Durchbruch zu sprechen. In den Rahmen der allgemeinen Betrachtungsweise gehören auch die Probleme der Resistenzerscheinung, des Schutzes von Bienen, Vögel, Wild- und Wassertieren, die umfassend und leicht verständlich dargestellt werden.

In einem *zweiten Teil* werden die Probleme der Zubereitungsformen behandelt, die trotz der Komplexität der Materie übersichtlich zu lesen sind. Die Eigenschaften und Herstellung sowie die hohen Anforderungen, welche an die Stäubemittel, Spritzmittel, Streumittel und Aerosole gestellt werden, sind im speziellen erwähnt.

Der zugehörigen Anwendung dieser Aufarbeitungsformen ist ebenfalls ein ausführliches Kapitel gewidmet, wobei im besonderen auch das Problem der Flugzeugapplikation dargelegt wird. Erstaunlich ist die Tatsache, daß 1952 in den USA bereits 4000 Flugzeuge im Einsatz gewesen sein sollen.

In *dritten Teil* werden dann die insektiziden Wirkstoffe und ihre Eigenschaften beschrieben. Den Anfang bilden die pflanzlichen Insektizide, von denen heute Nikotin, Rotenon und vor allem die Pyrethrine eine wirtschaftliche Bedeutung haben. In kleinerem Umfang wird auch auf die anorganischen Insektizide hingewiesen und anschließend sehr (allzu?) ausführlich auf die vielseitigen Aspekte der chlorierten Kohlenwasserstoffe eingegangen, wobei außerordentlich viel chemische, biologische und biochemische Literatur in den einzelnen Kapiteln verwertet wurde.

Das Kapitel der organischen phosphorhaltigen Insektizide wird durch eine allgemeine Betrachtung über Wirkungsweise, Toxizitätssteigerung durch Ester-Mischungen und systemische Wirkung von Insektiziden eingeleitet. Die spezifische Charakterisierung der einzelnen Produkte erfolgt durch Beschreibung von Herstellung, Anwendungsbereich und Wirkungsmechanismus, Toxizität für Warmblüter und Analyse sowie der Angabe von Spezialliteratur. Vielleicht darf als Desideratum eine konkrete Nennung praktisch wichtiger, spezifischer Einsatzgebiete erwähnt werden.

Mit Recht erfährt bei den Estern der Carbaminsäure Carbaryl eine ausführliche Behandlung; es ist das wichtigste sich im Handel befindliche Carbamat.

Weitere zum Teil kleinere Kapitel beleuchten die Themata: Akarizide, Bodenentseuchung, Vorratsschutz und Raumbegasung, Holzschutz mit chemischen Mitteln, Textilschutz, synthetische Pyrethrine, organische Thiocyanate, Insektenabwehrmittel, Lockstoffe.

In einem *vierten Teil* werden als Anhang sowohl für den Praktiker als auch für den Nichtfachmann einige wertvolle Hinweise gegeben: Erklärungen von Fachausdrücken; Deutsch-lateinisch-englisches Lexikon von Schadinsekten; eine sehr praktische Umrechnungstabelle ausländischer Maße; ein Fachliteratur-Verzeichnis; Adressen der deutschen Informationszentren für Vergiftungen.

Die gewaltig angewachsene Information hat den Autor ohne Zweifel zu einer Selektion gezwungen und wird ihm auch bei künftigen Auflagen die Notwendigkeit zur Straffung auferlegen. Trotzdem hätten vielleicht Substanzen wie Dursban, Abate, Dyfonate, Phosalon, Furadan, Buxten, Lannate, Neopynamin, die Arbeiten von Elliot et al. über auffallend aktive synthetische Pyrethrin-analoge eine Zitierung gerechtfertigt, und ebenso fehlt eine Erwähnung des Komplexes der Insektenhormone.

Bei der Übernahme einzelner Formeln ist Vorsicht geboten, da sich leider diverse Fehlen eingeschlichen haben (z. B. S. 165, 167, 193, 201, 204, 307, 334, 378, 399, 406, 407, 415, 515).

Die letztgenannten Mängel verhindern indes keineswegs, daß dem Band die Qualifikation eines außerordentlich nützlichen, klar gestalteten und gut lesbaren Handbuches gegeben werden kann.

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The Javan Rhinoceros (*Rh. sondaicus* Desm.) in Udjung Kulon Nature Reserve. Its Ecology and Behaviour

Field Study 1967 and 1968

R. Schenkel and L. Schenkel-Hulliger

CONTENTS

I. Foreword

Ecological interference with man, his distorted concepts of sportmanship and heroism, his claim of unrestricted rights to exploit nature, and his superstition have led many of the large mammal species to the verge of extinction. Also the five surviving rhinoceros species are endangered, most of all the two south-east Asian ones. The Javan rhinoceros, *Rhinoceros sondaicus* Desm., occurs only in one small area of 360 km² in the most western tip of Java. In considering this precarious situation, the International Union for the Conservation of Nature (IUCN) and World Wildlife Fund (WWF) have undertaken steps to save the species from extinction in collaboration with the Indonesian government. For this purpose a study of the remaining specimens was planned. After preliminary missions had been sent to Java, Prof. Dr. R. Geigy (Basel) started a project on behalf of the Swiss National Appeal of WWF. In this context the authors were sent to Java from April to November 1967. A patronage committee for Udjung Kulon under the chairmanship of Prof. Geigy was constituted and a second scientific mission was organized from March to October 1968 and at present a program for 1969 is being realized. This paper deals with the results obtained in 1967 and 1968.

We would like to express our gratitude to Prof. Geigy who has initiated this work and supported it all the time, to Dr. F. Vollmar, Secretary General of WWF, for his interest and his never failing encouragement, to the Indonesian authorities who facilitated our work in many ways: Mr. Sudjarwo, Director General of Forestry, Mr. Hasan Basjarudin, Mr. Made Taman and Prof. Dr. O. Soemarwoto; to the Ambassador of Switzerland, Dr. Réviliod, and the staff of the Swiss Embassy in Djakarta, finally to our collaborators in the field: Mr. Djuhari, Kepala Seksi Udjung Kulon, Mr. Widodo, assistant from Nature Conservation Service, and in 1968, Mr. Rolf Immler from the Swiss Tropical Institute in Basel.

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II. Introduction

A. The Javan rhino, history of its discovery and persecution

CAMPER (1772), Professor of Zoology in Groningen, was the first to suggest that the rhino living in Java was not identical with *Rhinoceros unicornis*. The relevant evidence was produced by RAFFLES (1817) who together with MARSDEN (1811), detected that the one-horned Javan species also occurred in Sumatra besides the Sumatran rhino *(Didermoceros* or *Dicerorhinus sumatrensis)*. As can be read in details in SODY (1941, 1959) and GUGGISBERG (1966), DESMAREST (1822) gave the first scientific description of the species and called it *Rhinoceros sondaicus*. The specimens at his disposition had been collected in Sumatra, but later they were believed to have come from Java. CUVIER (1829) therefore called the species by the name of *Rhinoceros javanicus*. Since then there has been some confusion as to the identity of the species and to its distribution. In Sumatra, Malaya, and South Burma it was confused with the Sumatran rhino, and farther north and east the species was believed to be identical with the Indian rhino *(Rh. unicornis)*. When its identity was more or less generally recognized in the second half of the 19th century, the species was near extinction in most parts of its former distribution range, which therefore could not be defined accurately. Did the species ever occur north of the Brahmaputra, e.g. in Sikkim,

and together with the Indian rhino in the Brahmaputra valley? It is, however, definite that *Rh. sondaicus* has occurred in Bengal (Sunderbans), Assam, Thailand, Indochina and South West China and still occurred in small numbers in Burma, Malaya, Sumatra, and Java in the 20th century. According to SODY (1941) the following are the last reliable reports of the existence of the species in the 20th century:

Burma: In 1920 one individual was shot by HUBBACK at Victoria Point, Tenasserim; after 1930 unreliable report by ALLSOP from Kahilu Reserve.

Malaya: 1932, one individual shot by VERNAY at Sungei Lampen (Telok).

Sumatra: 1925–30, most probably 12 individuals were shot by HAZEWINKEL in the Palembang region (S. Sumatra). Still in 1933, the Dutch Administration gave permission to HAZEWINKEL to shoot some more rhinos!

Java: 1934, one individual shot by FRANCK at Tasikmalaya. Since that time the only surviving rhinos live in Udjung Kulon.

With very few exceptions the white men who showed any interest in the Javan rhino, endeavoured to shoot it, either as "sportsmen" or as museum collectors, though they knew the vulnerability of the species and its susceptibility to poaching. Nowadays, the rhino is only persecuted for its horn, skin and blood which are still sold in China as medicine, especially as a charm of supposedly aphrodisiac action.

Reports on the way of life of the Javan rhino are poor, the most detailed accounts having been provided by HAZEWINKEL (1933) and FRANCK (1933/34) and since 1937 in numerous reports by HOOGERWERF.

B. Udjung Kulon Nature Reserve, the last refuge of the species

Udjung Kulon which forms the most western tip of Java was first mentioned as being inhabited by rhinos in 1861 (see SODY, 1959). At the beginning of the 20th century, the semi-island was a hunting area. In 1909 the rhino was declared a protected species, yet special permissions to hunt it, were easily obtained, e.g. a Mr. Kerkhoven managed to shoot at least 9 specimens in Udjung Kulon! In 1921 the area was declared a "Nature Monument" but its protection was only formal. In fact, poaching incidents were reported in 1930, 1933 and — 16 rhinos — in 1935/36. Finally in 1937 Udjung Kulon together with the adjacent Panaitan-(Prinsen)-Island, was declared a Nature Reserve, and a small guard organization was established. After World War II, periods of heavy poaching followed again. And still in 1963/64 a greater part of the very small population was killed.

C. Efforts of IUCN and WWF

During the last decade IUCN and WWF were alarmed by this development. L. TALBOT was sent on a first mission in 1964 to study the situation, J. VERSCHUREN followed in 1966/67 for 4 months and the authors in 1967 and 1968. Our mission had a double aim:

Firstly to study the Javan rhino, the size and reproductive capacity of its population, and the suitability of Udjung Kulon as a habitat; secondly to assist the Indonesian authorities in their effort to save the species. Our first observations in Udjung Kulon in May 1967 showed that quick action to reinstate the guard-system was urgent. Protection of Udjung Kulon was and still is of paramount importance in the fight for the survival of the Javan rhino, in addition the development of measures of management based on an ecological survey is very urgent. In different parts of Udjung Kulon we found evidence of poaching. Only two guard-posts on the islands north of Udjung Kulon were regularly occupied, and their huts were defective. The area most exposed to rhino poaching, the south coast, was almost unprotected. An application for financial support to the guard-system by WWF was made. Thanks to immediate help from WWF, the guard-system began to function again in June 1967. With a second grant in 1968 the guards were provided with salary contributions, uniforms, equipment, and medicine; the defective huts were repaired and new ones built; the motor-boat and the Landrover which had been given by WWF, could be maintained and run regularly to supply and control the guards. In 1968 we organized two courses for guards in shooting and other guard techniques.

III. Problems and methods of field research in Udjung Kulon

A. Topography

We first had to gain information on topography and vegetation of the reserve. An official map 1 : 50,000 of the area exists, dating allegedly from 1932, but obviously of much earlier origin. It soon became obvious that this map was very inaccurate in all details of the interior of the reserve such as water-courses, valleys, hills, etc. This proved to be a serious handicap, since most of the reserve is covered by dense vegetation, and this not only in the vast lowland, but also in the hilly regions; there are, thus, only few sites which offer any outlook.

The reserve covers 360 km^2 and extends about 20 km from north to south and from east to west. It may seem an easy task to reconnoître such an area by a series of parallel trips from north to south and from east to west. But already to reach a chosen point along the coast is very time consuming. In the interior progress is very slow. The passage through the dense and thorny vegetation usually has to be cut with the bushknife. Steep and slippery slopes, rivers, and stretches of muddy soil are frequent. Regions near the coast are often swampy and more or less flooded by sea-water at high tide.

Some of the guards were familiar with the forest, but they never made trips off the patrol-paths, nor did they stay there at night. Crossings through the interior from coast to coast take in most areas several days. Food and camping material must be carried and this again impedes rapid progress. We tried to improve the technique of forest marching, we made many one-day trips in

small groups, preferably in twos, and learned to cut through the thorny vegetation ourselves. With time, some of the guards also dared to go through the bush in twos and threes, others, however, were still afraid at night of ghosts or of the "magic tiger". Orientation is possible according to the sun, but on cloudy days and at noon a compass is indispensable.

B. Rhino research

Direct observation of rhinos turned out to be extremely difficult. This is firstly due to the small population, secondly to the dense vegetation and the lack of any observation point, and finally to the great shyness and pronounced nomadism of the rhino.

Periodical check-ups at wallows, paths, feeding areas showed that visits by rhinos did not occur daily, but at very irregular intervals. The same was found, when we spent series of nights near wallows or bathing places.

On preliminary trips we got to know those areas of the reserve where signs of rhino activity were more concentrated than in others. In such an area the chance of encountering a rhino still is very small. Generally the observer is more likely to find a fresh rhino track than a rhino itself. If the soil is soft, the pug marks can then be followed. The age of footprints cannot always be determined accurately, but when following a track, one almost invariably comes upon the dung of the rhino. The age of dung can be determined more accurately. Tracking is fairly easy in soft soil, but difficult in hard and dry soil or on dead leaves. Even if the rhino has been tracked carefully, observation may be jeopardized either by noise or if the rhino is reached by human scent.

In the course of the approximately 250 days of this study, altogether 27 encounters with rhinos, 13 in 1967 and 14 in 1968, occurred. Usually the rhino was seen, on a few occasions only heard and smelled very nearby. Once we were near a rhino for 55 minutes, in 3 instances from 15 to 25 minutes. In all other instances we saw the animal only for a few seconds to minutes, but on all these occasions the animal was at times hidden by vegetation.

To obtain additional information, all sorts of traces produced by the rhinos were studied. In this respect, experiences made previously with other rhino species, mainly the African black rhino, were of great advantage (SCHENKEL, 1966; SCHENKEL & SCHENKEL-HULLIGER, 1969).

Considering the enormous difficulties in finding a rhino, we could obviously not plan to mark some individuals. Animals could be differentiated to some extent by the size and shape of their pug marks and by the difference of width between fore- and hindfoot. The distance between the outer edges of the side-toes were measured carefully. The prints of one foot could show variations of 1–1.5 cm according to speed of pace, gradient of terrain and type of soil. For comparison identical measurements were taken of the Indian rhinos bred and kept at Basel Zoo [1]. In both years all the footprints observed were classified according to their width; the relative frequencies of the different size classes were calculated to obtain information on the age classes.

Special attention was paid to traces characteristic of the sex of rhinos, especially the pattern of urination. The size of the whole population was defined on the evaluation of traces, especially footprints. On two occasions, Nov. 1967 and Aug. 1968, a census was carried out by 6 teams simultaneously, who, each in a defined sector of the reserve, registered and measured all the new rhino tracks. Due to the limited number of collaborators, especially experienced team leaders, the following restrictions were necessary:

— Each census was carried out in two periods of 2 and 3 days with an interval of one day for reporting and preparing.
— The sectors of the teams did not cover the whole reserve, but all the areas which had previously shown most rhino traces.

Because of the nomadic way of life of the rhino, we had to take into account the fact that tracks of the same size in neighbouring sectors might be attributed to the same or to two different animals; we thus calculated a minimum and a maximum number. The possible distance covered by a rhino during the days of counting were judged according to our experience made in the different areas.

IV. Results

A. Udjung Kulon as a habitat

1. Topography

A map sketch of the reserve was drawn indicating the main rivers and drainage areas according to our experience *(Fig. 1)*. In their lower course most rivers form wide, meandering beds which are washed out by fresh water and, with the tidal changes, also by

[1] We are very grateful to Dr. E. M. Lang, Director of Basel Zoo, to Dr. H. Wackernagel and to Mr. Waldner for taking the measurements and for the permission to use these data.

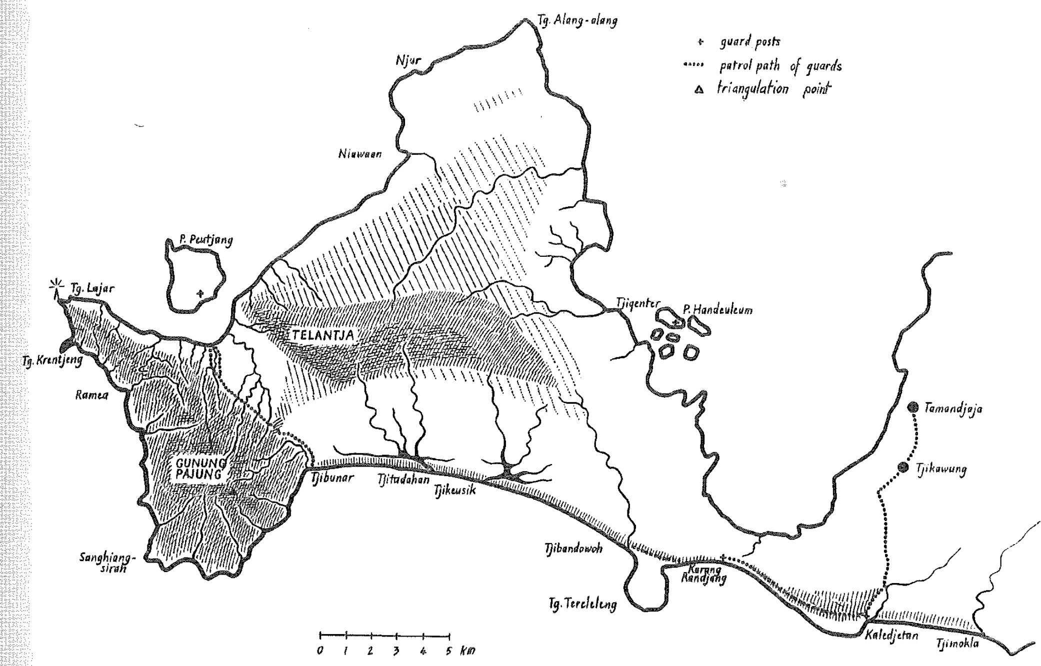

Fig. 1. Map sketch of Udjung Kulon Nature Reserve, Java.

sea-water. In 1967, the mouth of some rivers was closed by a barrage of sand and gravel due to the surf.

All the rivers which originate in Gunung Telantja and in the central elevation east of it, deposit lime sinter while still in the hilly region. In many places water cascades over sinter barrages lead from one basin to the next. The rivers of the Gunung Pajung massif and of the ridge west of it to Tandjung Lajar do not deposit lime sinter. In their upper reaches they form high waterfalls and washed out gorges and basins.

2. Vegetation and soil

An inventory of the plant species and communities of Udjung Kulon does not yet exist, nor has a study of its plant ecology been made so far. Endert (1952) and Koesnadi (1961) have characterized to some degree the vegetation of the different parts of Udjung Kulon. With regard to the ecology of the rhino the following questions arise:

— Which types of habitat are especially attractive for the rhino?
— In which types of habitat would it be possible to increase the number of foodplants by management?

Detailed studies have been started but are still far from permitting conclusions. Here the main types of habitat are outlined in a preliminary way:

— *Pajung massif and northwestern spur to Tandjung Lajar*

This area is mostly covered with high forest down to the coast. In the north and west the coastal strip is relatively rich in tree saplings and "boomheester" [2]. Further to the south, *Pandanus* sp. dominate the understorey near the coast. On the slopes the forest in many places consists of a higher stratum of trees and a middle stratum of *Arenga* palms *(A. obtusifolia)*. These palms are responsible for such poor light conditions in the lower stratum that no saplings can grow apart from young *Arenga*. Where there is slightly more light, *Donax canniformis* grows in dense stands. Near rivulets Salak palms (*Zalacca edulis*), different rattan palms, and lianas are frequent. On the northern slopes of G. Pajung, glades are found locally with *Lantana camara,* Hondje (*Nicolaia* sp.), Tepus (*Achasma* sp.), rattan palms and different tree saplings. In the higher regions of G. Pajung, the forest and its undergrowth are rich in species; *Arenga* palms are rare and Salak palms occur only near streams. *Rhapis flabelliformis,* special rattan types, and, locally, tree ferns and Hondje are frequent in the lower stratum.

— *Southern plains and depression between G. Pajung and G. Telantja*

Generally this continuous flat has a clay soil; it is drained by many rivulets and appears muddy in the rainy season. High trees are scattered. A large part of the area is covered by Salak stands intermixed with glades (*Lantana camara,* Hondje, Tepus, saplings, and creepers). Rattan palms form dense curtains on the higher plants bordering these glades. Locally, large stands of bamboo may occur, especially near the swampy lagoons of Tjikeusik and Tjitadahan. *Nipa* palms *(N. fructicans)* are characteristic of the sea-water swamps.

— *Dune-like ridges along the south coast east of Tjibunar*

The coast is formed by layers of sandstone near Tjibunar and of a sandy beach further to the east. The one to four ridges which run, like dunes, parallel to the coast, are covered by a characteristic vegetation: the first ridge with *Pandanus* sp., the second with *Lantana* thickets, scattered grass, and with a light forest in which *Laportea stimulans* often dominates, the next with mixed forest. On the northern slopes of each ridge, *Arenga* is frequent. The vegetation between the dunes is similar to that of the southern plains: water courses, swampy patches and glades, Salak stands, and tree clusters.

[2] Dutch word for tree-shrubs up to 20 m high.

— *Northern flats from Niawaan to the neck of Udjung Kulon*

These large flats lie almost at sea level and some are temporarily covered by sea-water. The main plant communities are: Forest growing on coral rock layers and in morassy areas flooded at high tide, with mainly *Rhizophora* sp. and *Bruguiera* sp.; swampy areas on the lower courses of most rivers with *Nipa* palms; large stretches, which are covered seasonally by fresh water, with grass or sedge-like reed vegetation; former grazing areas which had been kept open artificially for plain animals and are now overgrown by *Lantana camara, Epatorium* sp. and *Melastoma polyanthum;* former grazing areas already converted into a low forest dominated by *Ardisia humilis.*

In general the vegetation on the northern plains has a transitional character; former cultivation, the large tidal wave caused by the Krakatau explosion in 1883, and clearing activity during the last decades have inhibited the development of a climax vegetation.

— *Central hilly region from Telantja eastwards*

In its western and southern parts, the ridges consist of limestone, the valleys are sharply cut. Further to the east the country undulates; most valleys are soft with clay soil, hills and ridges are rounded. The vegetation is polymorphic and can only vaguely be characterized. In the western parts *Arenga* forest is frequent on slopes and plateaus; the higher crests have a forest which is rich in species of high trees and undergrowth. Further to the east, Salak palms are dominant in the valleys; bamboo types occur in similar locations and also on slopes. Glades similar to those in other regions, occur locally. On the foot regions of the spurs, the vegetation is often very dense with many thorny palms of the Salak and rattan types.

3. Seasonal changes of the habitat

According to local reports there is usually a rainy season from November to March and a season with less and only local rainfall from May to October. The two years 1967 and 1968 had very different weather. In 1967 there was no rainfall in Udjung Kulon from the end of May until the end of November. Most rivers and swamps above sea level dried out. A few rivers had some running water in their higher reaches, but no fresh water further down. Of the many rivers in the eastern main part, only Tjigenter, one branch of Tjitandahan and the short rivers north of Telantja (Tjiterdjun and Tjinogar) still had fresh water. Around G. Pajung most rivers were dry in their lower reaches. Tjibunar, Tjidaun and Tjitjadas had a little bit of water throughout. The branches of Tjiudjungkulon, Tjikuja, Tjikembang, Tjiramea and several others had a few basins with water higher up, but were dry near the coast. Accordingly, in 1967, the soil was hard and covered with rustling fallen leaves. The vegetation appeared desiccated in many areas, while in 1968, a rather normal year, the soil was moist and drenched in many places. Fallen leaves quickly rotted. Defoliation took place in both years during the period of May to October; it seems to depend on endogenous factors and not on climatic conditions.

The grass on the glades and especially in the plains adjacent to the north coast suffered most from the drought in 1967. In 1968 it was green throughout.

For tracking rhinos the conditions were obviously much better in 1968; large trips through the interior were, however, more difficult, because it was impossible to make use of dry riverbeds as in 1967. Many of the plains, which had been dry in 1967, were morassy in 1968.

4. Remarks concerning the mammals apart from the rhino

Udjung Kulon has a wide variety of different habitats and accordingly of different mammal communities. Some species are not restricted to one type of habitat, but appear adaptable. Generally, adaptable species on one hand, and forest species on the other, have a better chance of survival in Udjung Kulon than the species which are specialized for open grassland. Some of the mammals and their habitat are summarized in *Table 1*. The most successful large mammal is the wild pig *(Sus scrofa vittatus)*. The only large predator permanently resident is the leopard *(Panthera pardus)*. Both species are adaptable with a preference for a covered habitat. The two large ruminants, the Banteng *(Bos javanicus)* and the Rusa *(Cervus timorensis)* only occur in small numbers. During the last decade the grazing areas were no longer kept open. This has undoubtedly affected their population. Very few Rusa were

TABLE 1

Distribution of some larger mammals in Udjung Kulon

Species	Localization					Frequency of the species in Udjung Kulon 1967/68
	Near coast	Old grazing areas	Glades, Salak, scattered high trees	High forest	Mountain forest	
Bos javanicus	(+)	++	++	(+)	(+)	About 100
Cervus timorensis		(+)				1967 few seen 1968 none seen, only on Pulo Peutjang
Muntjacus muntjak				++	+	Not rare
Tragulus javanicus			++			Not rare
Sus scrofavittatus	+	+	++	++	+	Frequent, especially near rivers
Panthera pardus	+	(+)	+	+		Not rare
Cuon alpinus			(?)	(?)		Tracks seen 2 ×
Macaca irus	(+)	++		+	+	Frequent
Presbytis sp.				+	+	Frequent in the forest
Hylobates moloch				+	+	Rare

seen in 1967, none in 1968. The Banteng are attracted toward the old grazing areas, some of which have been reopened, but they cannot possibly live on the small amount of grass. They were found to move all over the reserve in the dense forest and to feed on bamboo, young palm leaves, bush, and saplings as well.

B. The ecology and behaviour of the rhino

1. Feeding behaviour and food

The Javan rhino is a browser and mainly feeds on twigs and branches. In the few cases where we could observe a rhino while feeding, the following behaviour patterns were noted:

— The rhino lifted its head and neck and stretched its mouth high up, seized a branch with the upper lip, cut it off and chewed it from proximal to distal;

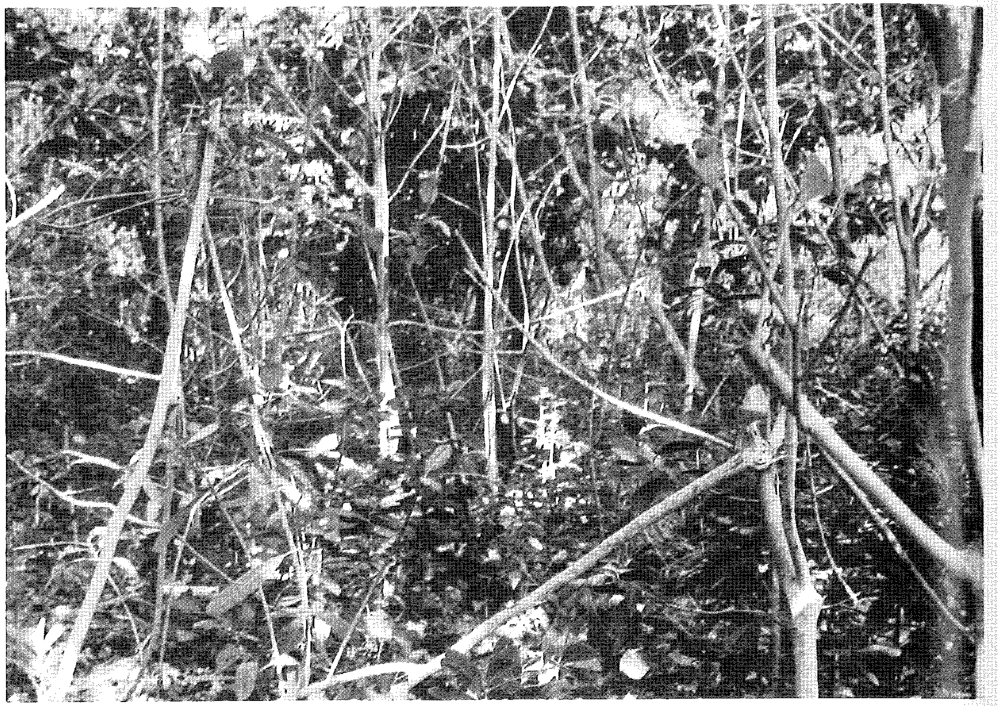

Fig. 2. Traces of feeding by rhino on Ficus septica saplings.

— if the top of a sapling was out of its reach, it seized the trunk with its jaws and broke it, then fed on the branches;
— in one case, a rhino did not at first succeed in breaking the trunk; it pressed the trunk down and gradually displaced the grip of the jaws upwards until the sapling broke.

Additional information on feeding was deduced from traces left by the feeding rhino; e.g. the whole crown of a sapling was fed *(Xanthoxylum rhetsae)* or a rhino had broken or damaged a sapling, but not fed on it (*Blumeodendron tokbrai* Kurz). The thickest stems broken by rhinos had a diameter of 12 cm.

Pigs also cut off saplings as well as palm leaves when they construct the nest for their litter, but at only 10 to 40 cm from the ground. Banteng also feed on the leaves of certain palms and on a number of bushes, but in contrast to rhinos they only feed on the leaves and the tips of thin twigs, while rhinos always chop off small branches.

Plants which are damaged by the feeding rhino usually will not die; instead of one sprout, several lateral shoots will grow in ver-

TABLE 2

List of food plants of the Javan rhino in Udjung Kulon *

Latin name	Family	Native name	Plant type	Frequency of feeding
Achasma coccinium Val.	Zingiberac.	Tepus	Shrub	++
Achasma sp.	Zingiberac.		Shrub	
Achromychia laurifolia Bl.	Rutac.	Djedjerukan	Boom-heest. **	1 ×
Aglaia sp.	Meliac.	Tjulan		1 ×
Alchornea rugosa M.A.	Euphorbiac.	Kisengal	Bush	1 ×
Allophylus cobbe (L.) Raeusch	Sapindac.	Tijukilan	Bush	1 ×
Alstonia angustifolia	Apocynac.	Lamepeu-tjang	High tree	1 ×
Antidesma montanum Bl.	Euphorbiac.	Huni	High tree	1 ×
Bombax mallabaricum		Dangdeur leuweung	High tree	+
Botryophora geniculata (Miq.) Beumée	Euphorbiac.			1 ×
Bridelia stipularis Bl.	Euphorbiac.	Kanjere	Tree	2 ×
Buchanania arborescens	Anacardiac.	Reungas manuk	Tree	1 ×
Caesalpinia sappan L.	Leguminos.	Setjang	Tree	1 ×
Callicarpa longifolia Lamk.	Verbenac.	Kutumpang		1 ×
Canarium asperum Bth. Var.	Burserac.	Kenari	Tree	1 ×
Canarium denticulatum Bl.	Burserac.	Kenari	Tree	1 ×
Cannangium odoratum (Lam.) Baill.	Anonac.	Kenanga	Tree	1 ×
Capparis microcantha	Capparidac.	Kledung	Tree	1 ×
Carallia brachiata (Lour.) Merr.	Rhizophorac.	Kikukuran		1 ×
Cassia javanica L.	Leguminos.	Bungbung dilang	Tree	1 ×
Cassia siamea	Leguminos.		Tree	1 ×
Claoxylon Polot Merr.	Euphorbiac.	Talingkup	Boomheest.	2 ×
Clausena sp.	Rutac.	Kipuak		1 ×
Clausena oliveriana K & V	Rutac.	Kipuak	Boomheest.	1 ×
Crypteronia paniculata Bl.	Crypteroniac.	Kibanen	Tree	1 ×
Cryptocarya sp.	Laurac.			1 ×
Cynometra sp.	Leguminos.	Kateng	Small tree	1 ×
Derris thyorsiflora Bunth.	Leguminos.	Toewa	Liana	1 ×
Desmodium umbellatum D.C.	Leguminos.	Kanjere laut	Boomheest.	++
Dillenia sp.	Dilleniac.	Sempur		
Dillenia aurea	Dilleniac.	Sempur batoe		++
Dillenia excelsa (Jack) Gilg.	Dilleniac.	Segel	Small tree	++
Diospyros sp.	Ebenac.	Kitjalung		
Diospyros macrophylla	Ebenac.	Kitjalung	Tree	+
Drypetes longifolia	Euphorbiac.	Bunijaga	Tree	1 ×
Elaeocarpus glabra Bl.	Elaecarpac.	Katu lampa	Boomheest.	1 ×

* The plants were determined in the Herbarium Bogoriense. Bogor (Director Mr. Dillmy).
** "Boomheester" = Dutch word for tree-shrubs up to 20 m high.

TABLE 2 (continued)

Latin name	Family	Native name	Plant type	Frequency of feeding
Embelia ribes Burm.	Myrsinac.	Areuj katjembang	Climber	1 ×
Embelia javanica D.C.	Myrsinac.			
Erioglossum edule	Sapindac.	Kelaju		
Eugenia sp.	Myrtac.	Djambu		
Eugenia densiflora Dl.	Myrtac.	Kopo badak	Tree	1 ×
Eugenia jamboloides K & V	Myrtac.	Kopo mangud	Tree	+
Eugenia malaccensis L.	Myrtac.	Djambu bod	Tree	+
Eugenia polyantha Wight	Myrtac.	Salam	Tree	++
Eugenia suringeriana K & V	Myrtac.	Kopo lalaju	Tree	1 ×
Ficus benjamina	Morac.	Tjaringin		1 ×
Ficus callosa Willd.	Morac.	Pangsar	Tree	++
Ficus fistulosa Reinw.	Morac.	Beunjing	Boomheest.	+
Ficus septica Burm. f.	Morac.	Ketjiap	Tree or Boomheest.	++
Firmiana malayana Kost.	Sterculidac.		Tree	1 ×
Garcinia celebica L.	Guttiferac.	Manggu leuweung	Tree	+
Garcinia dioca Bl.	Guttiferac.	Tjeuri	Tree	+
Glochidion philippinicum Robin	Euphorbiac.	Kipare		1 ×
Glochidion rubrum Bl.	Euphorbiac.	Kipare	Boomheest.	++
Hernandia peltata Meissn.	Hernandiac.	Kampis	Tree	1 ×
Hibiscus tiliaceus L.	Malvac.	Waru laut	Tree	+
Lagerstroemia sp.	Lythrac.	Bungur	Tree	+
Laportea stimulans	Urticac.	Pulus	Bush	2 ×
Leea indica (Murm) Merr.	Vitac.	Sulangkar	Boomheest.	+++
Lepisanthes sp.	Sapindac.	Kilalaju	Boomheest.	+
Litsea sp.	Laurac.			
Litsea noronhae	Laurac.	Huru bako	Boomheest.	1 ×
Mallotus moritzianus M.A.	Euphorbiac.		Boomheest.	1 ×
Mallotus philippinensis M.A.	Euphorbiac.	Kimejong	Boomheest.	+
Mallotus ricinoides M.A.	Euphorbiac.	Mara		1 ×
Memecylon sp.	Melastomatac.		Boomheest.	1 ×
Memecylon myrsinoides	Melastomatac.	Kitjalar	Boomheest.	1 ×
Microcos paniculata L.	Tiliac.	Liak	Tree	1 ×
Orophea enneandra	Anonac.	Kiteguh	Boomheest.	1 ×
Orophea hexandra Bl.	Anonac.	Sauheun	Boomheest.	1 ×
Parinaria sp.	Rosac.	Taritig		1 ×
Plectronaria horrida Schum.	Rubiac.	Kitjaroeloek	Boomheest.	1 ×
Poikilospermum suaveolens (Bl.) Merr.	Urticac.	Taliair	Liana	1 ×
Polyalthia sp.	Anonac.	Kajutiang	Tree	1 ×
Pometia pinnata Kost.	Sapindac.	Leungsir	Tree	1 ×
Premna obtusifolia R. Br.	Verbenac.	Kipahang	Boomheest.	1 ×
Pseuduvaria rugosa (Bl.)	Anonac.	Kipedes	Tree	1 ×
Pterospermum acerifolium Willd.	Sterculiac.	Bajur	Tree	+
Pterospermum javanicum Jungh.	Sterculiac.	Bajur	Tree	+

TABLE 2 (continued)

Latin name	Family	Native name	Plant type	Frequency of feeding
Pyrenaria lasiocarpa Koef.	Theac.		Shrub	1 ×
Radermachera glandulosa (Bl.) Miq.	Bignoniac.	Kipadali		1 ×
Randia patula Miq.	Rubiac.	Ampru	Boomheest.	1 ×
Saccopetalum horsfieldii Benn.	Anonac.	Kikalak	Tree	1 ×
Spondias dulcis Trost.	Anacardiac.	Kedongdong leuweung	Tree	1 ×
Spondias pinnata Kurz	Anacardiac.	Kedongdong leuweung	Tree	+++
Stelechocarpus burahol (Bl.)	Anonac.	Turalak		1 ×
Sumbaviopsis albicans J.J.S.	Euphorbiac.		Boomheest.	1 ×
Symplocos fasciculata Zol.	Symplocosac.	Djirak	Tree	1 ×
Taxotrophis taxoides Heyne	Morac.	Ulit	Bush	++
Tournefortia argentea L.	Borraginac.	Babakoan	Small tree	+
Uvaria littoralis Bl.	Anonac.	Kalak	Climber	1 ×
Villebrunea rubescens Bl.	Urticariac.	Nangsi	Boomheest.	1 ×
Vitex pubescens	Verbenac.	Laban		+
Wetria macrophylla (Bl.) J.J.S.	Euphorbiac.	Kelawer		1 ×
Xanthoxylum rhetsae Dl.	Rutac.	Kitanah	Bush	++

tical direction. This type of regeneration is obviously in the interest of the rhino, because the sapling will thus not so quickly grow out of the rhino's reach into a large tree which produces additional shadow and inhibits the growth of more saplings.

After feeding on one or more plants in a spot, the rhino slowly moves on through the vegetation in irregular bends to the left and to the right, stopping from time to time to feed again. The route of these feeding trips can be recognized by broken saplings and shrub-trees *(Fig. 2)*. It often leads through vegetation with signs of earlier feeding by rhino.

While feeding, the Javan rhino tends to change from one food plant species to another. Occasionally traces indicated that the rhino fed on one specimen only, though there were some more nearby, continued its trip and fed on another species. Some plants (e.g. *Lantana camara, Pandanus* sp.) were found only once to have been eaten though these species are very abundant.

The different species of plants which were found to have been eaten by rhinos in 1967 and 1968 are listed in *Table 2*. Only a few bush species and lianas are amongst the many food plants, most of them are saplings of larger trees and especially of "boomheester". The large number of species suggests that the rhino likes and probably needs a varied diet. Former authors (JUNGHUHN, 1845) claimed that the Javan rhino fed to a large extent on grass. This has not been confirmed and is unlikely since the lips and teeth of the Javan rhino are specialized for browsing. Obviously also in its former distribution, the species mainly fed on saplings and was attracted towards areas of secondary growth, e.g. deserted ladang[3] areas. HAZEWINKEL (1933), FRANCK (1933/34), HOOGERWERF (1950, 1952) have formerly described the feeding on saplings and listed a number of food plants. An extensive list of rhino food plants was compiled by EFFENDI (1967). Not all of these findings were confirmed by ours, and several plant species on which we observed traces of rhino feeding, have not been mentioned by the above authors.

2. Mud wallowing and bathing

Former observers have often mentioned that they came at daytime upon a rhino or even two lying in a wallow or river. Still, HOOGERWERF made this observation frequently before World War II. During our study we found at daytime only once a rhino lying in a river basin *(Fig. 3)* and three times in a mud wallow; in two other cases the animal had become alarmed and taken to flight before we could see it.

The last Javan rhinos are extremely shy and wary when wallowing or bathing; they more often visit these places at night than during the day. Rhinos bathe in river basins and in channels with brackish water. Some years ago a rhino was even seen lying in shallow sea-water.

The majority of wallows is hidden in very dense vegetation (e.g. Salak palms) and only accessible through rhino paths which form tunnels through the thicket *(Fig. 4)*. Some of the wallows and bathing places must have been used again and again over the years. They lie in the centre of a well-developed track-net, the tracks being often deeply carved into the ground. Others were only used temporarily or developed after a heavy rain in the soft clay, used once and then left.

If a mud wallow has been used recently, the water is muddy and often a strong smell of urine emanates from the wallow and also from the rhino's track. This observation was also been made by HOOGERWERF (1952) and others. The scent of urine attaches to the skin and when the rhino leaves the wallow and walks on the tunnel-like paths, the scent together with wet clay is transferred to

[3] Malayan word for areas of shifting cultivation.

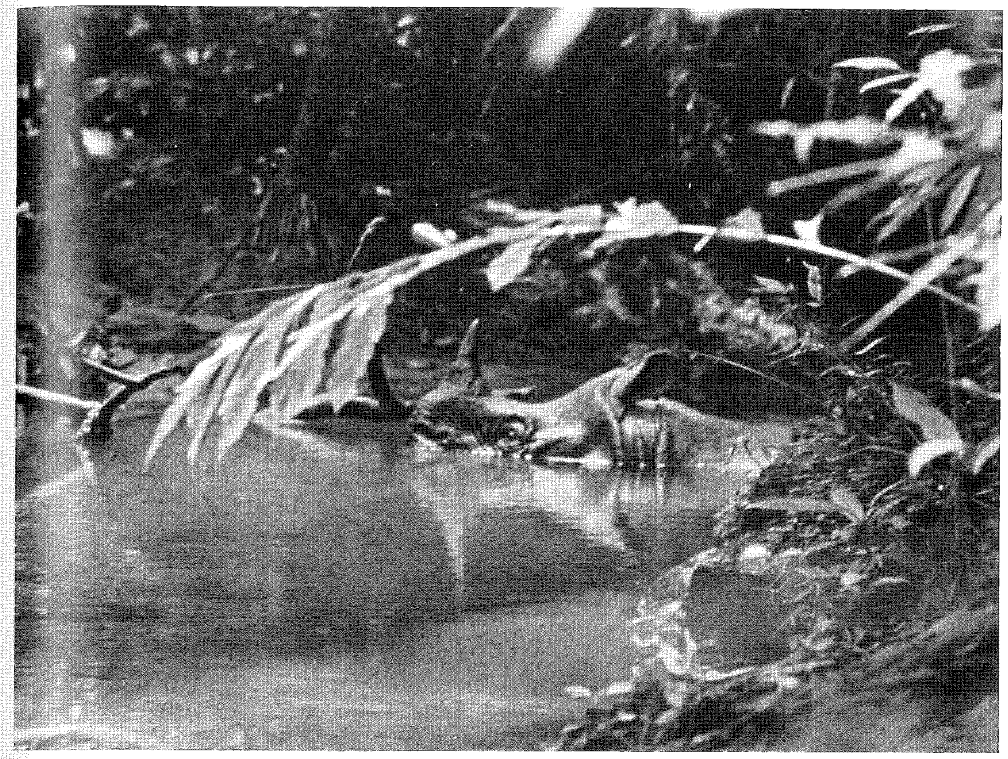

Fig. 3. Javan rhino resting in a river basin.

soil and vegetation and stays in the air of the tunnel for hours or even up to a day.

The functions of bathing and mud wallowing are manifold: Lying in water has an effect on the body temperature and on the skin condition. It protects the animal from ectoparasites, mainly biting *Diptera*. The layer of clay which covers the body after wallowing prolongates these protective effects. Urination in the wallow causes olfactory impregnation of the skin and thereby of the rhino's trail.

3. Drinking and salt licking

As to drinking and salt licking we have not made any direct observations. We do not know how often and how much a rhino drinks. Usually there is plenty of fresh water available in Udjung Kulon. In 1967, when fresh water was scarce, there were concentrations of rhino tracks near channels of brackish water, but not near the few basins and rivulets with fresh water.

Fig. 4. Rhino track leading to a wallow in dense vegetation.

We never found any salt licks as they have been described for all other rhino species. But, in Udjung Kulon rhinos may cover their need of salt when visiting the shore and the brackish rivers.

4. Defecation

When defecating, the Javan rhino deposits a number of dung balls onto the same spot, whereby only the last ones keep their

Fig. 5. Rhino dung.

shape *(Fig. 5).* The diameter was from 7 cm for an immature animal up to approximately 20 cm for adults. The dung consists of fibrous material, some fine, some coarse, and of pieces of tough leaves and small branches up to 6 cm long and 1 cm thick.

Fresh rhino dung is yellowish brown and has a strong smell similar to that of horse dung. The balls are never broken by scraping as in the African rhinos. Only twice, weak signs of rubbing with hind-feet without touching the balls were seen. After about half an hour the dung gradually darkens and dries on the surface. The age of dung can be judged within the first hours by checking its outside and inside temperature.

Fresh dung is often visited by dungbeetles (e.g. *Gymnopleurus planus, Copris* sp.). They break up the dung balls and raise soil in between the dung. Occasionally dung was found scattered around as with a broom seemingly by pigs, perhaps in search of insects. The Javan rhino deposits its dung preferably in two locations *(Table 3):*

TABLE 3

Localization of dung heaps (Observations made in the dry year 1967)

	In water, rivers, rivulets	In dry riverbeds	In wallows	On ridges near main paths or crossings	Elsewhere	Total
Number	57	60	0	76	55	248
%	23	25	0	30	22	100

— In running and standing water of rivulets and rivers. Often dung heaps of different age were seen near each other in these locations. In the dry year 1967, droppings, also fresh ones, were seen in dry river beds.

— On ridges or hills, on or next to main paths and especially at crossings. In such locations from two to a dozen dungheaps of different age were found within an area of less than 20 to 20 m. Such agglomerations of dungheaps are usually produced by more than one animal as can be judged from the size of the dung balls and the rhino tracks in the area.

These typical locations of dung deposits have already been described by former authors. ALLSOP (see THOM, 1936) and HAZEWINKEL (1933) mention their location in rivers, HOOGERWERF (1952) the agglomeration of many dung heaps. The rhinos in Udjung Kulon do not maintain large dung piles as the Indian rhinos. Yet, this has been reported by JUNGHUHN (1845) and may have occurred formerly in areas of high population density. We had no opportunity to directly observe a rhino when it came upon a dung heap, but it must often be stimulated to defecate in such a situation.

Defecation into standing water may also result in attaching smelly substances to the feet and impregnating the footprints of the rhino. Altogether defecation appears less ritualized in this small population of Javan rhinos than in the African species. Accordingly it must be less important in producing scent marks.

5. Urination

Rhinos urinate mainly in two situations: when lying in a wallow and while walking steadily. The smell of urine emanates not only from the track generally, but often with special intensity from a spot on the ground or on the vegetation at the side or above the path. In the latter instance, very fine droplets of reddish to yellowish urine cover the leaves up to two meters from the ground

and in a range of three meters along the path. Obviously the shower of urine is spread backwards-upwards. Such sites of urination can occur in intervals of less than 100 meters on the path. Often the urine is squirted just after a rhino has passed through very dense vegetation.

Smelly spots on the ground and large droplets on the vegetation near to the ground occur when urine is released in a downward splash. Considering that in all other rhino species, the adult male urinates in a backwards shower, while females and calves urinate in a stream, splash or squirt downwards (SCHENKEL & LANG, 1969) it is legitimate to explain the two types of urination for the Javan species in the same way. HUBBACK (1939) describes these patterns of urination for the Sumatran rhino. But for the Javan species it was assumed that the red liquid found on the leaves was blood from the rhino's nose. We never found a trace of blood, but the smell of urine was quite obvious.

In the Javan rhino ritualization is more pronounced in urination than in defecation. In considering the solitary way of life in dense vegetation, the value of a scent-marking system is evident. Its efficacy will gain by ritualization. In this respect there is a remarkable difference between the genus *Rhinoceros* and the African rhinos. In the latter, the bull also squirts urine in a shower, but in addition, both sexes scrape with their hindlegs in freshly deposited dung which results in scent impregnation of the footprints. In *Rhinoceros* defecation is poorly ritualized, while urination has undergone two different types of ritualization: The squirting of urine in the way common to all rhinos and the fixation of urination to wallowing. Obviously the method of the African rhinos agrees with their open habitat, while that of both *Rhinoceros* species is adapted to dense vegetation and the tunnel-like paths. As was pointed out elsewhere (SCHENKEL & SCHENKEL-HULLIGER, 1969) for the black rhino, squirting of urine is originally a reaction in the context of an encounter with another member of the species and was transferred to encounters with scent marks as substitutes of the partner and finally (by change of the releasing threshold) became an automatized scent-marking pattern. Urination while lying in a wallow is derived from a reaction common to many mammals, to urinate when coming into contact with surface water.

6. Resting and the need for cover

On most occasions where we followed fresh rhino tracks, we could only catch up with the animals when they were on a slow feeding trip or when they had stopped for a rest. Usually we found the animals between 10 a.m. and 2 p.m., the time during which they apparently more often rested than walked. On several instances we would hear a rhino from some distance walking and feeding in between and were able to follow at a distance. At intervals there was no noise from the animal and we could see that it remained motionless with its head hanging. Such phases would alternate with walking and feeding, gradually the resting interval became longer. The animal then preferably remained in dense undergrowth. Finally it stopped moving and feeding and remained on a spot.

On a number of occasions, we came, while tracking, upon animals standing motionless in dense vegetation. Usually we only saw the animal from a few meters and as soon as our scent reached it, it snorted and fled. On two occasions, animals, once an adult and once a subadult single animal, were found lying on the ground at noon.

Finally on five occasions animals were found between 10 a.m. and 2 p.m. while resting and sleeping in a wallow or river. This never occurred in 1967 when many wallows had dried out.

Resting rhinos were always very attentive. Their ears played permanently and immediately focused on any noise we produced when moving. When reached by our scent, the rhinos fled. This happened several times before we were near enough to see it. It is obvious that cover is essential for resting, and most likely – with the urge to rest – vigilance and the urge to search for cover increase. This behaviour complex has probably developed as a tradition under the persecution by man.

7. The track-system

Former authors (JUNGHUHN, 1845) describe well maintained track-systems in rhino areas. Reports exist especially from the end of the 18th and the first half of the 19th century when the rhinos were frequent in most forests, mentioning many large tunnel-like rhino tracks leading from the lowland up to the highest mountains. In Udjung Kulon there is no continuous track-system and there are large areas where no well trodden path is found. Paths are mainly seen in special topographical locations, most consistently along ridges, also as crossings from one valley to another over a low point of a watershed. Locally tracks are developed converging on wallows or crossing a valley or a river with steep banks or a sharp crest or thicket. Short tracks lead as ramps into river basins with steep borders.

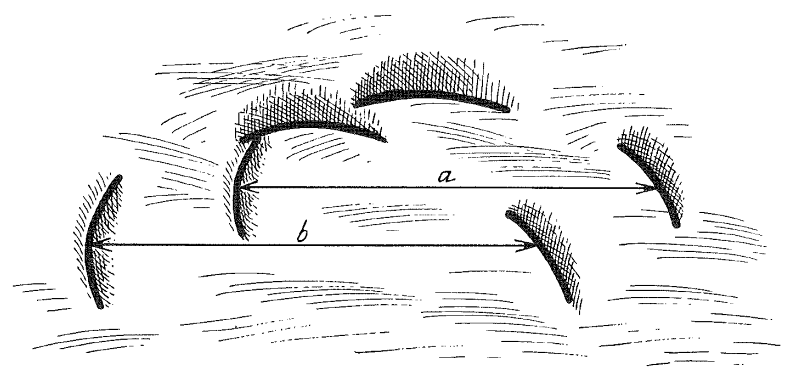

Fig. 6. Footprints of Javan rhino. Hindfoot (a) on top of fore foot (b).

Rhino paths are used for trips from one preferred location to another one. They suit the rhino's comfort, utilizing local advantages in topography and vegetation. Most well maintained paths are used by rhino and banteng concurrently. Nevertheless, the track-system is poorly developed in Udjung Kulon, obviously due to the low population density of both, rhino and banteng. A well developed track-system would be of advantage to the population. It would facilitate locomotion and also communication within the population. Apparently, the rhino have a strong tendency to walk on tracks; though they avoid human scent as much as possible, they like to walk on the few, well maintained patrol-paths of the reserve.

8. Patterns of locomotion

The usual pattern of locomotion is the pace common to all other rhinos, the horse and most ungulates of heavy build. The forefoot is lifted when the hindfoot of the same side is already half on its way. Then the hindfoot is deposited almost on top of the frontleg's pug marks *(Fig. 6)*. When the forefoot has made the step half way, the hindfoot of the opposite side is lifted.

Trotting was only observed in flight. Most probably it also occurs in premating behaviour and in fighting as with other rhino species. Gallopping was never seen over any distance. We had the impression that only the start to intense flight was made in a sort of gallop. Generally in rhinos, the gallop is not a frequent type of locomotion; it occurs more often in open habitat and on solid ground.

The ability of the heavy animal to master rough country is impressive. Rhino traces were found on the steep crests of G. Pajung; often traces of sliding over more than 1 m were seen on very steep and slippery slopes. The rhino is able to penetrate very dense and thorny vegetation. When passing under dense rattan palms, the extremely tough and rope-like stems of these hanging and climbing palms are pulled by the moving rhino until they split partially, their thorns being rubbed off. When a rhino moved through this type of vegetation, its pace appeared quite normal, only the noise revealed that the animal forcibly broke through obstacles.

Similar to the Indian, the Javan rhino does not hesitate to enter oozy clay. We found footprints of rhinos in locations where they had sunk more than 50 cm deep into the mud.

9. The pattern of daily activity

Unfortunately it was impossible to observe a single rhino for any length of time, so our statements which are based on track analysis mainly, are provisional.

Rhinos have rather irregular activity patterns as to place and time except that they reduce their activity during the hot hours of the day. We found them usually at noon resting in dense vegetation or lying in a wallow or – rarely – in a river basin. On four occasions rhinos were observed at night on a feeding trip, walking or bathing. Generally it seems that all activities can take place at day and at night, but rhinos seem to be more active at night and in the early morning than during the rest of the day. Since there exist no reports on an undisturbed rhino population, we do not know whether the preference for nightly activity has developed as a reaction to the persecution by man, or whether it is a reaction to the climatic conditions.

10. Social character and continuity of the population

Most of the rhinos which we saw or of which we saw only the footprints, were on their own. On two occasions two animals, mother and calf and several times the footprints of a large and a small animal (footprints of not more more than 23 cm), were seen together.

We found indications of a permanent loose association between 2–4 individuals of different size who together appeared and later again disappeared from an area. Yet these animals did not move in close contact with one another as an activity-unit.

On three occasions a rhino was heard to emit a loud blowing whistle in irregular intervals of more than a minute; in one instance the fresh footprints of another individual were detected in the neighbourhood. The whistle might function as a rather far-reaching signal between loosely associated individuals.

There was no indication that an adult male and a female stood together for any length of time; the pair bond is obviously not stable. Once we came upon the fresh footprints of two adult individuals which had followed one another to the beach. On a few other occasions we found the traces of an animal which had urinated frequently backwards-upwards onto the vegetation, presumably a bull, while following the trail of another rhino.

11. Relation to space: Preferred areas and nomadism

Since it was impossible to survey greater parts of the reserve within short intervals to obtain information on the movement of rhinos, we selected a small easily accessible area for regular surveys. After a number of daily trips, we, however, realized that the rhinos had left the area. We then included additional, more distant areas where we found traces of recent rhino activity. For this purpose we usually had to camp for a number of days. Again we found on several occasions that soon after our arrival there were no more fresh rhino tracks. Was the disappearance caused by our invasion of the area or did it simply occur in the context of the nomadic pattern of life? In a number of instances the rhinos obviously left the area after having come into contact with human scent. Yet, on other occasions rhinos had visited the area shortly before our arrival, had fed, wallowed and then moved away apparently without perceiving us. Many times we came into areas where we found a lot of old traces of rhino activity and no new ones, an indication that rhinos had visited the area some time ago and then left it again. Evidently, rhinos migrate irrespective of human interference. We have no reliable information on the size of the individual excursion range nor of the overall spatial-temporal pattern of movement.

In some areas we have found the same size footprints again after shorter or longer intervals. This could indicate that individuals have preferred areas which they visit from time to time. But there is no indication whatsoever that the Javan rhino in Udjung Kulon is fixed to a territory.

The areas in which concentrations of rhino activity were found are summarized for the years 1967 and 1968 *(Fig. 7)*. They include zones visited for feeding, wallowing and resting, and zones of passage.

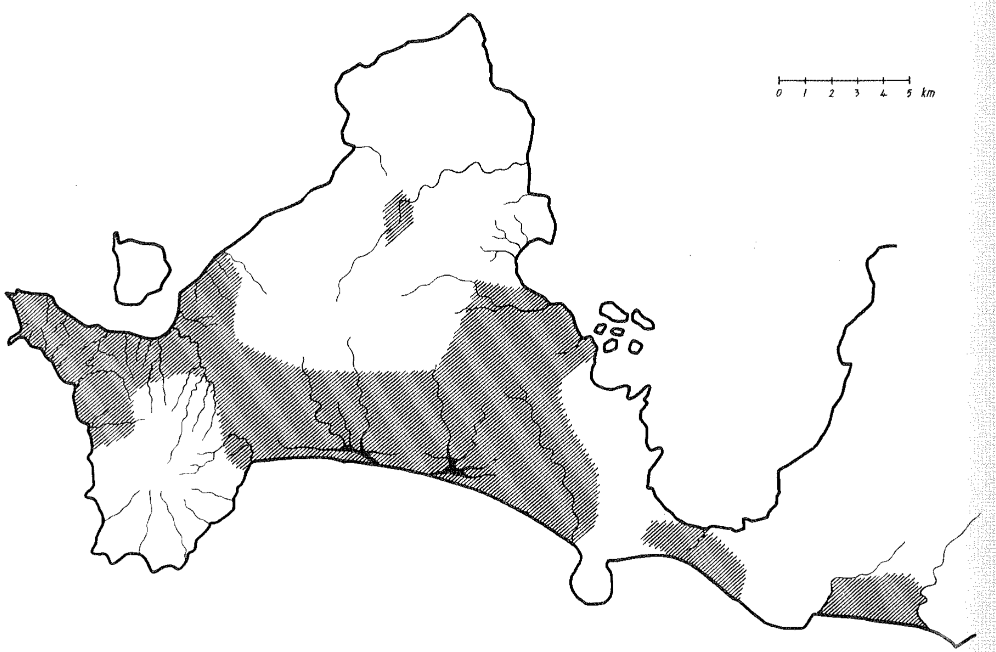

Fig. 7. Map sketch of Udjung Kulon indicating concentrations of rhino traces.

What is the ecological significance of the nomadism of the Javan rhino? The black rhinoceros *(Diceros bicornis)* is nomadic wherever its basic needs cannot be satisfied within a restricted area, e.g. where during the dry season surface water is far from feeding areas. It is more sedentary where water and food are available close by. In Udjung Kulon water is usually abundant, but food plants of the Javan rhino occur scattered and regenerate only slowly after having been browsed. Accordingly, the nomadism of the Javan rhino appears as an adaptation to the type of food plants, their scattered occurrence and to the rhino's feeding technique.

12. Reactions of rhino to man

During our study we observed different types of reactions of the rhino in encounters with man. The elementary patterns of these reactions, observed in 27 closely registered encounters, are summarized and analysed for their possible motivation and function *(Table 4)*.

In all encounters these elementary reactions were observed in sequences; some of these may be described:

TABLE 4

Elementary reaction patterns of rhino to man

Description	Motivation	Function
a. *Silent alertness:* The animal remains completely motionless except for its ears which focus in the direction of the disturbance *(Fig. 8)*. The reaction is caused by noise when approaching.	First degree of alarm excitement	To clarify the situation without being noticed
b. *Turning around in sudden alarm:* When standing, the animal suddenly turns around to face the observer with its ears erect. If lying at first, it suddenly rises and then turns around. The reaction occurs if the observer has approached without arousing the rhino's suspicion and the animal is suddenly aware of him. Alarm is provoked acoustically, but human scent may also be involved.	Higher degree of alarm	As above, but in more urgent situations, therefore without hiding
c. *Sudden rush away from disturbance:* After a. and b. the animal suddenly turns away from the disturber and crashes through the vegetation, first trotting, later pacing. Most probably this reaction occurs when the rhino has not perceived human scent, but when the disturber is rather close.	Tendency to avoid an encounter	Low intensity flight

TABLE 4 (continued)

Description	Motivation	Function
d. *Explosive snort and rushing away* (= more intense form of c.): The animal utters a loud and terrifying snort and crashes through the vegetation for a few seconds, probably starting with gallop and then changing to trot. This reaction is aroused by human scent. Occasionally it happened that the rhino was already on the alert before being reached by human scent. Possibly in a very shy animal, the approach of a source of noise alone can cause this reaction.	High intensity of avoidance behaviour associated with a weak component of aggression	First produces frightening effect following by flight or a phase of silence to clarify the situation or to sneak away. Typical reaction of forest dwellers
e. *Snorting and rushing in aggressive exploration:* The violent rush is clearly directed against the disturber. The reaction is caused by human scent associated with noise whereby the latter directs the rush. A similar rush of a rhino was described by HOOGERWERF (1938) who, however, assumed that the rhino had not perceived his scent.	More pronounced component of aggression, not incessant, with latent tendency to flee	Aggressive exploration
f. *Nervous steps on the spot and empty horn-push:* On two occasions a rhino which had at first reacted with c. or d. was later approached again when it stood attentive in dense vegetation. From time to time it made nervous steps on the spot, turning its head with ears erect. A few times it shook the head upwards as in an empty hornpush. The reaction was probably released by inconsistent and weak noise.	Components of tendency to explore, of aggression and of inhibition, all of low intensity	Exploration on easy going terms
g. *Sneaking away:* The rhino sneaked away silently after a., c. or d.	Tendency to avoid an encounter in a status of low or decreasing tension	See above, d.
h. *Moving off:* The rhino moved off in a noisy way, it could not be decided whether it was trotting or pacing.	Lasting strong tendency to avoid a disturbance	See above, d.

I. Sequence: a, b, d, h: The rhino was first alerted, then turned around to face the disturber, reacted with a snort, rushed away and continued for some time to move noisily.

II. Sequence: b, d, a, d, a, d, h: The rhino was stalked by the observer; it turned around, reacted with a snort and rushed away for a few seconds, then remained completely silent; then it repeated the snort-and-rush twice, finally it moved off noisily.

III. Sequence: a, b, c, a, f, c, g: A lying rhino was alerted, it rose in alarm and without snorting rushed through the thicket; then it

Fig. 8. Javan rhino on the alert in dense vegetation.

remained silent; when approaching carefully the observer saw the rhino again on the alert with its ears focused towards him. The animal after some minutes became disquiet, stepped on the spot and threw its head up. Suddenly (when reached by human scent?) it rushed off noisily into dense vegetation and then sneaked away silently.

IV. Sequence: b, e, a, d, a, d, h: A lying rhino rose in alarm when the observers were quite close, it turned around, rushed forward in their direction while snorting. They hid behind a tree. The rhino stopped at some meter's distance, then slowly approached. Suddenly, when very close, it snorted and rushed off for some meters, remained motionless, snorted again and rushed off.

During our stay in Udjung Kulon it was reported that a pilgrim out of a group on its way to Sanghijangsirah (southwestern tip of Udjung Kulon) had been attacked by a rhino in a bamboo thicket near Tjibunar. The man was said to have been bitten, knocked over and bitten again. He was seriously injured and had to be carried to the next village. The pilgrims had entered the reserve illegally and disappeared before we could clarify the incident.

Also, according to former authors (see SODY, 1959; HOOGERWERF, 1938) the Javan rhino has been reported to sometimes attack man. As with the Indian rhino, wounds are inflicted by bites with the incisors of the lower jaw.

Obviously the factors which determine the reactions of rhino to man are heterogeneous. Not only the initial disposition and the type of disturbance are essential; the reactions of both partners to one another shape the outcome. The following circumstances seem to decide between aggression and flight in the rhino: Self-assurance of the rhino towards man and the possibility to locate man optically, especially while moving, are factors in favour of attack; on the other hand, the shyness of the rhino, the difficulty to locate the disturber and the presence of human scent concurrently reduce the probability of an attack.

It seems justified to assume that rhinos not only show immediate reactions to man, but due to past experience also long-term changes in disposition. As has been shown for other rhino species, the reactions to man are influenced by tradition transferred from the mother to the calf (SCHENKEL & SCHENKEL-HULLIGER, 1969). Most probably the shyness of the last Javan rhinos is a tradition which has developed under the pressure of persecution; perhaps even their preference for certain areas in Udjung Kulon is part of this tradition.

C. The present situation of the rhino population in Udjung Kulon

1. Size and composition of the population

a) Age classes, a comparison between the Indian and the Javan rhino

Immature rhinos were seen only on three occasions, two times together with the mother and once one on its own. The number of immatures had to be estimated from the number of small footprints. Unfortunately, we lack for the Javan rhino sufficient evidence concerning the relation between size of footprints and age of the rhino. For comparison, the respective data of Indian rhinos kept and bred at Basel Zoo were used. The width of the footprints of adult Indian rhinos is in the same range as that of Javan rhinos *(Table 5)*, only the hoof of the central toe is wider in the Indian rhino *(Fig. 9)*. It seems legitimate to assume that the width of the footprint after birth increases at a similar rate in both species. In

TABLE 5

Comparison of footprints of adult Indian and Javan rhinos

	Width of forefoot (cm)	Width of hindfoot (cm)
INDIAN RHINOS *		
"Arjun" ♂ at approx. 8, 10 and 11 years	27–29	25–27
"Joymothi" ♀ at approx. 21 years	26–27	23.5–25
"Moola" ♀ 10½ years	27–28	25–26
JAVAN RHINOS		
Largest footprints of single animals	29.5–30.5	28–30
Footprints of mothers accompanied by an immature animal	26–28	25–27

* Living at Basel Zoo, measured at intervals until March 1968.

Basel Zoo the footprints of three Indian rhinos of known age were recorded during the first years of their life *(Table 6)*. These figures show that for this species there is no sexual difference of footprint size during the first year and that in females full size is reached after 2½ to 3 years. With 3 years they also reach sexual maturity. It appears justified to correlate width of footprints and age classes for the Javan rhino according to the time-table of the Indian rhino *(Table 7)*.

b) Size of the population and age classes

The data which are summarized in *Table 7* were obtained by two different types of counting:

— With the census of November 1967 and the one of August 1968, maximum and minimum numbers were obtained for the whole population and for each class of footprints.

— From all the footprints which had been registered during 1967 and again during 1968, the % distribution of the different classes of footprints was calculated for each of the two periods. These data were collected mostly in those parts of the reserve which we chose for special surveys. Therefore they may not be representative for the whole reserve. It is well possible that very young animals do not migrate as much as older ones and were missed to a larger extent by this type of survey. The percentage of small calves therefore may be lower than in the census.

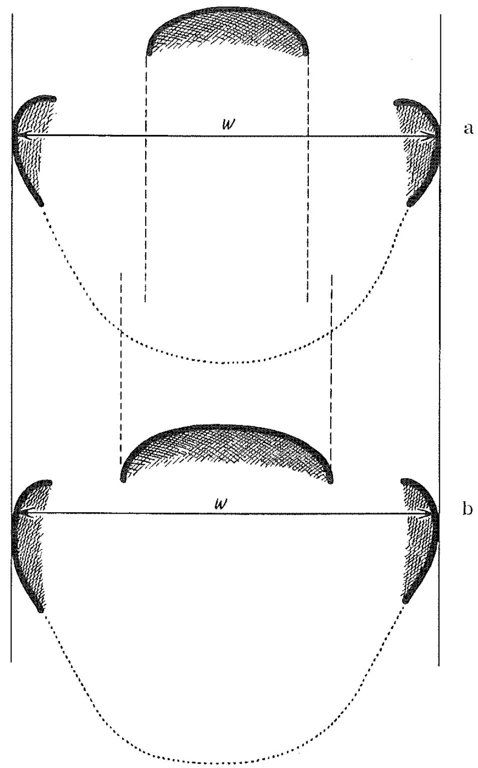

Fig. 9. Footprints of the Javan (a) and the Indian (b) rhinoceros; width of the footprint.

TABLE 6

Footprint measures of immature Indian rhinos (bred at Basel Zoo)

Individual born	«Pandur» ♂ 7. 7. 1967		«Puri» ♂ 22. 12. 1967		«Nanda» ♀ 25. 8. 1965	
Age	Forefoot	Hindfoot	Forefoot	Hindfoot	Fordfoot	Hindfoot
19 days	12–12.5	12–12.5	—	—	—	—
56 days	14–14.5	13.5–14	—	—	—	—
4 months	16.5–17	16–16.5	17.5–18	16.5–17	—	—
$6^1/_2$ months	20	17.5–18.5	19.5–20	19	18–20	17–18
9–$9^1/_2$ months	22–23	20	22–23	20–21	—	—
$11^1/_2$–12 months	23–24	20–21	23–24	20–21	—	—
14 months	—	—			22–23	22–23
21 months	—	—			24–25	23
$25^1/_2$ months	—	—			24–25	23
32 months	—	—			26	23–25

TABLE 7

Results of rhino census and proportion of footprint classes

Footprint classes	I	II	III	IV	V	Total
Forefoot	< 20 cm	20–23	24–25	26–28	29–30	
Estimated age	< $^1/_2$ yr	$^1/_2$–1 yr	1–2 yr	adult ♀♀ subad. ♂♂	adult ♂♂ largest ♀♀	
1967						
Census (Nov.)	1	1–2	2–3	9–10	8–12	21–28
All footprints recorded	2	35	54	106	85	282
= %	0.7	12	19	37.5	30.5	100
Probable numbers of rhinos	1	2–3	5	9	7	24–25
1968						
Census (Aug.)	1	1	2	8–14	8–11	20–29
All footprints recorded	4	18	35	107	107	271
= %	1.5	6.5	13	39	39	100
Probable numbers of rhinos	1	1–2	3	10	10	25–26

Altogether the results obtained with the two different types of survey agree fairly well.

The average annual increase of immature animals (class I and II) calculated from both years and both types of estimate was 2 to 3 animals. If females reach sexual maturity as in the Indian rhino with approximately 3 years and are pregnant for about 16 months (SCHENKEL & LANG, 1969), the females belonging to category IV would for the first 2–3 years have no calf. If we assume a sex ratio of 1 : 1 altogether, 3–4 individuals of category IV would be females without a calf. The population would then be constituted as outlined in *Table 8*.

TABLE 8

Estimated proportions of the different age and sex classes

Immatures 0-2 years	Single adult females	Mothers	Subadult and adult males	Total
5–6	3–4	5–6	10	23–26

c) *Sex ratio*

A sex ratio of 1 : 1 has been assumed for the above calculations, though little information on the actual numbers of males and females exists. Former authors have claimed that the female Javan rhino has no horn or only a small hump. SCHUHMACHER (1966) has photographed a Javan rhino which had no horn, but also the ears of this individual were rudimentary and it may not have been normal. All the rhinos wich we ourselves have seen with the exception of the three immatures had a definite horn. Also, all the rhinos which the guards reported to have seen in 1967 and 1968 had a horn. Clearly amongst all these individuals some were females.

In the black rhinoceros a sex ratio of 1 : 1 has been calculated for three different areas (KLINGEL & KLINGEL, 1966; ROTH & CHILD, 1968; SCHENKEL & SCHENKEL-HULLIGER, 1969). Considering the number of immatures, it is justified to accept a similar proportion for the Javan rhino in Udjung Kulon.

d) *Life cycle*

Based on our observations in Udjung Kulon and on studies of the Indian rhino in the zoo (LANG, 1961; SCHENKEL & LANG, 1969), the life cycle of the Javan rhino has been outlined tentatively *(Table 9)*. The length of the reproductive phase of females is unknown; in comparison with other rhino species it may be assumed that the reproductive phase lasts about 30 years. We have no evidence for the rate of mortality not due to poaching.

TABLE 9

Life cycle of the Javan rhino: a suggestion

♀♀	The first 1–2 years associated with the mother	Sexual maturity at 3 years	First calving at 4–$4^{1}/_{2}$ yrs	Interval between parturitions $2^{1}/_{2}$–3 yrs
♂♂	Like ♀♀	From 2 to approx. 6 years on independent but still subadult		Sexually mature from 6 years on

2. Discussion of Udjung Kulon as a habitat

The last Javan rhinos survived in Udjung Kulon, because in this remote and hardly accessible area they were comparatively well protected from man. With the present low population density, the chance to poach a rhino is relatively small. If the rhinos are protected from poachers by a well organized guard-system, there is a good chance that the population will increase. With a higher population density, poaching will be easier and therefore protection will even gain in importance.

In normal years the needs of the rhino such as cover, wallows, and bathing places are provided amply in Udjung Kulon. Only as to food plants the habitat does not appear optimal. The saplings of the plant species on which the rhino feeds are widely scattered and not frequent. Nowhere in the reserve larger stands of food plants are found. In this respect the nomadism of the rhino is essential. A low population density when not in balance with the food supply aggravates the situation of the rhino in three ways:

— Saplings of food plants are not chopped or broken in time to grow new shoots within the reach of the rhino; if growing without having been chopped, they soon become inaccessible for the rhino.
— The track-system, which would facilitate movement if well maintained, loses its favourable qualities.
— Communication within the rhino population suffers directly with the low population density and indirectly with the deterioration of the path-system.

At present, the composition of the rhino population shows that its reproduction is not abnormally low; seemingly the animals are in good condition and do not suffer from any deficiency of the habitat. But future population growth due to effective protection might lead to serious food shortage.

V. Synopsis and conclusions

The Javan rhino is adapted to a transitional habitat between low or open (usually secondary) vegetation and tropical forest. It is specialized to feed on saplings of many species of trees. In former times it was accordingly attracted to the secondary growth of areas cleared by man. In the ensuing ecological conflict, the rhino was defeated and could only survive in those areas for which man did not compete – high mountains, dense and swampy forests.

With spreading human settlement and improved weapons, the species eventually has been eradicated within its former distribution range, Udjung Kulon being its last refuge.

Besides food, the Javan rhino requires mud wallows and bathing opportunities and cover from heat, irradiation and, most important, from man, the only enemy of the species. The feeding technique of the Javan rhino is also typical for the other forest-dwelling rhino, *Didermoceros sumatrensis* (THOM, 1936; HUBBACK, 1939; STRICKLAND, 1967). In chopping saplings, cracking them, or breaking them completely, the rhino does not kill the plants but induces them to grow new shoots within its reach. This regeneration process takes time. In Udjung Kulon where foodplants are scattered and rather scarce, rhinos therefore have developed a nomadic way of life and forage while on the move. Size and overlapping of the individual excursion ranges and the patterns of movement and nomadism are not yet defined.

As in other rhino species, wallows and rivers are not only used for wallowing but also for resting. These rests have a temperature-regulating function and a protective effect on the skin; besides, urination in the wallow contributes to scent-marking the rhino's paths. The scent attaches to the whole body and adheres to the tunnel-like trails in dense vegetation. Besides urinating in the wallow, the Javan rhino also squirts urine while walking; probably, as in other rhino species, the bull, in a ritualized way, squirts in a backwards-upwards shower. In females urination is probably less ritualized unless they are on heat.

The role of defecation in olfactory communication within the population is less pronounced than in the African rhinos. A majority of dung heaps is deposited in rivers and rivulets, often repeatedly in the same location. Defecation also often takes place in a location near main paths or crossings. The Javan rhino does not rub its hindfeet in the freshly dropped dung as do the African species. This technique of trail-marking is more adapted to open and dry country, while urination combined with wallowing more to a wet habitat and dense vegetation.

Former observers have reported the many well trodden paths which were maintained by both, rhino and banteng. Due to the low population density of both species in Udjung Kulon, the path-system is poorly maintained; only in special locations where locomotion is canalized, the paths are well trodden.

The Javan rhino, like most other heavy ungulates, can pace, trot, and gallop; it is able to cope with very rough country, steep and slippery slopes, mud, very dense and thorny vegetation. All our observations indicate that the Javan rhino's activity is not governed by a stereotyped daily program; continuous observation of an animal was, however, not possible.

The Javan rhino is a solitary animal; mother and calf live together for about 1–2 years, the association of bull and cow is certainly for short duration. Groupings were observed of 2 to 4 animals which live probably in a permanent loose association. Besides scent traces, a special far-reaching whistling call may function as a signal between members of such a grouping. The Javan rhinos do not defend territories, but live as independent nomads in large excursion ranges used by several individuals.

The rhino's reactions to man are shaped by the long enmity between them. Most individuals are extremely shy, yet in some of them aggressive components were observed. The excitement of the rhino is especially intense if it perceives human scent. Scent alone usually elicits flight, but if combined with an acoustic stimulus, the rhino may first show aggressive exploration behaviour. When the human disturber is seen, self-confident animals may even attack.

The small rhino population of Udjung Kulon seems to reproduce adequately. Whether it will increase in the future, depends entirely on its protection from poaching and on sufficient food supply. Udjung Kulon is not an optimal habitat as to food. Preferred foodplants occur widely scattered and are rather scarce. In many parts of the reserve plant communities have developed which do not permit saplings of rhino foodplants to develop. If, thanks to strict protection, the rhino population will increase, the habitat will need improvement by well planned measures of management. At present, however, the efforts of WWF and the Indonesian government to protect Udjung Kulon from poachers are paramount to the survival of the species. With the future in view, already now efforts have been started to develop measures of management in favour of the rhino. Finally the possibility to capture a few rhinos of both sexes and to breed them in qualified zoos should be considered when the population has increased.

The species of the Javan rhinoceros must be saved from extinction by all means. There is a good chance of success provided the efforts of WWF in collaboration with the Indonesian government are continued.

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Zusammenfassung

Im Rahmen einer Mission des World Wildlife Fund untersuchten die Autoren Ökologie und Verhalten der letzten Java-Nashörner (*Rhinoceros sondaicus* Desm.). Diese leben im Udjung Kulon-Reservat, im westlichsten Zipfel von Java, dem letzten Gebiet, in dem sie noch nicht der menschlichen Verfolgung vollständig erlegen sind. Das Reservat ist fast völlig mit dichter, hoher Vegetation, meist mit Wald, bedeckt. Im Unterholz dominieren vielerorts Palmen. Ein Nashorn bekommt man nur selten zu Gesicht, am ehesten noch, indem man bei feuchter Witterung einer frischen Spur folgt. Die Tiere sind dem Menschen, insbesondere seinem Geruche gegenüber äußerst scheu. Zu direkter Beobachtung des Verhaltens bietet sich nur selten eine Gelegenheit. Dennoch war es möglich, durch Auswerten aller Spuren der Nashörner, Fuß-Spuren, Wechsel, Mist, Harn, Suhlen, Badebecken, Freß-Spuren, ein differenziertes Bild der Lebensweise, der Verhaltensformen und der ökologischen Bedürfnisse der Art zu erarbeiten. Auch die Größe und Zusammensetzung der Population konnte annähernd bestimmt werden. Aus den beiden Zählungen, in den Jahren 1967 und 1968, ergab sich, daß der Bestand sich zwischen 20 und 30 Individuen hält; davon dürften 5—6 Tiere weniger als 2 Jahre alt sein. Die Population pflanzt sich demnach fort. Für die Erhaltung der Art ist strikter Schutz vor Wilderern die wichtigste Voraussetzung. Auf weite Sicht sind Maßnahmen zur Vermehrung der Futterpflanzen für das Nashorn dringend, da sämtliche der regelmäßig gefressenen Arten, vor allem Schößlinge verschiedener Baumarten, im Reservat eher selten sind. Untersuchungen, auf denen die Planung derart gezielter Maßnahmen aufbauen kann, wurden bereits in die Wege geleitet.

Résumé

Dans le cadre d'une mission du « World Wildlife Fund », les auteurs ont fait des recherches sur le comportement des derniers rhinocéros de Java (*Rhinoceros sondaicus* Desm.). Ces animaux vivent dans la réserve d'Udjung Kulon, la presqu'île la plus occidentale de Java. Cette réserve est presque entièrement recouverte d'une végétation haute et dense, principalement de nature forestière. Dans ces conditions, il est très difficile d'apercevoir et d'observer un rhinocéros ; c'est lorsque la terre est humide que l'on peut reconnaître ses traces et, en pistant l'animal, on a peut-être la chance de le rattraper. Il s'enfuit aussitôt qu'il perçoit l'odeur de l'homme, ce qui fait que l'observation directe ne fournit que des résultats fragmentaires sur le plan éthologique. Cependant, les rhinocéros laissent des traces diverses : des empreintes, des passées, des bauges, des dépôts selles et de l'urine, et ils occasionnent egalement des dégâts aux plantes fourragères. Cela permet, par une analyse soigneuse, de tirer des conclusions concernant les habitudes et les besoins écologiques de l'espèce. Un recensement des individus de cette population de rhinocéros a été réalisé en 1967 et 1968 sur la base de l'analyse des traces fraîches. L'effectif se monte de 20 à 30, dont 5 ou 6 semblent avoir moins de 2 ans, ce qui indique que l'espèce se reproduit. Pour garantir la survie du rhinocéros de Java, il faut absolument qu'Udjung Kulon jouisse d'une protection efficace. En outre, il faudra prendre des mesures pour augmenter le nombre des plantes fourragères préférées par le rhinocéros. Ce sont pour la plupart les pousses de différentes sortes d'arbres qui sont bien loin d'abonder dans la réserve.