was not employed here because of the large amount of plaster (0.5 - 0.8 kg) required for each cast.

footprints of adult rhinos and young calves were not more than 1/2 cm from the mean of a series of measurements, if the measurements were made on level ground and not too muddy soil. The track sizes of subadults and young adults were somewhat more variable and could deviate up to 1 cm from the mean. The variation of tracks ascending or descending slopes or passing through very soft soil could be much larger. Measurements were therefore only taken where the ground conditions satisfied the requirements mentioned above. Whenever possible at least five measurements each of fore- and hindfeet were taken and the most frequent size recorded.

The track of an individual could further be characterized by traces which identified the rhino's sex or, by its permanent association with the track of another rhino. In all but one case (individuals K and L, see table 1.1) these permanent associations were between an adult and a subadult or juvenile rhino.

Different rhinos with the same track measurements could not be distinguished from one another by this method unless their separate identity could be established on the base of other information. It was therefore not possible to identify every rhino (or track) encountered and to distinguish all rhinos from one another. However, it was possible to distinguish some rhinos from all others and a list of these rhinos is given in table 1.1.

1.4.3 Information on activity

An efficient way to gather information on the rhinos' activities was to follow their tracks. I searched for tracks along the main trails or the patrol paths of the study area and when a suitable track had been located I followed it as long as possible. In the beginning I necessarily had to follow the tracks of unidentified rhinos, but later I concen-

Table 1.1 List of rhinos identified during the study

Identification	Sex	Track size *	Area where encountered	Remarks
A	♀	24/25	Cibandowoh	
B	♀	24/25	Kalejetan/ Karangranjang	accompanied by calf
C	♂	25/26	Kalejetan/ Isthmus/ Cibandowoh	
D	♂	25/27	North coast opposite P. Peucang/ Tg. Layar	
E	♂	23/25	Cibunar	subadult
F	♂	28/29	G. Payung	
G	♂	26/28	Alluvial Plain (study area)/ Telanca	
H	♀	24/25 + 16/17 (21.11.78)	Citadahan/ Cikeusik	accompanied by calf after Nov. 1978
I	♀	24/25 + 14/15 (15. 3.80)	Citadahan/ Cibunar	accompanied by calf after March 1980
J	♀	26/271/2	Citadahan/ Cikendeng	
K/L	♀♀	26/27 25/26	Citadahan Telanca	permanently associated
M	♂	25/27	Telanca/Alluvial plain (north of study area)	

* The first number is the width of the hindfeet, the second that of the forefeet in cm. This notation will be used throughout this paper

trated on and actively searched for the tracks of known individuals.

When tracking rhinos, I usually spent four continuous days in the forest, returned to P. Peucang for one night to pick up new supplies, process leaf samples etc. and continued to follow the track for the next four days or until it was lost. The nights in the forest were spent near the track or in one of the small huts if these were within reasonable walking distance.

I always worked with a guard who carefully followed the track while I followed behind and noted all observations of interest. Progress was slow but it was possible to keep the distance between us and the rhino constant. The following information was recorded:

- Direction taken and distance coverd by the rhino: The distance was recorded as the number of paces taken by me. I kept track of the number of paces with a small counter. The approximate direction was recorded by compass as one of its sixteen main directions (N, NNW, NW, WNW etc.).
- All rhino traces encountered. These included: feeding traces, urination and defecation, traces of wallowing and resting, signs of interaction between individuals.
- The type of vegetation passed through.
- Topographical features (slopes, streams, swamps etc.).

Tracking was only possible when it had rained and the ground was soft enough for the tracks to be visible. Therefore, it was generally limited to the months of the wet season. In August 1978, a normally dry month, an exceptionally large amount of rain fell and tracking was possible. Heavy rainfall on the other hand tended to obliterate tracks. In the wettest months tracking became difficult and was only possible over short preriods of time.

1.4.4 The study area

Two reasons led to the decision to concentrate my research on a study area. The first, mentioned above, was the extreme density of the vegetation which impeded movement and made the determination of any geographical location difficult. The second reason was that I hoped by concentrating on a certain area to be able to identify more individual rhinos. To facilitate movement through the area a network of paths was cut (figure 1.7). These were surveyed with a compass and a measuring tape. Metal markers were nailed to trees every hundred meters to provide reference points. Two small huts, one in the northeast corner of the study area the other near the mouth of Citadahan, were constructed to provide a place where the night could be spent when tracking rhinos over several days.

The study area was situated around the Citadahan basin (figure 1.5). This area was found suitable because it contained a large amount of shrubland and other secondary vegetation and rhinos were abundant. It could be reached from P. Peucang within a reasonable time and had the advantage that a trail led around two of its sides. In the north it enclosed the lower slopes of the Telanca plateau and in the east the hills of the watershed between Citadahan and Cikeusik. In the west it extended to the main trail leading from Cidaon to Cibunar and in the south down to the coast. The size of this area was 15.63 km^2. The low lying area of the alluvial plain around Citadahan and extending northeastwards was swampy during the rainy season. One area especially, near the foot of Telanca was very badly drained and the water there stood ankle deep. The vegetation consisted of the mosaic of secondary vegetation types described above. Large tracts of Arenga forest were found in the west along the main trail, in the north on the slopes of Telanca and in the south on the old sanddunes.

1.4.5 Course of the study

This study was begun in February 1978 and lasted until May 1980. Research was carried out continuously with the exception of the months of April and August in 1979 when I was absent from the reserve. Every 2 1/2 to 3 months I left Ujung Kulon and travelled to Bogor and Jakarta for about 7 - 10 days.

During the first months of the study I was introduced by Prof. Schenkel to the reserve and to his methods. In a next phase which lasted approximately three months I began tracking rhinos and developing my own methods of research. During this period I established my base first at Handeuleum, then at Kalejetan before I finally moved to P. Peucang. One purpose of this was to visit certain parts of Ujung Kulon which I did not know yet, the other was to evaluate different areas regarding their suitability for rhino research. I finally chose the area between Cibunar and Cikeusik as the area in which I would concentrate my research (see 1.4.4). During the dry month of September 1979 when rhino tracks could not be followed I cut the paths of the study area up to and including path C with the help of the guards. At the same time the hut near the mouth of Citadahan was erected. Tracking of rhinos, which had benn begun in March 1978, was continued until the end of the rainy season in 1979.

During the last year of the study I included other aspects into my research, especially a study of the availability of food resources. I also evaluated another method of estimating the size of the population. From March to May 1980, when conditions were exceptionally good, I tracked rhinos again. During the latter part of the dry season in 1980 I extended the network of paths in the study area to its final size.

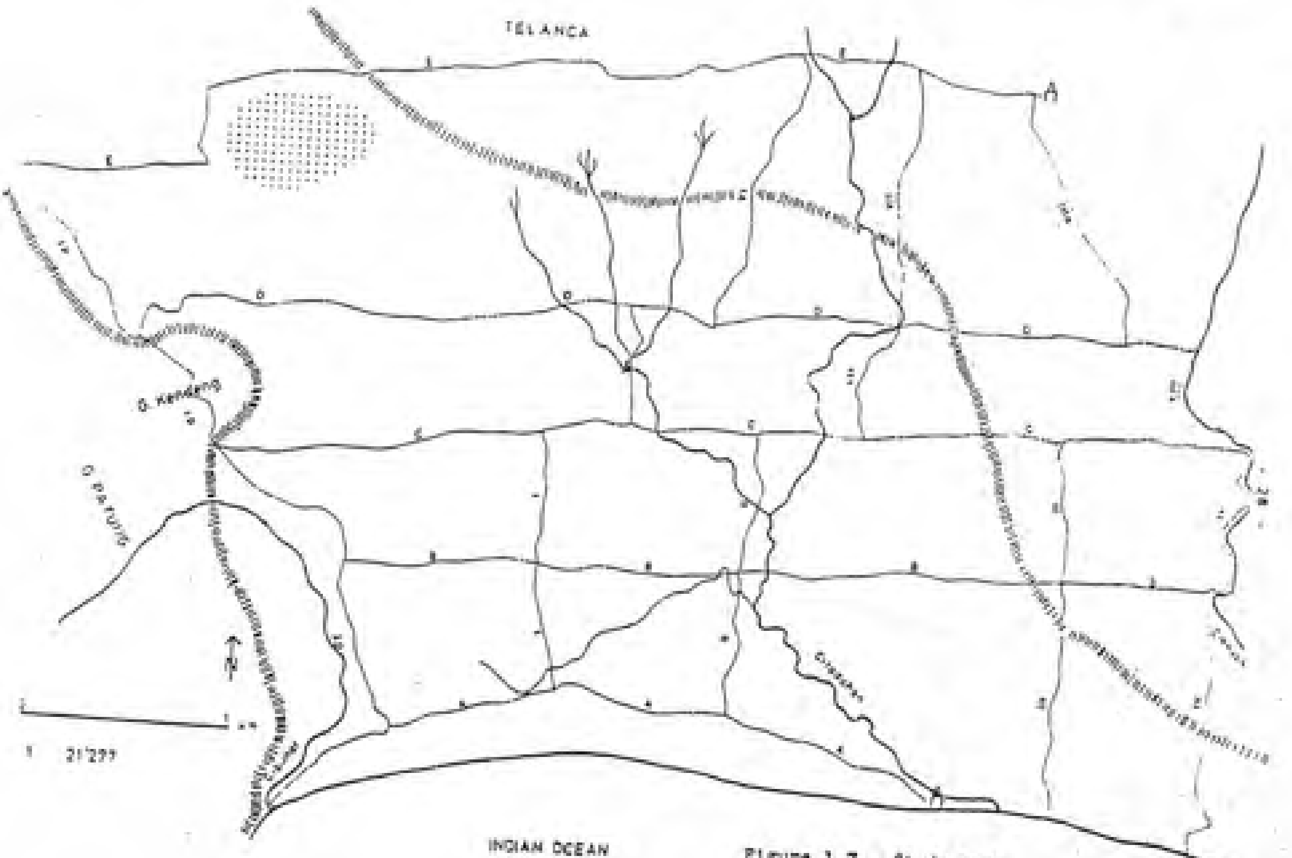


Figure 1.7 Study area

Legend to figure 1.7:

c	prepared path or trail with identification. J.p. and A are permanent patrol paths.
	shelter
	swamp
	limit of hilly/mountainous area

2. POPULATION SIZE AND STRUCTURE

In this section estimates of the size of the population obtained by using two different methods shall be presented. The different results allow a comparison and evaluation of the two methods. I further intend to present estimations of two characteristics of the population — age structure and sex ratio.

2.1 Methods

2.1.1 Determination of population size

2.1.1.1 The census

The first method used to estimate the size of the rhino population was the one introduced and described by Schenkel and Schenkel-Hulliger (1969a). It was used by them for all rhino counts in Ujung Kulon since 1967. This method shall be briefly described here.

The object of the census was to make a direct count of all rhinos on the base of tracks. A number of groups, each consisting of 3 to 4 men, traversed the peninsula and the area east of the isthmus along transects which passed through all major geographical units (i. e. the basins of all major streams, the central plateau, G. Payung etc.). Transects did not follow a fixed compass bearing, because this was considered too time consuming in certain types of vegetation or in mountainous terrain. To facilitate orientation the routes usually followed such topographical features as streams, mountain ridges or the coast. All participants were guards from the staff of the reserve (plus myself), and each group included at least one guard, who was known to be an experienced and reliable observer of animal tracks. All rhino tracks that were encountered were recorded by their measurements, age, direction and location. A census took three days to complete.

To estimate the size of the population only tracks approximately 36 hours old or less were counted, with the exception of a few tracks which, although older, had not been encountered elsewhere within a radius of six kilometers. Such older tracks were not frequent however. To avoid counting the tracks of the same individual twice it was assumed that fresh tracks with equal measurements and found in locations less than 2 km apart had been made by the same rhino; if they were found more than 4 km apart two rhinos were counted. If the distance between the two tracks was between 2 and 4 km they were counted as one or two rhinos. Thus for each census a higher and a lower total resulted.

How close the estimated number of rhinos came to the actual number depended on several variables. The first two concerned the accuracy with which tracks could be measured and their age estimated. The third condition concerned the number of transects that were coverd and thus the distance between them. The number of transects was necessarily limited by the number of men available for the census. The distance between transects could be considered correct if it could be assumed that a rhino would cross a transect at least once within 48 hours. On the base of the distances known to be travelled by rhinos within 24 hours (see 4.4.2) the intervals between the transects appeared to be sufficiently small so that the assumption could be made. One further condition was that all tracks that crossed a transect could in fact be seen by the teams.

The census yields not only an estimate of the population size but also information on the age structure of the population (by correlating track sizes with age classes, see 2.1.2.1) and the distribution of rhinos in Ujung Kulon. From repeated censuses over long periods of time information on changes may be obtained.

During my study two censuses were carried out: the first from 16 - 18 November 1978 and the second from 2 - 4 March 1980. In order that the results be comparable with those of former censuses, the routes chosen for the transects were basically the same as formerly (figure 2.1). Both censuses took place in the transition period between the dry and wet season. The weather was similar on both occasions: several brief showers of rain fell, which were not long or heavy enough to wipe out any tracks. The ground was sufficiently soft so that all tracks were clearly imprinted and the probability of overlooking a track was virtually nil. On the other hand the soil was firm enough to permit accurate measurement.

2.1.1.2 Extrapolation from average density in a limited area

The aims of the second method were to determine the average density of rhinos in a limited area over a certain period of time and to estimate the size of the total population through extrapolation. The limited area chosen for this purpose was the study area.

In order to gather information on the number of rhinos present in the study area, it was patrolled 18 times between

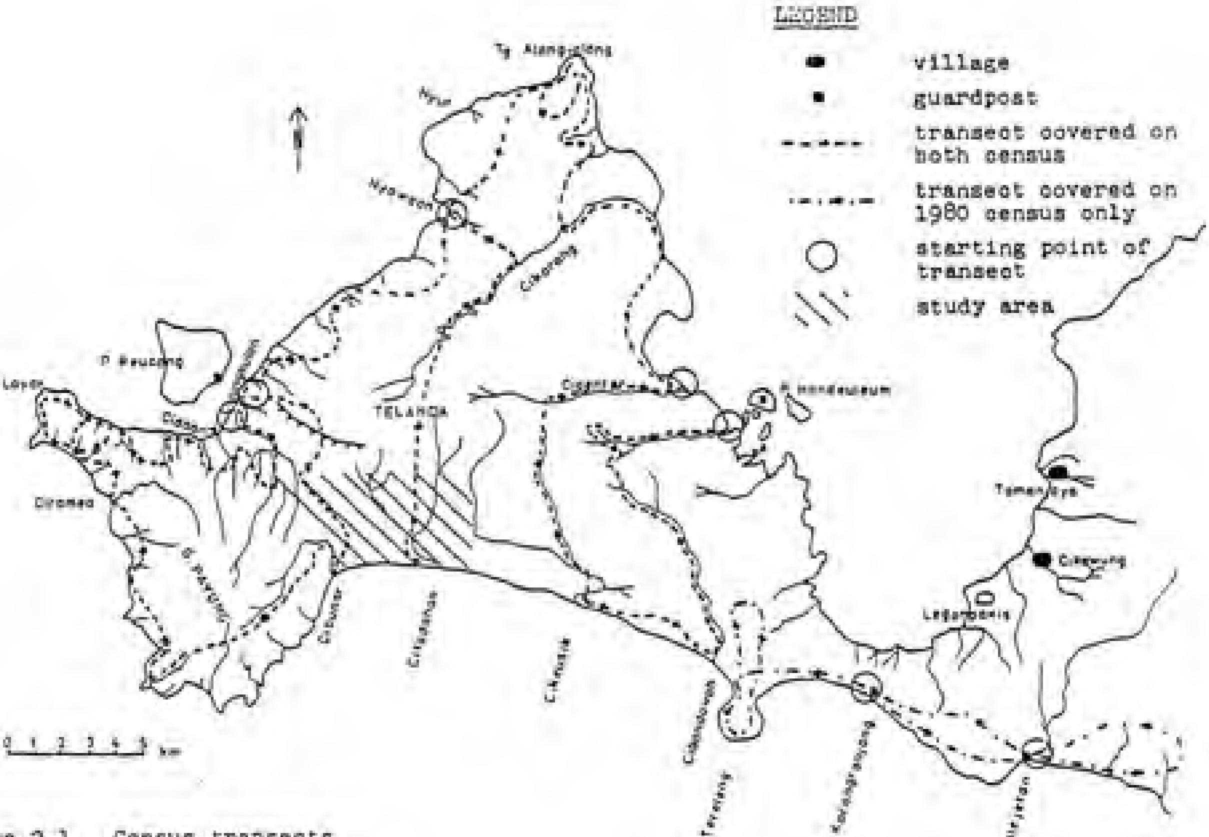


Figure 2.1 Census transects

December 1979 and April 1980. At least three patrols were carried out in each month. Two men (a guard and I) patrolled the study area in such a way that each path was covered at least once. This took two days to complete; on the first day the northern half and on the second day the southern half was patrolled. Path C which separated the two halves was patrolled on both days. Patrols were carried out at irregular intervals but an interval of at least one day lay between two patrols. All tracks were recorded with their measurements, age, direction and any other signs of rhino activity near the patrol paths.

When extrapolating the size of the rhino population in Ujung Kulon from the average number of rhinos present in the study area it had to be taken into account that the rhinos are not distributed evenly over the peninsula. On the base of the census results the total area occupied by rhinos was therefore divided into a high density and a low density area. The size of each area as well as the density of rhinos was roughly estimated. From these figures an estimate of the size of the rhino population in Ujung Kulon could be made.

2.1.2 Population structure

2.1.2.1 Age classes

Estimates of the number of rhinos in different age classes were based on the correlation between age and the width of the forefoot. Two classes were distinguished: rhinos with a forefoot width of 24 cm or less and rhinos whose forefoot were wider than 24 cm. This division corresponds roughly to that between immatures and adults although it is not entirely correct. While females with forefoot sizes of 25 cm are already mature (as evidenced by the fact that some females with these measurements were accompanied by calves), males with the same measurements are still subadults (see 5.5). All individuals with sizes of 24 cm and less may be considered immature however.

A finer subdivision of age classes was not feasible. Among adult rhinos the correlation between age and size of forefeet is not very well known. Size differences probably reflect individual differences rather than age, although rhinos with forefoot widths of 25 and 26 cm are probably in most cases young adults (or in the case of males even subadults, see above). Among immatures the ages corresponding to certain forefoot sizes can be roughly estimated (see 5.6.1). However, the number of immature rhinos, especially with a forefoot width of less than 22 cm, that were encountered on the two censuses was low, so that a further subdivision of age classes did not appear useful.

2.1.2.2 Determination of sex

Because of the difficulties of observing rhinos their sex could almost never be determined by their genitals or external appearance (sexual dimorphism, see 5.1). Adults could often be sexed by their urination pattern or because they were accompanied by an immature animal. In other rhino species different urination patterns for the two sexes have been observed: males frequently squirt their urine upwards and backwards in a fine spray (Ceratotherium simum: Owen-Smith (1973, 1975); Dicerorhinus sumatrensis: Hubback (1939), Borner (1979); Diceros bicornis: Schenkel and Schenkel-Hulliger (1969b); Rhinoceros unicornis: Ullrich (1964), Laurie (1978)), while females usually release their urine in a continuous stream down between their hind legs. From the Indian (Laurie 1978), Sumatran (Sonne-Hansen 1972) and the black rhinoceros (Schenkel and Lang 1969, Schenkel and Schenkel-Hulliger 1969b) it is reported that females occasionally squirt urine as well. However, it appears that they do so less frequently and less vigorously than males. When tracking Javan rhinos it was found that some individuals had squirted urine very frequently. Their urine was found as droplets scattered over the vegetation at certain spots along their track up to a height of about 2 m. Other individuals had urinated directly onto the ground at infrequent intervals. Although I never observed a Javan rhino while urinating it may be assumed from comparison with other rhino species that the former were males and the latter females (Schenkel and Schenkel-Hulliger 1969a).* This is supported by the observation of the male urination pattern along the track of the one male that could be sexed by its genitals. Although males sometimes squirt urine frequently they do not do so regularly and often travel distances of several hundred meters without. Therefore identification of a rhino's sex required that a track that had not been rained upon be followed over a distance of approximately 1 km. Only on a few occasions did I come across a track which could be identified immediately on the base of the urination pattern.

A further possibility of determining an adult rhino's sex were permanent associations between an adult and an immature. These were always considered to be a female and her calf. It was impossible to identify the sex of immature animals (with the one exception of a subadult male, see 5.6) because of the absence of any sex specific urination patterns.

* In a recently made film ("The river of secrets", D. Plage, Anglia Television (1981)) a male Javan rhino accompanying a female is seen to squirt urine.

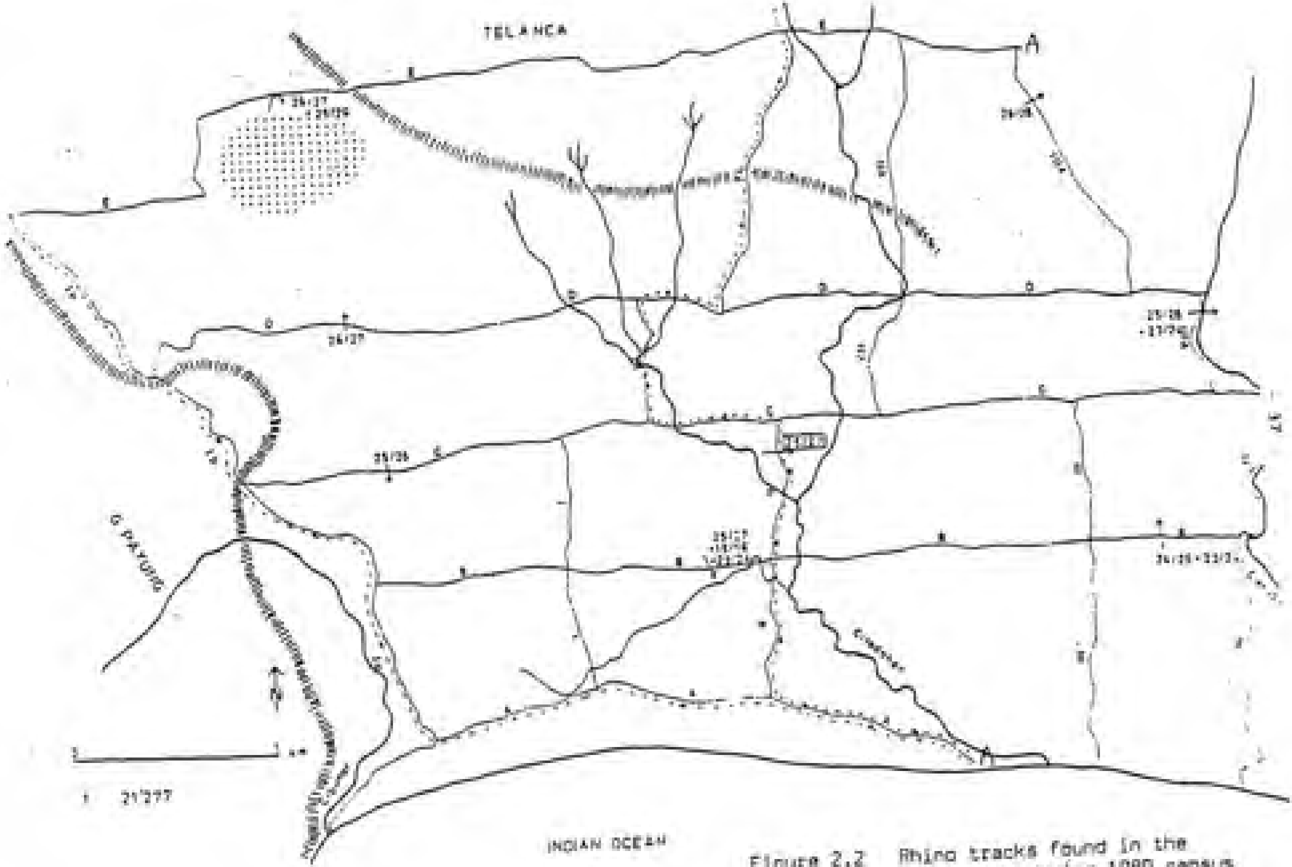


Figure 2.2 Rhino tracks found in the study area during 1980 census

LEGEND to figure 2.2

	contour of G. Payung and Telanca
	swamp
	shelter
t	trail, identification
	main path Cidaon - Cibunar
	trails followed by transect group (Nyawaan-Citadahan)
75/28	measurements and direction of rhino tracks
75/27	track found by both transect group and group patrolling the study area

2.2 Results

2.2.1 Population size

2.2.1.1 Census results

The results of the two censuses carried out in November 1978 and March 1980 are shown in table 2.1. A census undertaken by Schenkel and Schenkel-Hulliger (pers. comm.) in February 1978 yielded a slightly lower result than the one carried out later in the same year. The increase from November 1978 to March 1980 was proportionally much larger than the one from February to November 1978. This was not only due to a real increase of the population size. In March 1980 the study area

Table 2.1 Census results 1978 / 1980

Census	November 1978	March* 1980
Lower Total	46	58 (47)
Higher Total	53	69 (57)
Mean	49.5	63.5 (52)
Increase (%) absolute		28.3 (5.1)
Annual rate** of increase		20.5 (3.8)

* figures in brackets: totals of transect groups only

** in %. Calculated from the formula for geometric population growth: N_t / N_0 = e^{rt}

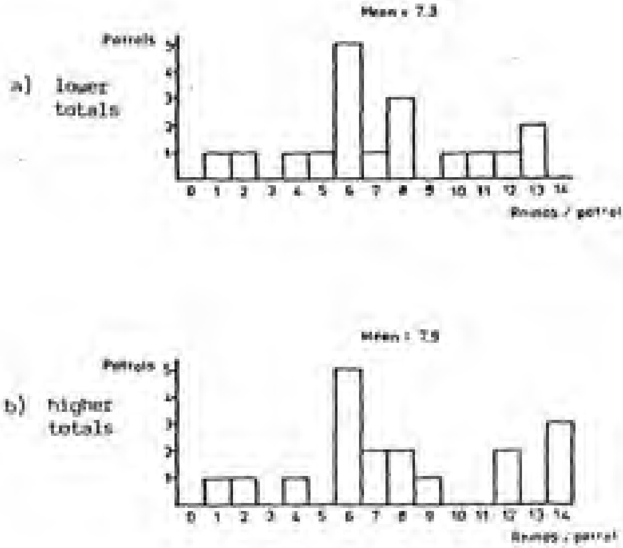
was patrolled by a separate group in addition to the traditional transects covered by other groups. In figure 2.2 all fresh rhino tracks that were found by the group which patrolled the study area are entered as well as the route taken by the group whose transect passed through the area (transect Nyawaan - Citadahan). Though this group followed the available trails and did not cut through the forest, their route followed as closely as possible the route that would have been taken if no trails had been present. The only rhino track found by the transect group in the study area (and seen by the group patrolling the study area as well) was that of a 25/27. Thus while the patrolling group found the tracks of 12 - 13 rhinos (the 26/27 between trails D and E was considered ambiguous), the transect group encountered only one of these. From this follows that when an area is patrolled intensively, more rhinos can be found there than when only a transect is laid through it. This again suggests that the figure arrived at by the transect method of the census is a low estimate and that the actual size of the population is larger.

2.2.1.2 Population size estimated through extrapolation

Each time the study area was patrolled the number of rhinos inside the area was determined (i. e. excluding those whose tracks showed that they had moved out of the area). As during the census, some ambiguous cases were recorded which were counted as one or two rhinos, thus giving a higher and a lower total. The lowest number of rhinos found inside the study area on any patrol was 1 (n = 1), while the highest was 14 (n = 3). The average number of rhinos found over all 18 patrols was 7.3 - 7.9 (averages of the low and high totals respectively). This equals a density of 0.47 - 0.51 rhinos/km^2. The results of the patrols are summed up in figure 2.3. Heavy rain fell just before or during some of the patrols and may have wiped out some tracks of rhinos actually present inside the study area so that they were not counted. The results given below are therefore probably somewhat too low.

As mentioned above, Ujung Kulon can be divided into two areas of different rhino density. Figures 2.4 and 2.5 show the locations of the rhino tracks that were counted on the two censuses in 1978 and 1980. Most of them were found in the

<u>Figure 2.3</u> No. of rhinos in the study area per patrol



area south of the line Cigenter - mouth of Cijungkulon down to the south coast. (The distributions were quite similar to the one described by Schenkel and Schenkel-Hulliger (1969a), except that only a few rhinos were found on the north slopes of G. Payung and none east of Tereleng). The size of this high density area was estimated to be about one third (= 100 km^2). In the high density area the population density was assumed to be the same as in the study area. In the low density area the population density was estimated to be 0.1 $rhinos/km^2$ or about one fifth of that in the high density area. This latter figure was derived from the distribution of tracks on the 1980 census.

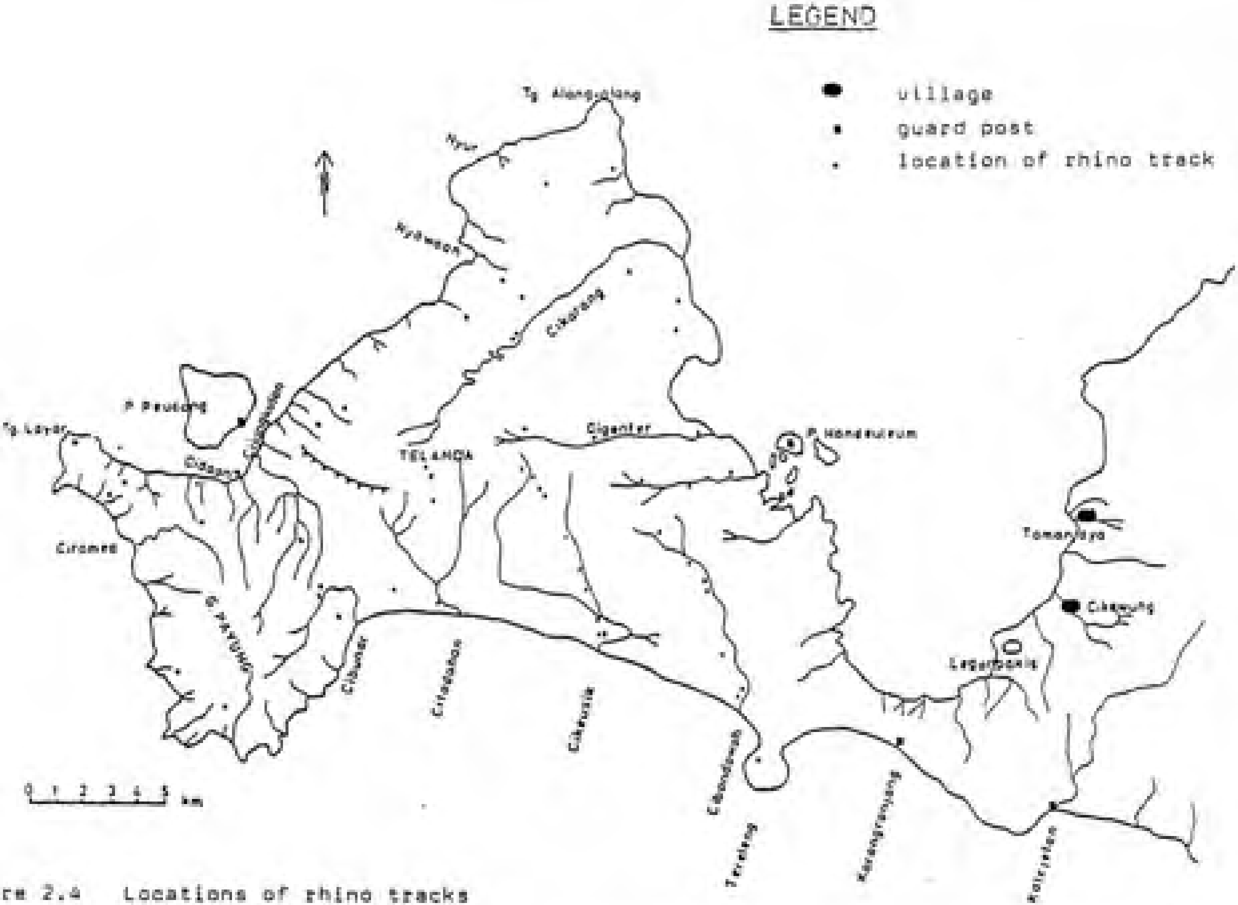


Figure 2.4 Locations of rhino tracks found during 1978 census

Figure 2.5 Locations of rhino tracks found during 1980 census

Using these figures the size of the population may be calculated as follows:

Area	Size (km^2)	Density	est. no. of rhinos
High density (minimum)	100	0.47	47
High density (maximum)	100	0.51	51
Low density	200	0.10	20

Total	Minimum:	67
	Maximum:	71

2.2.2 Population structure

2.2.2.1 Age structure

The distribution of rhino tracks found on the two censuses in 1978 and 1980 among the two age classes is shown in table 2.2. The results show a considerably higher proportion of immatures in 1980. The increase is however not large enough (χ^2 = 1.51, p > 0.05) that a real increase in the proportion of immatures may be inferred from it. The difference was more probably caused by the uncertainties of the census method and the difficulties of detecting the tracks of immature rhinos. As demonstrated below, the groups travelling along the transects of a census do not register all rhinos in Ujung Kulon. The number of mother/calf units that are counted may vary and their proportion in the census total does not necessarily correspond to their true proportion in the population.

The tracks of calves are more difficult to detect than those of adults because, not only are they smaller and may be easily overlooked next to the tracks of the adult female, but

Table 2.2 Age classes

Year	Immature (< 24 cm)		Adult (> 24 cm)		Total
	no. of tracks	%	no. of tracks	%	no. of tracks
1978	3 - 4	6.5/ 7.5	43 - 49	93.5/92.5	46 - 53
1980	10 - 11	17.2/15.9	48 - 58	82.8/84.1	58 - 69

Table 2.3 Pressure exerted on feet

Age	Weight (kg)*	Width of feet (cm)	Area of soles (cm^2)	Pressure (kg/cm^2)
3 - 4 months	200	15/16	755.6	0.26
12 months	600	20/21	1'321.0	0.45
young adult	1'600	25/26	2'043.6	0.78

* The smaller weights are of a male calf, the larger of an adult female of R. unicornis kept in the Basel zoo (Lang 1961). Body weights of Javan rhinos of corresponding ages may be somewhat lower but this would not change the observed trend of higher pressure in older animals.

also because their footprints are less deeply imprinted in the soil. The reason for this is the lower pressure exerted by calves upon the soles of their feet. The younger the calf, the lower the pressure and therefore the greater the difficulty of detecting its footprints. Table 2.3 shows the correlation between age and the pressure exerted by the weight of the body per cm^2 of sole surface for captive Indian rhinos. While it must be assumed that in the Javan rhino these figures are somewhat lower, the correlation between age and pressure exerted on the feet may be considered similar to that in the Indian rhino.

The smallest tracks found by any transect group during both censuses measured 22 cm. It does not follow, however, that younger animals with smaller measurements did not exist, but rather that they were overlooked. When following cow/calf pairs it was noticed that the tracks of younger calves, i. e. with measurements below 22 cm, were visible over about 50 % of the distance travelled by the cow/calf pair. Usually they were visible in soft ground only.

2.2.2.2 Sex ratio

It was not possible to determine a rhino's sex each time the rhinos themselves or their tracks were encountered. Therefore, the sex ratio could not be determined from the results of the censuses or the patrols of the study area. However, the sex of 18 different individuals could be determined over the time period of this study. Because some of these rhinos were encountered repeatedly in the course of the study, I have only considered here the encounter in which their sex was determined for the first time. 13 of these were sexed after tracking them over a distance of at least 1 km. 2 could be identified as females, after tracking them for less than 1 km, by the tracks of accompanying calves and 3 (1 ♂/2 ♀♀) could be sexed immediately upon encountering their tracks. Of the 18 rhinos 7 were males and 11 females. This corresponds to a sex ratio of 0.64 : 1. These figures do not exclude the possibility of a 1:1 ratio (χ^2 = 0.89, p > 0.05). It is not known whether the sex ratio is the same in all areas of Ujung Kulon or, whether differences may be found between areas (e.g. there might be relatively more males in areas of less suitable habitat etc.).

2.3 Discussion of methods for determining the population size

In order to appreciate the results obtained by each method it is necessary to discuss the shortcomings and, whether the assumptions made above could be met, for each method in turn. Improvements are discussed as well and a comparison of the two methods is made.

One possible source of errors in the census method is the quality of the work done by the teams — namely, the accuracy with which the age of a track can be estimated, the accuracy of measurement and the inclusion of all tracks which cross the transect in the record. False age estimates or track measurements will lead to tracks being wrongly included in or excluded from the total estimate. Tracks that are overlooked will lower the total. On many occasions it was possible to compare the measurements taken by several guards from the same track. With very few exceptions these were always in agreement with each other. Age estimates made by different observers were cross-checked in the same manner and only small divergences were noted. This lends confidence to the accuracy of the age estimates and track measurements. The extent of the error caused by these two factors is therefore considered to be small. Moreover, since in some cases the tracks of two rhinos are counted as one rhino while in other cases they are counted as two rhinos, these mistakes will cancel each other out to some degree. The extent of the overall error may be further minimized by distributing the most reliable guards among the transect groups, as was the habit on the census (see 2.1.1.1). This will also reduce the probability of a track being overlooked, as the main causes for this are carelessness and inexperience.

Another source of errors is the way in which different tracks with the same measurements are counted. The decision whether to attribute them to one or to two rhinos is based on the knowledge of the average distance travelled by a rhino within 24 hours (see 4.3.2). For solitary rhinos this was found to lie between 2.2 and 2.6 km, for cow/calf units and mixed sex groups it was somewhat lower. These distances represent the length of the path covered by the rhinos. Because of the meandering of the rhino's path, the linear distance between any two points where the rhino had been at the beginning and the end of a 24 hour period is smaller. Movements over longer distances within 24 hours appear to be rare and the decision to count two tracks with the same size that are more than 4 km apart as originating from two individuals will lead to only a small overestimation. On the other hand the decision to attribute tracks that are less than 2 km apart to the same rhino or, if the distance lies between 2 and 4 km, to one or two rhinos, will probably more often result in less rhinos being counted than are actually present. The effects of over- and underestimation will again compensate each other to a certain degree so that the overall effect may be considered to be small.

The last assumption however, namely that a rhino crosses a transect at least once every 48 hours, was not fulfilled. This is clearly demonstrated by the results obtained by the group that patrolled the study area during the 1980 census (see figure 2.2). Several causes are responsible for this. In some cases a rhino's general direction of movement may have been more or less parallel to a transect at the time of the census. In other cases rhinos did not move far enough to cross a transect. Rhinos may remain within parts of their home range for periods up to three weeks (see 4.3.4). Especially where food is abundant, or in the case of cows accompanied by younger calves this area may be very small. If this part of the home range is not traversed by a transect the rhino may go unrecorded. Furthermore the home ranges of some rhinos, especially females, are so small that they are not traversed by a transect. The home range of the female H (see figure 4.12) may serve as an example here. In some other cases the rhino may have crossed a transect within the 48 hour period but just after the passage of the transect group, so that its fresh tracks were not encountered while its older tracks were discounted, being estimated to be older than 36 hours. From the evidence found in the study area it appears that such cases of rhinos being missed by the census groups are not rare. The result of the census must therefore be considered a low etimate of the total population size.

A possibility of improving the census method would be to increase the number of transects. This would lower the chances of rhinos not being recorded. More transects would however also mean that more men would be needed to carry out the census. There is a limit to the number of men that can be drawn off for the census in order not to strip the reserve of its protection and there are good reasons against bringing in people from the outside (e. g. potential poachers might gain knowledge of the reserve in this way).

The alternative method of estimating the population size through extrapolation from the average density in a sample area suffers from several shortcomings as well. In the first place there are the difficulties of track measurement and age estimation which have already been discussed above. In the second place there is the irregularity with which the patrols in the study area were carried out. The sampling can therefore not be considered truly random. How much this has influenced the present result is difficult to estimate. Thirdly, the assumptions concerning the population density in different parts of Ujung Kulon are only very rough estimates. The division of the reserve into only two areas of different population density is artificial and conceals any more subtle variations of rhino density. A somewhat finer distinction, e. g. between three or four densities, would have been desirable. Because of the large size of the two areas even slight deviations from the assumed densities would have a significant influence on the estimated total population size. Furthermore, any possible seasonal fluctuations have not been taken into account. Most probably, however, these are not pronounced in Ujung Kulon.

The presently estimated population size of approx. 70 individuals appears somewhat too low. On the 1980 census 63 rhinos were counted, which is only 7 less than the total calculated on the base of the average density in the study area. Considering that in the study area alone there were over ten rhinos more than recorded by the transect group, it would seem that more than 7 rhinos were missed by the other transect groups.

The extrapolation method could be considerably improved by cutting more sample areas, each about 5 - 10 km^2 in size (e. g. two each in the low and high density areas), and determining the average number of rhinos present in each over a certain period. The main disadvantage of this method is the time required to implement it. It would take one to two months to cut the trails in all areas and then they would have to be patrolled for a period of at least three months to obtain a sufficiently large sample. In addition the possibility of poachers using the trails leading to the sample areas and gaining easy access to the interior of the peninsula should be kept in mind (especially in the period after the patrols have been completed and before the vegetation has grown over the trails again).

When the two methods for estimating the size of the rhino population are compared it may be seen that the advantage of Schenkel's census line in its efficiency when effort and results are compared. Even though a considerable number of men is required to carry out the census it can be done in a very short time. This type of census has been used since 1967 and therefore the guards are familiar with the method and do not require any long instructions. Even though the result obtained gives a low estimate of the population size, the general trend of development of the population can be seen when comparing the results from different years. In addition this method shows where concentrations of rhinos are found in the reserve. The comparison of the results of different years will also show whether the areas of high density are changing.

Because of the large time investment required, the extrapolation method is not suited to be repeated annually. The estimate arrived at by this method may however be considered to be closer to the true number of rhinos in Ujung Kulon than the one obtained by the census method, although it still is only a rough estimation. Its result is useful to derive a correction factor by which the result of the censuses can be multiplied in order to arrive at a figure which is closer to the true size of the population. For example in 1980 the number of rhinos counted by the traditional census method was 52, the number estimated by the extrapolation method about 70. In this case the factor would be 1.35.

3. P O P U L A T I O N   D Y N A M I C S

The size of a population and its variations are directly influenced by four parameters: natality, mortality, immigration and emigration. The Javan rhino population in Ujung Kulon is most probably the last existing one. Even if other populations should still exist they would be completely isolated from Ujung Kulon. Therefore there is no immigration into or emigration from the reserve. The other two parameters as well as movement across the isthmus are discussed below.

3.1 Natality

Nine calves were recorded to have been born during the period from February 1978 to May 1980 (27 months). This corresponds to 4 calves born per year.

The year of birth and the location where the tracks of the 9 calves were encountered for the first time are shown in table 3.1 and figure 3.1. The year of birth was worked out from the size of the footprints (see 5.5) since the tracks of newborn calves were never encountered. For example, all calves estimated to have been born in 1979 were in fact encountered in 1980.

Table 3.1 Birth years of calves

Year	1978	1979	1980
No. of calves	3	5	1

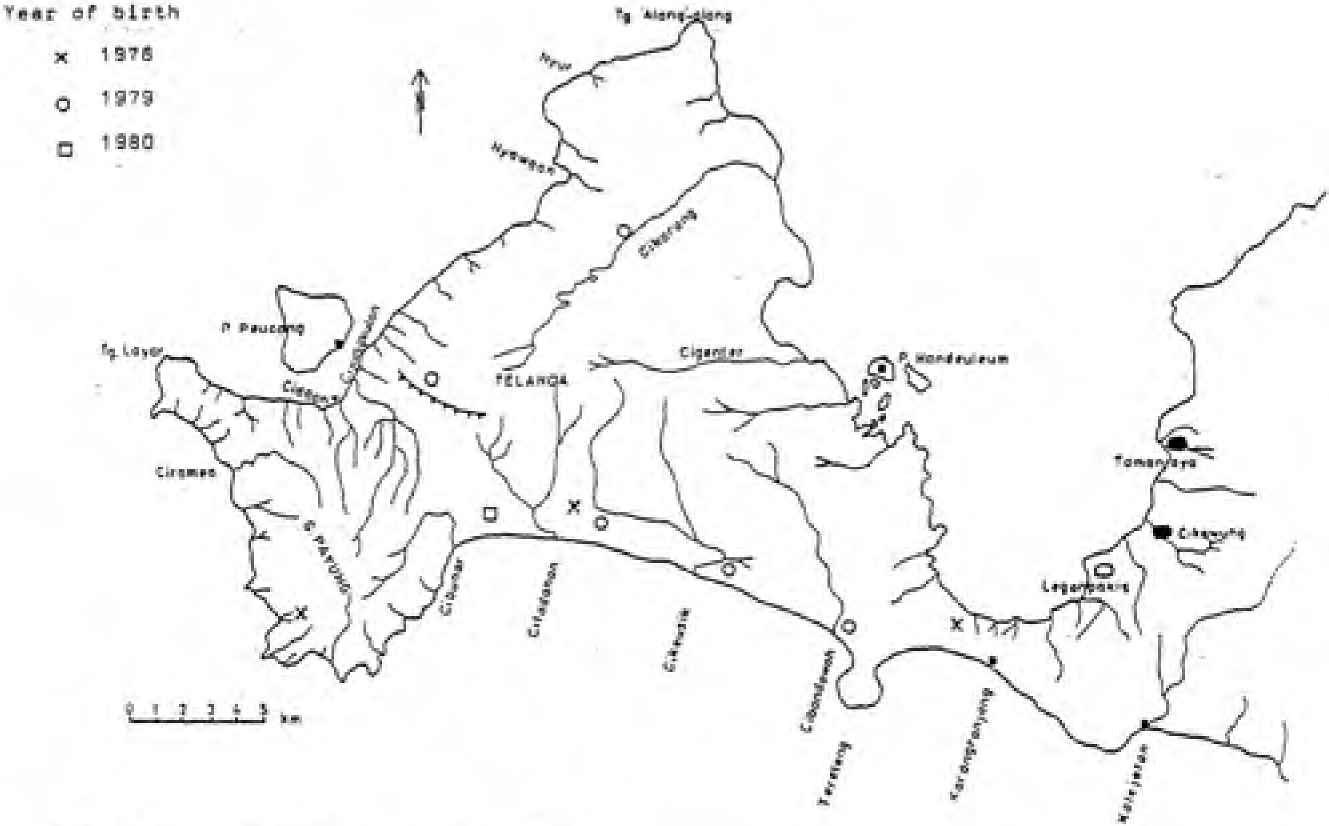


Figure 3.1 Locations of calves tracks

Four calves born per year corresponds to an annual birth rate of 0.111 per adult female (if a population of 75 rhinos, a proportion of 81 % adults and a sex ratio of 0.64 : 1 are assumed). The average intercalving interval for each female would be 6.9 years. Considering that a female may, potentially, bear a calf every 3 1/2 - 4 years this birth rate indeed is very low. For the Indian rhino population in Chitawan (Nepal) the annual birth rate per adult female was estimated to be 0.286 (Laurie 1978) and for two populations of black rhinos in northern Tanzania 0.250 and 0.263 respectively (Goddard 1967). When looking for the causes for such a low birth rate in the Javan rhino it must first be asked how reliable are the figures from which the rate was calculated. In view of the difficulties of observing the tracks of calves and the fact that I seldom visited some areas of Ujung Kulon, it is very likely that not all calves born during the study period were registered. Furthermore it is possible that for two reasons the number of adult females is lower than the estimated 36. In the first place the age class with forefoot measurements larger than 24 cm probably includes a certain number of subadult animals. Secondly, it is possible that the observed sex ratio differs from the true one and that the proportion of adult females in the population is smaller than assumed. For these reasons the birth rate may be slightly higher than the figure given here.

Nevertheless other causes must be considered to have a strong influence on the observed low birth rate. Old females may stop breeding entirely or may not succeed at raising a calf during the last years of their life. Conversely, the firstborn calves of young females may not always be viable. The low birth rate may therefore be the result of the presence of non-breeding adult females and perinatal mortality. Another cause might be a high level of mortality among young calves. If these calves died before their existence was recorded, it would lead to the impression of a low birth rate. Possible causes for calf mortality are discussed below.

3.2 Mortality

Deaths were recorded very rarely during the period of this study. While a freshly dead carcass may be detected by its stench up to a distance of about 100 m, it will rot away rapidly over the next 2 - 3 weeks and the bones will be scatterted by scavengers (leopards, pigs, monitor lizards). Such remains would be undetectable from a distance of even a few meters and, even when detected, the date and cause of death would remain unknown in most cases.

There is only one certain record of a rhino having died between 1978 and 1980. The carcass was found (during my absence) near the jetty at Cidaon and could be identified by the shape of its horn as the male D whose home range lay along the north coast between Telanca and Tg. Layar (see figure 4.11). The guards who found it stated that no wounds or signs of disease could be detected. To judge from the worn condition of its teeth it had died of old age.

Another rhino (female J, home range see figure 4.12) disappeared from the study area around December 1979 where it had been encountered regularly before. The rhino's disappearance was sudden and its tracks were never encountered again. It is possible that rhinos may shift their home ranges for various reasons -- for example competition with conspecifics, habitat deterioration or human disturbance -- and that this female's disappearance had such causes. However, no changes of the environment were observed and it is considered very likely that the female had died.*

Although it is not possible to state the death rate as a figure on the base of this limited information an approximate estimation may be made from the census results of the past few years. From the small increase of the population size a death rate slightly below the birth rate may be inferred.

3.3 Movement out of the peninsula

The movement of rhinos across the isthmus was monitored along the trails leading northwards from the guardposts at Karangranjang and Kalejetan. The guards travelled upon these trails almost daily and any rhinoceros crossing them were unlikely to have gone undetected in the rainy season. The guards noted their observations in the report books at the guard posts, where I periodically collected them.

In April 1978 there were 4 individuals (3 adults and 1 calf) east of Kalejetan. It was not known how long they had been there, however, they soon moved west onto the peninsula again and after that the area was visited only sporadically by rhinos. Every one or two months a rhino would move east, spend about 5 days east of Karangranjang and then wander back again. Until 1980 all tracks east of the isthmus had the same measurements (25/26) and presumably in all cases it was the male C. This male had been encountered in the area of the isthmus in 1978. In 1980 two tracks with other measurements were found on three occasions east of Karangranjang. Although tracks were not visible on the trails during the dry season.

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* In this context the deaths of five rhinos in December 1981 / January 1982 need to be mentioned (Schenkel and Schenkel 1982). It was presumed that they had died of some disease although the exact nature of this disease was not determined.

there is no reason to assume that more rhinos moved east during this time of the year than during the wet season, since seasonal changes of the environment east of the isthmus did not deviate perceptibly from those on the peninsula.

The question must be asked why such a small number of rhinos made use of the area east of the isthmus, especially since the vegetation east of Kalejetan is similar in appearance to that of areas favoured by rhinos, i. e. patches of shrub vegetation are abundant and water is available. Parts of the area around Cimokla were under cultivation, however, until a few years ago and the number of rhinos present there may always have been small because of human disturbance. (However, Schenkel and Schenkel-Hulliger (1969a) found concentrations of rhino tracks east of Kalejetan; see figure 3.3). In addition large tracts of Arenga forest between Karangranjang and Kalejetan separate the favourable areas around Kalejetan from the nearest ones on the isthmus. Population pressure in the region of Cibandowoh/Tereleng may not be strong enough yet to motivate rhinos to travel such long distances through areas in which food is sparse.

3.4 Discussion of the population trend

Even though the birth and death rates are not, or not exactly known, the average annual rate of population increase for the period from 1967 to 1980 may be calculated from the formula $N_t / N_o = e^{rt}$, where

N_t = population size at time t
N_o = population size at time o
t = time in years
r = instantaneous rate of increase

The average population estimates of the censuses increased from 24.5 in 1967 (Schenkel and Schenkel-Hulliger 1969a) to

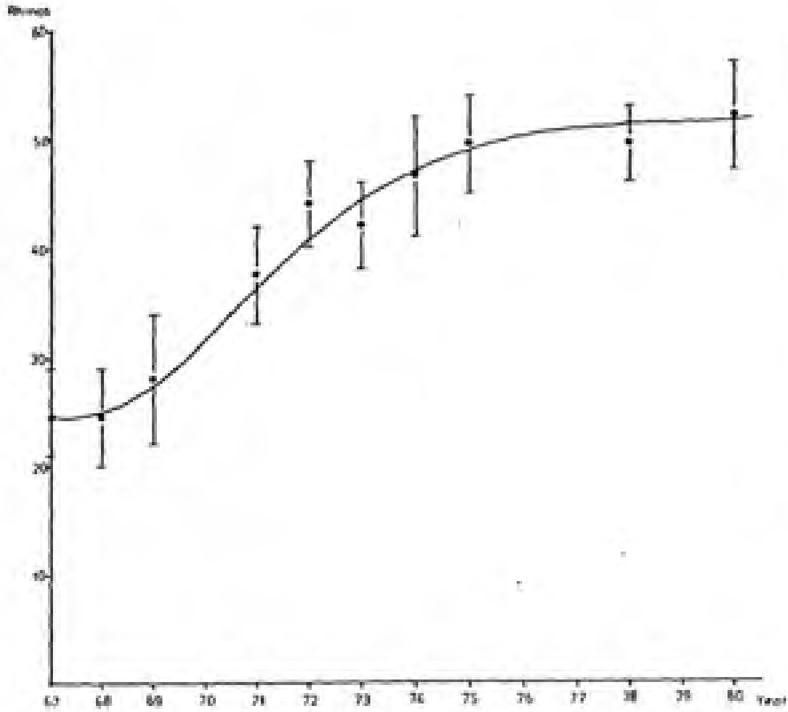


Figure 3.2 Results of censuses (mean and range) carried out between 1967 and 1980. Curve fitted by eye. (Data from Schenkel and Schenkel-Hulliger 1969a, 1975, 1977; table 2.1)

52 in 1980 (12.5 years) (in order that the estimates of all censuses be comparable only those rhinos encountered by transect groups in 1980 are considered here). By solving the above formula for r a finite rate of increase of 1.062 is obtained (finite rate = e^r). In other words, from 1967 to

1980 the population estimates rose at an average rate of 6,2 % per year. Although the census estimates deviate from the real size of the population, the comparison of the results from several years still reflects the population trend and the figure of 6,2 % may be taken as an approximation of the true rate of increase.

However, a constant annual increase would imply constant birth and death rates. The results of the censuses carried out since 1967 (figure 3.2) indicate that there has been some variation of these rates. From 1968 to 1972 the population increased rapidly and constantly. Thereafter the increase slowed down and between 1975 and 1980 was very small. The curve fitted over the data is highly suggestive of a density-dependent, or logistic growth curve. This raises the question whether population growth has slowed down because the size of the population has approached the carrying capacity of the environment or, whether this must be considered only a transitory phase and a renewed growth of the population in the future may be expected again.

It will first be necessary to look at the reactions of populations when they reach the carrying capacity of their environment. The maximum size of an animal population is limited by the availability of resources necessary for the survival of its members. In many cases this will be food, but other resources such as water, places to raise offspring or places of refuge may be limiting as well. Basically, two types of responses to resource limitations have been observed. Populations showing the first type increase in size as long as the limiting resource — in this case always food — is available but at the same time deplete it. Once the food supply has been exhausted, mortality will increase drastically. Animals may die of starvation or, because of their weakened condition, may succumb to diseases or predators. The effect will be a sudden crash of the population. Once the food resource has recovered the population may begin to increase again, and the cycle is repeated. This type of reaction is more common among short-lived animals with high reproduction rates. Under certain conditions, however, it may also apply to long-lived animals with low reproduction rates (e. g. reindeer populations introduced to small islands from which predators were absent (Klein 1968)).

The alternative response is a stabilization of the population size at a level near the carrying capacity of the environment through regulating mechanisms inherent in the population (i.e. density independent), thus avoiding an overexploitation of resources. Such regulating mechanisms may be found in the behaviour of the species. This is the case when some individuals are denied access to resources through conspecifics (territoriality) or are relegated to habitats of inferior quality where their chances of survival are lowered. Behavioural responses that are density-dependent occur as well. A common response to high population density is emigration (Lidicker 1962). The size of the population may, however, also be regulated through physiological regulation of reproduction. Its effects are deferred maturity, reduced fertility and increased calf mortality. An example of physiological regulation may be found among populations of the African elephant (Loxodonta africana) where contraction of their range due to human pressure resulted in higher population densities (Laws 1974). The size of a population may also be controlled through environmental factors, such as predation or disease, whose effect is density-dependent.

The development of the Javan rhino population in Ujung Kulon since 1967 suggests that the first type of response -- overexploitation of food resources and subsequent population crash -- is unlikely. The population has remained at nearly the same level since 1975. Population crashes are, however, sudden and not preceded by a long phase of decreased population growth. As mentioned, the curve suggests that the population has reached the maximum size that Ujung Kulon can support and is regulated through one or several of the above-mentioned factors. Nevertheless, two observations appear to be relevant in this context. First, the very low birth rate, which seems to support the hypothesis that the size of the population is being regulated through physiological factors. Secondly, it appears that the size of the area in which the density of rhinos is highest decreased between 1967 and 1980. A comparison of the extent of the high density areas in 1967/8 (figure 3.3) with their extent in 1978/80 (figures 2.4 and 2.5) shows that although their area expanded northward onto the Telanca plateau, only a few rhinos were found in the northern part of G. Payung at the time of this study and, except for an occasional visitor, none in the area of the isthmus or east of it.

These two facts -- low birth rate and reduction of range -- are difficult to reconcile under the assumption that the size of the population has reached the carrying capacity of Ujung Kulon. If this was in fact the case since 1975, then why were formerly densely populated areas abandoned, especially why has the density of rhinos not increased in the northern part of G. Payung and east of the isthmus where there seem to be large areas of suitable feeding habitat? On the other hand, if carrying capacity had not been reached yet, why did the population growth slow down after 1975? Some alternative explanations for the observed pattern of population increase shall be explored here.

<u>Vegetational changes</u>: Where rhinos are currently found at low densities, changes in the vegetation may have rendered these areas less suitable as foraging habitat. There is evidence

Figure 3.3 Concentrations of rhino tracks in 1967/8 (Schenkel and Schenkel-Hulliger 1969a)

that this may have occurred in areas along the north coast. Hoogerwerf (1970) recorded that rhinos used to occur fairly commonly in the northern parts of Ujung Kulon around Nyur/Kyawaan and Citelang/Cikarang. In recent years, however, the density of rhinos in these areas has been low. It is here, in the northern coastal plains, that changes of the vegetation are thought to have occurred more rapidly than in the higher lying areas farther inland (Hommel 1983).

Disease: At least five rhinos (4 adults, 1 calf) were killed in 1981/2, presumably by some disease, in the area Cibandewah-Karangranjang-Kalejetan (Haerudin et al. 1982, Haerudin pers. comm., Schenkel and Schenkel 1982). It is possible that the pathogenic agent is always present latently but becomes pathogenous only when the population reaches a certain density. If this density is lower than the one at which emigration occurs then the disease might prevent emigration by keeping the population density at a level below the one to which it would be restricted by food supply alone. On the other hand low quality or a limited available quantity of food may have rendered the rhinos susceptible to the disease. But if food is the limiting factor this again raises the question, why there has not been any movement to areas of low density.

Dispersal: Javan rhinos may have a low tendency to disperse. Young rhinos which have separated from their mothers may be primarily attracted to the area in which they were raised, because of their familiarity with it. Likewise, rhinos that have once gained a certain familiarity with an area may be little inclined to leave it, unless forced to by a deterioration of the environment, pressure of conspecifics or human disturbance.

Inbreeding: The Javan rhino population in Ujung Kulon has been isolated from other populations for a considerable time, the last rhino outside the area of the present reserve having been shot in 1934. The massive reduction of the population through poaching up to 1967 must have considerably increased the amount of inbreeding. High rates of inbreeding may have deleterious effects on the reproductive output and general fitness of a population. In captive ungulates the mortality of inbred offspring is higher than of non inbred (Ballou and Ralls 1982). In livestock and laboratory breeding experiments a general loss of vigour, declining reproductive performance and random changes in morphological, physiological and behavioural traits of inbreeding lines has been noted (Soulé 1980). Although, such observations from captive populations cannot be generalized, the possibility that the low observed birth rate has been caused by increased inbreeding must be taken into consideration.

Age structure of the population: The slowdown of population growth may have been caused by a large percentage of old individuals in the population in 1967/8. Such a situation could have conceivably arisen if older and more experienced rhinos were better able to avoid being poached than subadults and young adults. Thus the age structure of the population may have become bimodal, that is there were large proportions of both old adults and immatures but only a small percentage of young adults. Presumably many of these old adults died after 1975. Their low fertility towards the end of their lives would have lowered the population birth rate and their own deaths would have off-balanced any increase from the births of younger females.

It is impossible to state with any certainty which of these factors has been the cause of the observed decrease of population growth. Possibly several factors were involved. If one or more of the first three factors — vegetational changes, disease or limited powers of dispersal — is the cause, then the population may in fact have reached the maximum size possible in Ujung Kulon, and a further growth is not to be expected. However, I consider it unlikely that changes of the vegetation have been the cause. In most parts of the reserve changes have not occurred as rapidly as along the north coast. Large areas of shrubland — which is considered to be suitable rhino foraging habitat (4.1.3) — are found in the northern part of G. Payung, especially on the spur leading down to Tg. Layar and east of Kalejetan. In both areas rhinos are presently found at low densities. This makes it difficult to accept that the population has reached the carrying capacity unless it is assumed that the rhinos' capacity for dispersal is very low. This would be surprising, however, in a species that can travel distances of several kilometers per day (see 4.3).

Because of the relatively short period of approximately 15 years (1967 - 82) that this long-lived species has been under continuous observation and because there is no detailed information available on the age structure of the adult population in 1967 it is difficult to draw any precise conclusions whether the decrease of population growth after 1975 was a consequence of an overaged population. If this was the case, then the population can be expected to increase again after a period of stagnation, unless it is being limited by density dependent factors. This is, however, considered unlikely since emigration is presumed to occur before a decline of population growth, as long as suitable habitat is available into which the emigrants can disperse. As has been mentioned above this appears to be the case in Ujung Kulon. The small population growth from 1978 to 1980 and the increasing number of rhinos that moved across the isthmus in 1980 point to a renewed growth of the population. Because of the losses incurred through the disease in 1981/2, which possibly were considerably larger than five rhinos, the renewed population growth may have been further retarded for several years.

4. E C O L O G Y

4.1 Feeding ecology

The aim of the investigations into the feeding ecology of the Javan rhino was to obtain information which would contribute to the defintion of its ecological niche. Basically the questions asked were: (1) What does a rhino eat? (2) Where does it feed? (3) How can the observed pattern be explained? In particular I shall concentrate on the following aspects:

1. Diet
   a) Composition of the diet
      This includes a list of the plant species eaten by rhinos and which parts of the plants are eaten, as well as an assessment of the relative contribution of each plant species, in terms of quantity, to the diet.

   b) Availability of foodplants
      An estimation of the relative quantity of food available of each foodplant species in the study area.

   c) Food preference
      From comparison of the results of 1a) and 1b) above the relative preference of rhinos for each species can be estimated.

2. Feeding habitat

   a) Use of habitat
      Estimated on the base of the proportion of the total quantity of food consumed in each type of vegetation.

   b) Availability of habitats
      Determined as the relative occurrence of each type of vegetation in the study area.

c) Habitat preference
From comparison of the results of 2a) and 2b) above the preference of rhinos for each type of vegetation can be estimated.

3. Causes underlying observed preferences

In addition the two following aspects shall be considered:

4. Seasonal variations

a) Seasonal variation of total quantity of food consumed

b) Seasonal variation of the proportion of certain food species in the diet.

5. Salt requirements

4.1.1 Methods

To obtain information concerning points 1 to 4 above I relied on the following two methods:

- evaluation of feeding events
- sample plot method to study the vegetation in the study area

The method used to obtain information concerning point 5 will be described in the relevant section (see 4.1.6).

4.1.1.1 Evaluation of feeding events

Which plants had been eaten by rhinos was determined from feeding traces. Javan rhinos eat mainly leaves, young shoots and twigs of saplings, bushes and climbers. The feeding traces can be distinguished easily from those of other browsing ungulates, except banteng, by: (1) the manner in which twigs and branches are bitten off, (2) the height at which feeding traces are found and (3) the extent of damage done to the foodplant. Rhinos bite off twigs of 0.5 - 2 cm diameter. Branches of taller saplings or of climbers are pulled down. If the crown of a sapling is out of reach, the rhino may break the sapling with its jaws or press it down with its head or body. For a more detailed description of feeding behaviour Schenkel and Schenkel-Hulliger (1969a) may be consulted.

Each time a rhino ate from a plant, this was called a feeding event. For each feeding event the following information was recorded:

1. Species
   a) Name of the species

   b) The part of the plant that had been eaten:
      leaves, twigs/branches, fruit, flowers

   c) The type of the plant:
      tree, palm tree, bush, climber, herb

2. The type of vegetation in which the plant stood, including the amount of shading by taller vegetation. The latter was estimated on a scale from 0 (= no shading) to 10 (= complete shading).

3. A rough estimation of the quantity consumed
   The original size of the foodplant and the quantity that had been eaten could be roughly estimated from the remains. The consumed quantity was classified as: small, medium, large. The category "small" included all cases where a rhino had taken a few bites from a plant or the consumed plant was very small. For foodplants other than climbers the quantities classified as medium or large respectively averaged eight and fifteen times more than those in the small category. Smaller quantities were consumed of climbers than of other plant types. The largest quantity eaten of a climber species only corresponded to the category 'medium' of other plant types. Therefore, size ratios of the three categories were estimated to be 1 (small) : 4 (medium) : 8 (large) in the case of climbers.

Banteng feed partly on the same plant species as rhinos and the feeding traces of the two species cannot be distinguished in all cases. To avoid including plants which had not been eaten by rhinos, feeding traces were only recorded when footprints around the feeding site indicated clearly that a rhino had fed there. Foodplants were recorded both when tracking rhinos and when feeding traces were encountered by chance.

A short twig with some leaves attached was taken as a sample from all plants which could not be identified directly in the field. The sample was pressed between newspaper in a simple bamboo press and dried in the sun. All samples were later identified at the Herbarium Bogoriense (Bogor/Indonesia) by members of its staff. Since rhinos feed primarily on immature plants, flowers or fruit were practically never found on foodplants and therefore no samples of these parts could be taken. To check the reliability of the method of identifying plants by their leaves alone, several samples of known species were included in each batch of samples delivered to the Herbarium. These controls were always identified correctly and identification was therefore considered to be reliable.

In some rare cases foodplants could not be identified because the rhino had eaten all the leaves of the plant, so that only the stem was left and no sample could be taken. All samples sent to the Herbarium could be identified to the genus and in most cases (approximately 80 %) to the species level. For the determination of the rhino's diet (i. e. list of foodplant species and the proportion of each species in the diet), feeding records were taken into account only if (1) the species could be identified: (2) identification was solely possible at the genus level, but the plant in question was unique of its genus; or (3) there were several plants belonging to the same genus, but each could be identified by its local name by a guard whom I knew to be reliable in identifying plants. (This was checked by having different plants of the same species identified by the same guard and having them identified again later in Bogor.) The scientific names used here are according to those used by Backer and Bakhuizen van den Brink (1965).

4.1.1.2 Sample plots

Information on the vegetation of the study area was obtained by studying the vegetation in sample plots. The aim was to acquire information on the following subjects:

- relative frequency of species of saplings, bushes and climbers in the study area.
- relative frequency of species of saplings, bushes and climbers in each type of vegetation.
- proportion of the area of the study area covered by each type of vegetation.
- quantity of food available in each type of vegetation.

The sample plots were of circular shape with a radius of 15 m (area = 706.9 m^2). One hundred and three plots were situated at intervals of 200 m along the paths B, C, D and E of the study area. In each plot the following information was recorded:

- Potential foodplants:

  species, number of individual plots, height, (heights were estimated), size as a potential food source (small, medium, large, corresponding to the size categories described above).
  For climbers only species, number and size were recorded. It was not possible to count individual plants, since this would have meant following every single strand, of which there may be several per individual plant, down to the stem to determine the number of individuals. Therefore, the number of strands

per species present in the plot was counted. The following were considered potential foodplants:

(1) all climbers whose lowest leaves were within a rhino's reach (< 2.5 m).
(2) all saplings that were at least 1.50 m tall and had a maximum stem diameter of 15 cm. According to observations made during this study these were the size limits of saplings eaten by rhinos. The stem limit corresponds well to that of Schenkel and Schenkel-Hulliger (1969a). According to Hoogerwerf (1970) saplings with larger stem diameters are occasionally broken or pushed over and eaten.

- The type(s) of vegetation:
  if several vegetation types were present I recorded the percentage of the plot area covered by each type. The number and species of potential foodplants were recorded separately for each type of vegetation.

- The amount of shading by taller vegetation:
  measured on a scale of 0 to 10 as above. Shading was recorded once for the whole plot and separately for each vegetation type, if more than one was present.

4.1.2 The diet

4.1.2.1 Species composition and proportion of species in the diet

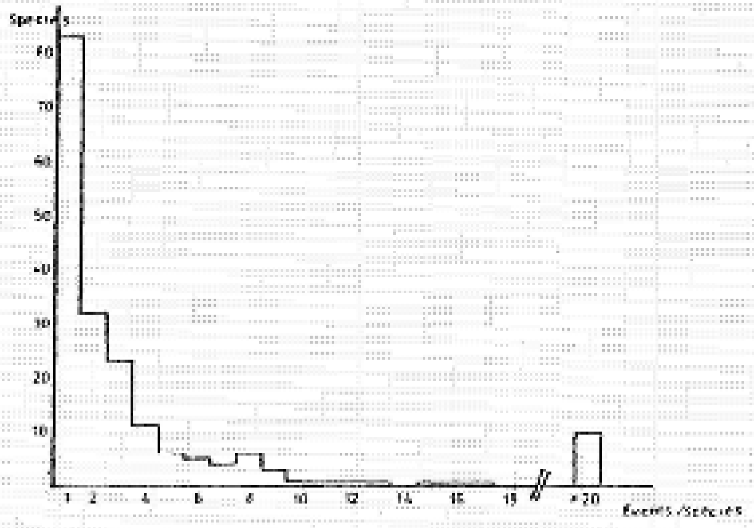
A total of 1'222 feeding events was recorded. The list of foodplants comprises 190 species from 61 taxonomic families, thus showing a very varied diet. All species recorded more than five times are listed in table 4.1. A complete list of all foodplant species may be found in appendix I. Not all species were represented equally in the diet: a few species were eaten frequently, but the majority only occasionally (figure 4.1). More than half of the records — (699 = 57.2 % — were from the first ten species (= 5.3 % of all species recorded) in table 4.1. All 35 species in the table, which represent only 18.4 % of all species recorded, totalled 926 (= 75.8 %) feeding events. Most food species were recorded only once or twice.

Table 4.1 List of foodplant species recorded as having been eaten more than five times

Species	Growth form	Records	%
Amomum sp.	h	337	27.6
Leea sambucina		86	7.0
Spondias pinnata		72	5.9
Dillenia excelsa		55	4.5
Uncaria sp. (ferrea?)	c	31	2.5
Poikilospermum suaveolens	c	29	2.4
Merremia vitifolia	c	25	2.0
Lantana camara		24	2.0
Mikania cordata	c	24	2.0
Syzygium polyanthum		22	1.8
Derris elliptica	c	17	1.4
Embelia ribes	c	16	1.3
Lagerstroemia flos-reginae		15	1.2
Hibiscus tiliaceus		13	1.1
Pseuduvaria reticulata		12	1.0
Ziziphus horsfieldii	c	11	.9
Barringtonia macrocarpa		10	.8
Kleinhovia hospita		9	.7
Musa sp.	b	9	.7
Saccopetalum horsfieldii		9	.7
Bridelia stipularis		8	.7
Diospyros macrophylla		8	.7
Fagara rhetsa		8	.7
Merremia umbellata	c	8	.7
Pongamia pinnata		8	.7
Sumbaviopsis albicans		8	.7
Combretum latifolium	c	7	.6
Ipomoea illustris	c	7	.6
Lepistemon urceolatum	c	7	.6
Symplocos brandisii		7	.6
Alangium salviifolium	c	6	.5
Dracontomelum mangiferum		6	.5
Ficus variegata		6	.5
Litsea noronhae		6	.5
Planchonia valida		6	.5

Abbrev.: b = wild banana tree
c = climber
h = herbaceous
all other species are trees or bushes

Figure 4.1 Frequency distribution of feeding events per species



The majority of plant species eaten were dicotyledones (179 species = 94 %). Only 11 monocotyledonous species were recorded and only 2 of these (Amomum sp., Musa sp.) were recorded more than twice. About two thirds of all species were saplings, mature trees or bushes, about one quarter climbers (table 4.2). Only few species of other growth forms that are common in Ujung Kulon, such as palms, pandanus, gingers or herbs figured in the diet. It was never observed that grasses were eaten.

Table 4.2 Growth forms of foodplant species

Growth form	Species	%
Trees, bushes	130	68.4
Climbers	51	26.8
Other	9	4.7
Total	190	100.0

In comparison with lists of foodplants compiled by former authors (Schenkel and Schenkel-Hulliger 1969a, Hoogerwerf 1970) the large number of species of climbers recorded in this study is remarkable. One reason for this may have been that I recorded more feeding events when tracking rhinos than the other investigators. Feeding traces of rhinos being tracked are usually fresher than traces which are randomly located. While still fresh the probability of being detected is about the same for feeding traces on saplings and climbers but elder feeding traces on climbers are less conspicuous and more easily overlooked than those on saplings or bushes. When following tracks significantly more feeding events on climbers were recorded than when not tracking (table 4.3). Thus a larger number of climber species were recorded when tracking, since probably the number of species recorded increases with a growing number of feeding events recorded as more and more rarely eaten species are added to the food

Table 4.3 Comparison of number of feeding events/ species recorded when tracking and not tracking

a) Events

	climbers	non climbers
tracking	221	671
not tracking	52	278

$\chi^2 = 10.62,\ p < 0.001$

b) Species

	climbers	non climbers
tracking	48	105
not tracking	23	80

$\chi^2 = 2.06,\ p > 0.1$

list. However, the number of climber species recorded when tracking was not significantly higher than when feeding tracks were encountered at random. In fact the number of climber species recorded in random encounters was much larger than the number recorded by other authors. The difference of methods can therefore only be a partial explanation for the larger number of climber species found in the diet. A possible explanation might be that vegetational differences between the areas where the studies were carried out by the various investigators were the cause of the different observations. Schenkel and Schenkel-Hulliger (pers. comm.) studied rhinos mainly along the north coast where tall trees are more abundant than in the study area. Where trees are common, climbers grow out of the reach of rhinos and are available in lesser quantities. It is also possible that the

Table 4.4 List of foodplants with QI > 20

Species	Growth form	QI	%
Spondias pinnata		519	19.0
Amomum sp.	h	257	9.4
Leea sambucina		242	8.8
Dillenia excelsa		189	6.9
Poikilospermum suaveolens	c	77	2.8
Lagerstroemia flos-reginae		50	1.8
Uncaria sp. (ferrea?)	c	49	1.8
Kleinhovia hospita		45	1.7
Mikania cordata	c	43	1.6
Sumbaviopsis albicans		43	1.6
Dracontomelum mangiferum		39	1.4
Ficus variegata		38	1.4
Hibiscus tiliaceus		38	1.4
Musa sp.	b	35	1.3
Merremia vitifolia	c	34	1.2
Saccopetalum horsfieldii		34	1.2
Derris elliptica	c	33	1.2
Planchonia valida		33	1.2
Chisocheton microcarpus		26	.9
Embelia ribes	c	26	.9
Gossampinus valetonii		24	.9
Sterculia urceolata		23	.8

Abbrev.: b - wild banana tree
c - climber
h - herbaceous
all other species are trees or bushes

number of climber species growing under shaded conditions is smaller.

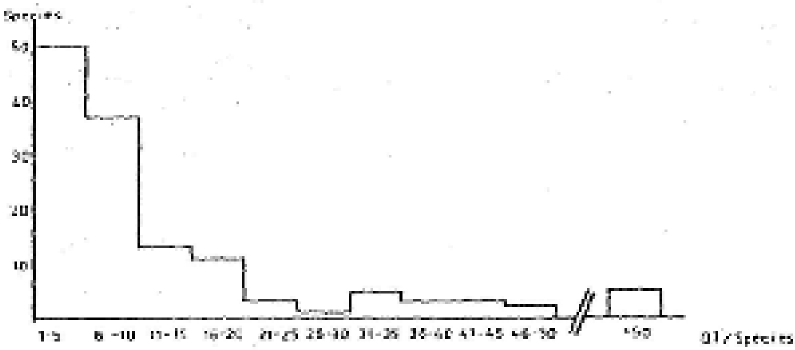
The number of times a food species is consumed is not a very good measure of its contribution to the diet in terms of quantity. For example the most commonly eaten species, Amomum sp., offers only one mouthful per plant because of its small size, while a rhino can obtain a much larger amount of food from a single sapling or bush. The quantity eaten was recorded for 788 of the 1'222 feeding events. To each size category a numerical value was assigned: 1 (little), 4 (medium) and 6 (much) for climbers and 1, 8 and 15 respectively for all other plant types. The values correspond to the size ratios. The values were summed up for each species to yield an index of the quantity consumed (QI). All species with a QI > 20 are listed in table 4.4; the QI of all species may be found in appendix 1.

The statement made above concerning the relative contribution of individual species to the diet applies here as well: A few species were eaten in large quantities and constituted the bulk of the diet, while of most species only small quantities were consumed (figure 4.2). The first four species alone of table 4.4 made up 44.1 % of the total quantity eaten. These four species may be called the principal food species. The proportion of climbers in the diet was much smaller when the quantity eaten was taken into account than when the frequency of consumption was considered (table 4.5).

Table 4.5 Relative proportion of quantity eaten per growth form

Growth form	Total QI	%
Trees, bushes	2'015	73.6
Climbers	423	15.4
Amomum sp.	257	9.4
Other	42	1.6
Total	2'737	100.0

Figure 4.2 Frequency distribution of QI's



4.1.2.2 Parts of plants eaten

Rhinos feed almost exclusively on leaves, twigs and branches. Branches up to a diameter of 1.5 cm were observed to have been consumed; thicker branches were broken off frequently but never eaten. Rhinos consumed young leaves and non-lignified shoots in most cases. The bark of trees was never observed to have been eaten (cf. Hoogerwerf 1970). Flowers and fruit were eaten only infrequently; three cases were recorded:

- Once a male flower-pod of a sugar palm (Arenga pinnata) was eaten. These flower-pods may be rich in sugar. The local people tap the stems by which the pods are attached to the palm to obtain sap from which palm sugar is produced. Normally the flower-pods of the sugar palm are out of the reach of rhinos.

- Once a seed of a Pandanus sp. was found in the dung.

- One rhino (male D) visited a certain place near Cijungkulon repeatedly over a period of two weeks during the fruiting period of Dillenia aurea to eat the fruit that had fallen from the trees and were lying on the ground. These fruit are a bit larger than an apple. The same place was visited again in the following year during the fruiting season of D. aurea by a rhino that ate the fruit. (Its identy could not be established but possibly it was the same individual.)

Flowers and fruit are rarely found in the diet of the Javan rhino because they usually grow beyond a rhino's reach. Possibly only fruit larger than a certain size are taken. The fruit of a fallen strangling fig (Ficus sp.) (small fruit, diameter approx. 1 cm) as well as the cauliflorous fruit of Stelechocarpus burahol (medium sized fruit, diameter approx. 5 - 7 cm, large seeds, little flesh) were ignored by rhinos passing close by them.

4.1.2.3 Availability of foodplants

The availability of all species of trees, bushes and climbers was estimated from the counts made in the sample plots (4.1.1.2). Other growth forms were not counted as these were eaten only in small quantities by rhinos, with the exception of Amomum sp. An index of quantity available (QI_a) was calculated for each species in the same manner as was done for plants recorded in feeding events: the size of each plant was roughly estimated as one of three categories (small, medium, large), a numerical value was assigned to each size class and these were added for each species. The numerical values chosen were 1, 10 and 20 respectively*. All species with a

QI_a > 100 are listed in table 4.6 and all climber species with a QI_a > 20 in table 4.7 (the results for all species are listed in appendix II).

4.1.2.4 Food preferences

I shall now consider the preferences of rhinos for various food species, that is the extent to which these species were consumed in relation to their availability (Petrides 1975). Preference indicates to what degree a certain food species is sought after, but not how large the proportion of this species in the diet is. The degree of preference may be expressed numerically by the relative preferability index (RPI) which is the ratio of the proportion of a food species in the diet to its relative availability. A ratio > 1 means that the species was eaten in proportionally larger quantities than available, and indicates that rhinos showed a preference for that species.

Relative preferability indices were calculated for all species that were either abundant in the diet (table 4.4) or abundant in the environment (tables 4.6 and 4.7) or both, and are listed in table 4.8. Because the availability of _Amomum_ _sp_. was not determined, this species was not included in the calculation of RPI's, and the proportion of the other species in the diet adjusted accordingly. The availability of _Amomum_ sp. is high and its RPI was estimated to be slightly lower than 1. Its exclusion had the effect of slightly inflating the RPI values of all other species.

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* The numerical values chosen in this case were larger than those chosen for feeding events reflecting the larger ratios between size categories of intact plants compared to those between the categories of the quantity eaten by rhinos. Rhinos never ate all food availbale from a large bush or tree.

Table 4.7 List of potential foodplants (non-climbers) found in sample plots with $QI_a > 100$

Species	QI_a	%	rhino foodplant
Leea sambucina	2'607	17.85	+
Dillenia excelsa	2'126	14.56	+
Barringtonia macrocarpa	583	3.99	+
Lagerstroemia flos-reginae	539	3.69	+
Syzygium polyanthum	514	3.52	+
Baccaurea javanica	444	3.04	+
Symplocos sp. (Sauheun)	398	2.73	+
Pseuduvaria reticulata	310	2.12	+
Diospyros cauliflora	244	1.67	+
Memecylon oleaefolium	239	1.64	+
Spondias pinnata	201	1.38	+
Diospyros macrophylla	192	1.31	+
Litsea noronhae	158	1.08	+
Drypetes longifolia	147	1.01	-
Pentace polyantha	142	.97	+
Saccopetalum horsfieldii	132	.90	+
Callicarpa longifolia	124	.85	+
Cordia sp. (Kenal)	119	.81	+
Stelechocarpus burahol	106	.73	-
Glochidion rubrum	102	.70	+

Table 4.6 List of climbers found in sample plots with $QI_a > 20$

Species	QI_a	%	rhino foodplant
Mikania cordata	301	2.06	+
Lepistemon binectariferum	90	.62	+
Uncaria sp. (ferrea?)	86	.59	+
Merremia vitifolia	75	.51	+
Embelia ribes	63	.43	+
Merrembia umbellata	55	.38	+
Derris elliptica	53	.36	+
Uvaria littoralis	48	.33	+
Ziziphus horsfieldii	43	.29	+
Tetracera scandens	38	.26	+
Flagellaria indica	28	.19	+
Smilax leucophylla	27	.18	-
Poikilospermum suaveolens	21	.14	+

The area in which the availability of foodplants was sampled corresponded to the study area north of the sand dunes

Table 4.8 Relative preferability indices of foodplants

Species	RPI
Kleinhovia hospita	270.81
Ficus variegata	223.74
Sumbaviopsis albicans	23.02
Planchonia valida	21.57
Poikilospermum suaveolens	21.57
Dracontomelum mangiferum	20.88
Spondias pinnata	15.20
Derris elliptica	3.67
Uncaria sp. (ferrea?)	3.35
Merremia vitifolia	2.67
Embelia ribes	2.24
Merremia umbellata	1.82
Saccopetalum horsfieldii	1.52
Mikania cordata	0.84
Lagerstroemia flos-reginae	0.55
Leea sambucina	0.55
Dillenia excelsa	0.52
Tetracera scandens	0.46
Flagellaria indica	0.42
Litsea noronhae	0.41
Pentace polyantha	0.41
Ziziphus horsfieldii	0.41
Diospyros cauliflora	0.39
Diospyros macrophylla	0.37
Pseuduvaria reticulata	0.27
Lepistemon binectariferum	0.26
Syzygium polyanthum	0.22
Memecylon oleaefolium	0.20
Uvaria littoralis	0.12
Barringtonia macrocarpa	0.09

The following species were recorded as foodplants but not recorded in the sample plots. An estination of the rhinos preference for them is given.

Chisocheton microcarpus	high
Gossampinus valetonii	high
Hibiscus tiliaceus	high
Musa sp.	high
Sterculia urceolata	low-moderate

The following species were recorded as foodplants, but the quantity eaten was not recorded. Therefore, the RPI could not be calculated. All were rarely recorded to have been eaten, but were common in the study area (table 4.6). Their RPI was therefore estimated to be low.

Baccaurea javanica
Callicarpa longifolia
Cordia sp. (Kenal)
Symplocos sp. (Sadheun)

running parallel to the south coast plus a strip, about 500 m wide, north of and adjacent to path E. This area was smaller than the one in which the feeding events were recorded. This raises the question of whether the sampling has been adequate. About 90 % of the 788 feeding events used in this analysis were recorded in the area in which the availability of foodplants was estimated. Of the remaining 10 % of events recorded outside this area about 7 % were recorded in vegetation types which occurred inside the sampled area as well. Only 3 % of the feeding events were recorded in vegetation types which had not been sampled. In view of this small percentage of records from non-sampled vegetation types the sample was considered to be representative.

Of the four principal food species of the Javan rhino only one — Spondias pinnata — is also a preferred species. On the other hand most of the species that contribute between 1 and 3 % of the bulk of the diet are moderately to highly preferred species. Five species that were recorded as foodplants were not encountered in the sample plots, but all of them were known to occur in the study area. The RPI value of four of them was estimated to be high. This was supported by the observation that all plants of two of these species, namely Hibiscus tiliaceus and Musa sp., that were encountered by rhinos whose tracks I followed, were eaten. Plants of the genus Sterculia were abundant in the sample plots. Their species, however, could not be determined. Some or even many of them were probably S. urceolata. Its RPI was, therefore, estimated to be low to moderate. In addition, four species were recorded to have been eaten, but the quantity consumed was not recorded. There are few feeding records for these species but all four were found to be abundant in the environment. Their preferability was estimated to be low.

Table 4.9 Classification of vegetation types made during this study and corresponding classification of plant communities by Hommel (1983)

Ammann	Hommel
Mountain forest	Neesia community
Forest	--
Arenga forest	Arenga obtusifolia comm.
Bambu cangkeutook (= Bamboo C)	Schizostachium zollingeri comm.
Bambu duri (= Bamboo D)	Bambusa blumeana comm.
Salak	Salacca edulis comm.
Shrubland, no trees	
Shrubland + bushes	Calamus-Amomum comm.
Shrubland + trees	

4.1.3 Feeding habitat

4.1.3.1 Vegetation types

At the time this study was undertaken no study of the vegetation and no classification of plant communities had been made. I therefore made my own rough classification of vegetation types based on structural and floral characteristics such as the presence or absence of tall trees or the presence of conspicuous dominant plant species (e. g. bamboos). The classification was made by judgement rather than by a detailed analytical study of the vegetation. This classification corresponded quite well to that of Hommel (1983) (table 4.9). The vegetation types are described in 1.3.4

Three types of shrubland were distinguished according to whether tall trees were absent, some scattered trees were present or the shrubland was dominated by tall (over 2 m high) bushes. All three shrubland types correspond to Hommel's Calamus Amomum community. No seperate distinction was made for the vegetation growing on the beach ridge of the south coast (Hommel: Dendrocnide-Eupatorium community), which was included under shrubland. In the western part of the study area a type of forest with very few palms occurred (termed "forest"), for which no corresponding community name could be found in Hommel. Smaller patches of this forest type were found in the central and eastern parts of the study area as well.

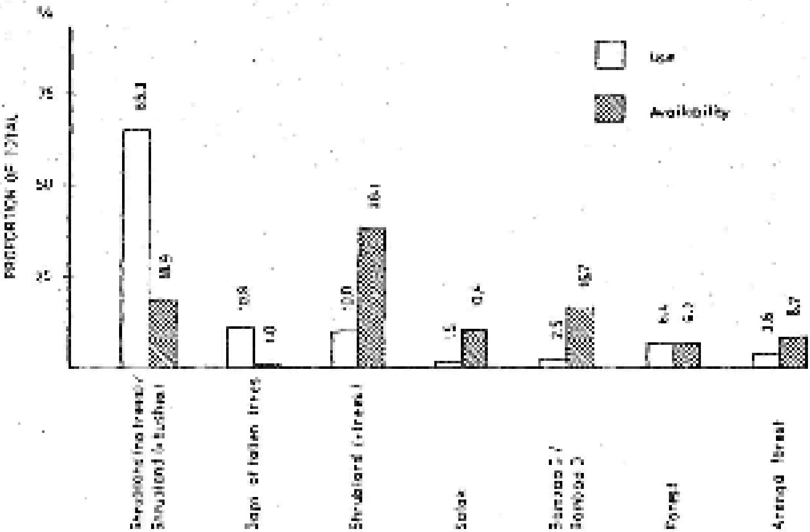
4.1.3.2 Use, availability and preference of vegetation types

To which extent the different types of vegetation were used as feeding habitat was estimated by the relative quantity of food consumed in each tpye of vegetation. The type of vegetation in which the foodplant stood, as well as an estimate of the quantity consumed, was recorded for 682 out of the 1'223 feeding events. The results (figure 4.3) show that the largest quantities of food were consumed in shrubland and in forest gaps created by fallen trees.

The availability of vegetation types in the study area was assessed from their proportion in the total area of the sample plots (see 4.1.1.2).

The rhino's preference for, or rejection of the different vegetation types as feeding habitat was estimated by comparing the proportion of food taken in them with their relative availability (figure 4.3). The most preferred types of vegetation were the gaps of fallen trees followed by shrubland without trees. The use of forest corresponded to

Figure 4.3 Use and availability of vegetation types



its availability. Rhinos showed a negative preference for all other types of vegetation, especially those characterized by bamboos or Salacca edulis.

Here again it must be asked what the effects are of the fact that the availability of vegetation types was sampled in a smaller area than the one in which feeding events were recorded since the availability of vegetation types inside and outside the sampled area are not the same. Most feeding events recorded outside this area were located either to the south (sanddunes, beach ridge) or to the north (Telanca) of it. These areas contain a large proportion of Arenga forest but practically no bamboo types or salak. The estimate of the availability of the first type of vegetation, as shown in figure 4.3, is therefore somewhat too low, and that of the latter two types somewhat too high. The selection against Arenga forest as a feeding habitat must be considered to be more pronounced than indicated here. Another effect is that one type of vegetation in which rhinos are known to feed, namely the narrow strip of vegetation directly adjacent to the beach, was not included in the sample of available vegetation types. Only about 1 % of all feeding events were recorded in this type of vegetation however. The size of the area occupied by it is very small, and it probably represents less than 1 % of the total area in which feeding events were recorded. The effect of its omission can be considered to be negligible.

4.1.4 Factors underlying the feeding pattern of the Javan rhino and the observed preferences

There are some particularities which characterize the Javan rhino's way of feeding: the wide range of foodplant species, the constant change from one food species to another while feeding (Schenkel and Schenkel-Hulliger 1969a) and the observed preferences for certain parts of the plants, for certain plant species and for feeding in certain types of vegetation. These particularities are the results of selective pressures which have acted upon both the rhino and its foodplants. The selective pressures themselves are a product of interactions between the rhinos and their foodplants on the one hand, but also of interactions between rhinos and competing herbivores as well as between foodplants and other plant species. Here I am concerned with the properties of foodplants as well as with environmental factors which actually influence the observed feeding pattern and preferences. For this purpose I intend to relate the characteristics of the Javan rhino's way of feeding to information available in literature on some of the factors that may influence them.

I will first consider the factors underlying the observed preferences for certain parts of plants, for different species of foodplants and for different types of vegetation. Some possible factors are listed here:

Factors influencing preferences for parts of plants and for species of foodplants:

- Nutritional value
- Defences — physical / chemical

Factors influencing choice of feeding habitat:

- Density of foodplants
- Average quality of foodplants
- Availability of other resources

These factors and the Javan rhino's adaptations will be discussed below. In some cases I will present additional observations made during this study.

4.1.4.1 Factors influencing choice of parts eaten and preferences for species

Physical structures used in defence

Plants may protect themselves or some of their parts against herbivores with anatomical structures such as thorns, spines or hair. Especially large spines and thorns are expected to be effective against large herbivores such as the rhino. In Ujung Kulon rhinos occasionally ate *Streblus spinosus*, a small shrub whose stem and twigs are covered by 1 - 2 cm long thorns. *Flacourtia rukam*, a tree armed with long, branching spines, was never observed to be eaten, although it was not rare in the study area. Nor has this species ever been listed by other researchers (Schenkel and Schenkel-Hulliger 1969a,