THE ECOLOGY AND BEHAVIOUR OF THE GREATER ONE-HORNED RHINOCEROS

By

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A dissertation submitted to the University of Cambridge for
the degree of Doctor of Philosophy

Selwyn College
Cambridge.

December 1978

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36	1	7	include'
47	3	3	numbers
54	3	9	on elephant back or on foot than from one in a machan
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99	1	8	three were still without calves and at least
102	4	2	(Section 3.2.2)
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116	4	1	I reduced the first bias
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133	table 4.5		Tall grassland, Monsoon: -.63
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164	1	7	June, July, November and December.
	2	2	across its boundaries,
174	table 4.9		M056,1975: 1 4 3 - F113,1975: 2 - - -
175	para 2	line 3	male ranges were less variable
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	table 4.15		m087, Number of Locations: 75
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199	para 1	line 1	five individuals were seen on over 2% of visits
		2	to blocks A,B,C or G, but never in blocks D or E.
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208	5	1	changes
209	2	1	highest rate of sightings was in the
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217	fig. 5.1		A♂ S♂
218	5.2		expressed as a percentage of all recorded
	para 2	line 1	57.7%
225	1	2	Nine of these sounds
233	fig. 5.3		Neutral outcome: 22 (x2)
235	table 5.11		S, Total: 112, 35.3
236	para 2	line 3	per 100 hours in associations was
238	1	6	females, roaring appeared to
244	2	1	squirting
247	1	7	urination on
255	1	2	tracks, dung or urine
	2	1	60.2%
261	4	1	The rhino_ took
267	table 5.26		A♀ with C, Total: 98.0, (10.9%), (1.1% C, Total: (2.6%

p. 270	para 1	line 4	63.3%
274	fig. 5.8		A♂
275	5.9		A♂
	para 1	line 2	initiated against rhinos of other sex and age classes.
281	fig. 5.14(leg)		The frequency of females in oestrus, according to
285	para 4	line 0	5.5.2.3
	2	6	shuffle
293	3	6	physical contact than infants did.
297	fig. 5.16		Individual 100: n= 46
	5.17		110 113 122, 161: n= 36
306	table 5.36		M003, Mean observation duration: 7.5
310	para 3	line 5	seem
329	1	3,4	cannot have more offspring by successive matings with different males,
332	4	2	are partly genetic
339	2	8	are the offspring of the resident strong male.
360	3	3	rhinos may have been subject to predation
373	2	16	gradual afforestation
379	3	7	Laokhawa
394	1	4	The soils are
401	4	1	DIPTEROCARPACEAE
	6	1	* Equisetum sp.
		2	_ E. debile Roxb.
402	1	32	* Erianthus filifolius
		34	* E. rufipilus
404	14	1	* Oxalis corniculata
406	3	1	SOLANACEAE
		4	_ S. surabtense
	11	1	* Typha elephantina
407	(a)		Order Lagomorpha: Rabbit Oryctolagus cuniculus Linnaeu Order Cetaceae: _ Narwhal Order Proboscidae: Loxodonta africana Blumenbach
408			Order Perissodactyla: Malayan Tapir Tapirus indicus Desmarest
419			m076,D1: 46 F130,G3: 8 f165,E2: 6
420			f098,Blocks A to D, ONDJ + Total: 1 47 m087,Blocks A to E, ONDJ + Total: 3 20 M045,Blocks F to G, JJAS + Total: 64 115 m076,Blocks A to E, FMAM + Total: 5 8
422	(b)		A♂♂ S♂ ♂Calf ♂Calf
423	(c)		A♂♂ ♂ Calf (x3)
424	bottom		$F \times A \times 10^{-2}$
428		5	Camper, P. (1782)
Plate 35 Caption			The animal on the right

Throughout the dissertation:

For:-		read
Mallotus phillippensis		Mallotus philippinensis
Zizyphus jujuba		Zizyphus mauritania
Bauhinia malabaricum		Bauhinia malabarica
Borner (1977)		Borner (1979)

PREFACE

The work described in this dissertation was carried out from the Department of Applied Biology, University of Cambridge under the supervision of Dr J.C. Brown, Dr G.B. Schaller and Dr B.C.R. Bertram. This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration. No part of this dissertation has been submitted to this or any other university for any degree or diploma.

ACKNOWLEDGEMENTS

This study would not have been possible without the help of several organisations and many people to whom I wish to express my sincere thanks. There is only space here to mention a few of the people who gave so generously of their time and skills.

The project was financed by the New York Zoological Society and conducted under the auspices of that Society's Center for Field Biology and Conservation: I am particularly grateful to Mr W. Conway and Dr G.B. Schaller for their keen support. His Majesty's Government of Nepal permitted me to live and work in the Royal Chitawan National Park and provided me with highly trained elephants and elephant drivers. Conservator of Forests, Mr E.J. Rana and Mr B.N. Upreti and Mr H.R. Mishra of the Wildlife Section of the Forest Department wholeheartedly supported the project and helped me all they could both in Kathmandu and in Chitawan. The National Geographic Society donated as much colour photographic film as I could use, and Rank Pullin Controls lent me an image-intensifying device which greatly facilitated nocturnal observations. During the period I spent writing up in Cambridge I was very grateful and honoured to be elected a Fellow of Selwyn College and to receive a grant from the W.A. Meek Fund to supplement that from the New York Zoological Society. The Department of Applied Biology kindly provided me with a spacious room in which to write.

Mr J. Blower helped me to plan the study while I was still in England and continued to assist in numerous ways while I was in Nepal. Park Wardens T. Maskey and F. Poppleton were frequent visitors to my headquarters and were always ready to help in any way. The park guards always welcomed me to their guard posts and guided me cheerfully around their beats at all hours of the day and night. The elephant drivers at Sauraha were also keen and expert helpers; in particular Naryan who also taught me much about the

animals and plants of Chitawan. I was always sure of a welcome at Tiger Tops Jungle Lodge when I visited the west of the Royal Chitawan National Park. I am most grateful to Chuck and Margaret McDougal, Jim and John Edwards, Lisa Van Gruisen, Captain Gurung and the staff of Tiger Tops for the frequent loan of elephants, innumerable delicious meals and many hours of companionship.

I thank Chuck McDougal and John Seidensticker for many discussions on the ecology and behaviour of the animals of Chitawan; they and John Edwards, Frank Poppleton, Kirti Man Tamang and Mel Sunnquist kindly gave me information on rhinos whenever they saw something interesting. I am grateful also to Hardy Fueherer and Dieter Plage for flying me over my study areas on several occasions.

Simon Michell and Ranald Laurie helped me keenly, energetically and fearlessly as field assistants for several months. I am most grateful for their considerable help and for their company. Somala ('Maila') Kumhal was my most constant assistant and companion. He turned his hand to everything from elephant driving to cooking and language teaching, arranged the building of my houses and machans and was a keen,observant and almost tireless companion during long nights of rhino watching. I thank Maila in particular, his family and many of the other people of Jaimangala and Sauraha who helped me during the project in so many ways.

I would also like to thank those people with whom I stayed during my visits to Kathmandu, in particular Frank and Inge Poppleton at whose home I was a frequent visitor. I often burned the midnight oil there while writing up my six-monthly reports. My thanks also to Lisa Van Gruisen, Belinda Wright, Aledis Green and Dina Sackman for help in typing and duplicating my reports, and to Jim Edwards and Elizabeth Hawley for looking after my mail in the Tiger Tops office.

Dr G.B. Schaller, Dr J.C. Brown, Dr N. Owen-Smith and Professor R. Hinde kindly read and commented upon my field reports while I was in Nepal.

Several people, notably my parents, Mr and Mrs Alan Laurie, Ranald Laurie, Simon Michell and Ian Mackrill came out to Nepal loaded with project supplies. I am also grateful for the help of Dr R.M. Laws who arranged for rhino teeth to be sectioned at the British Antarctic Survey, to the staff of the herbaria at the Department of Medicinal Plants, Kathmandu, Kew Gardens and the British Museum (Natural History) for plant identifications.

The dissertation has benefitted from the comments, criticisms and suggestions of many people, including Dr B.C.R. Bertram, Mr D. Brown, Mr J. Fadden, Dr A.H. Harcourt, Dr P.J. Jarman, Dr R.C. Malpas, Dr C. Marsh, Dr R.C.D. Olivier, Mr N. Polunin, Dr D. Rasmussen, Dr D. Watling and Miss H. Uryu. I wish to thank all these people; in particular Brian Bertram who spent many hours reading and discussing the initial drafts with me, and Haruko Uryu who typed the initial drafts and drew many of the figures. Thanks also to Pat Reay who typed the final version and to Mr S. Revell for his expert photographic assistance.

ABBREVIATIONS

Apart from standard abbreviations, and those explained in the text, I have used the following notations to describe rhinos' sex and age classes.

(a) General

A = Adult
S = Sub-adult
C = Calf

Thus, A♂ = adult male and S♀ = sub-adult female. In this context, ? = sex not determined; thus S? = sub-adult of unknown sex. Also, A♀ + c = a cow-calf pair.

(b) Identified individuals

Prefixes to individual identification numbers signify the sex and age of the individual;

thus M = adult male
m = sub-adult male
F = adult female
f = sub-adult female.

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SUMMARY

A field study of the greater one-horned or Indian rhinoceros (*Rhinoceros unicornis* L.) was carried out in the Chitawan Valley of southern Nepal between December 1972 and June 1976. The sub-tropical riverine forests, swamps and up to eight metres tall grasslands of Chitawan are probably similar to those in which the Indian rhino evolved. The monsoonal climate, fires, floods, frequent changes in river courses and the activities of man and his domestic stock result in a great diversity of early successional vegetation stages on the valley floor.

Rhinos were observed on foot, from elephant back and from tree-platforms, for a total of 1,182 hours (6,401 sightings, 3,126 rhino hours). More than 200 rhinos were individually identified from differences in horn shapes, nicks in the ears and bumps and irregularities in the patterns of the skin folds. The total population size was estimated to be between 270 and 310 individuals, with population densities, in the favoured flood plain habitats, of up to 4.85 rhinos per km^2. The overall sex and age composition of the population was 32.3% adult females, 19.9% adult males, 21.2% sub-adults and 26.6% calves. Females first calved at a mean age of 7.1 years, and the median intercalving interval was 2.8 years. Minimum annual mortality rates were estimated to be: perinatal - 5.6%, juveniles - 8.5%. sub-adults - 1.2%, adults - 3.4%. Causes of death included poaching, tiger predation on the calves and intraspecific fighting among the males. The population was estimated to be increasing at a rate of between 2% and 6% per year.

Rhinos fed from 183 species of plants belonging to 57 botanical families, but grass (50 species) made up between 70% and 89% of their diet according to the season. Other foods included browse and aquatic plants. Rhinos spent 36% of their time feeding during the monsoon and between 57% and 65% during the winter and the spring. Considerable seasonal variations in food availability resulted in regular movements of rhinos between habitat types. In general, rhinos' ranges were smallest in the areas of greatest habitat diversity. The mean '90% range' area (smaller than the total range) for the 37 most frequently sighted individuals was 3.26 km^2, and there were no significant differences between the range sizes of each sex and age class.

Rhinos were predominantly solitary, although temporary aggregations at wallows and feeding grounds were fairly frequent. Only 9.6% of observations were of groups other than cow-calf pairs. The most common type of group consisted of sub-adults - mainly sub-adult males. Ten auditory displays were distinguished and visual displays, although less striking, included baring the lower incisor tusks. Scents were carried in the dung, the urine and the pedal scent gland. Squirt-urination and foot-dragging displays were performed only by breeding males.

There was some degree of range exclusivity among breeding males, but no true territoriality. Poor visibility and the relatively unpredictable distribution of resources in time and space have perhaps selected against a territorial mating system. Relationships between ecology and social organisation are discussed with reference to other species.

Threats to the continued survival of the Indian rhino include poaching, encroachment by cultivators and stock-grazers, erosion as a result of annually increasing flood levels and invasion of some of the Indian reserves by exotic plants. In order to spread the risk of a catastrophe and to ease the possible overcrowding in the two national parks, reintroductions of rhinos to other protected areas are proposed.

1. INTRODUCTION

1.1 Aims of the study

This dissertation concerns a study of the ecology and behaviour of the greater one-horned rhinoceros (*Rhinoceros unicornis* Linn.) in the Royal Chitawan National Park, Nepal between December 1972 and June 1976. Very little was known of the biology of the greater one-horned or Indian rhino before this study began.

The main aim of the study was to provide information about this rare and endangered species, which would be useful in making plans for conservation and management. Information was needed on:-

(a) numbers and distribution,
(b) population dynamics,
(c) diet,
(d) movements,
(e) behaviour and social organisation.

Beyond the purely practical aims of the study, I wanted to investigate the relationships between ecology and social organisation, and the selection pressures for the observed social organisation. I aimed to make comparisons with the ecology and behaviour of other ungulates, especially rhinos, and to consider carefully the ways in which individual differences in behaviour might affect reproductive success.

1.2 Previous knowledge of the species

There are numerous historical records and hunters' tales concerning the Indian rhino, and several anatomical treatises and reports on the species in captivity. This study, however, is the first prolonged scientific study of the Indian rhino in the wild. The African rhinos, on the other hand, have been studied in detail, and there is also some information available on the two south-east Asian species. Brief descriptions of the five living species of rhinos and their distributions, and the main sources of information are given in Appendix A. Here, I give a brief account of the literature concerning the Indian rhino.

In the Chandogya Upanishad of 900 BC, the rhinoceros was recorded as an animal which, with the elephant and the buffalo, lived in marshes and grazed on river banks (Rao, 1957). There are even older records of the species: 4,000 year old carved seals from Harappa and Mohenjodaro in Pakistan bear unmistakeable representations of *Rhinoceros unicornis* (Lang, 1961). The first reference to the Indian rhino by a western author was by Ctesias, the Greek physician to Queen Parysatis of Persia, who wrote a book about India in which he mentioned the "Indian Ass" from whose horn a poison detecting cup could be made. Although Ctesias' description was rather muddled and included cloven hooves and a horse's mane, the reported properties of the horn were not his invention. Cups carved from rhinoceros horn were believed by many to be a protection against poison, and medicinal and magical properties were, and still are, attributed to the rhino's horn and to most other parts of its body (Casal, 1933; Prater, 1971; Hoogerwerf, 1970; Van Strien, 1974).

Rhinos were exhibited occasionally in Alexandria during the second and third centuries BC and,more frequently, in Rome from the first century BC onwards. It appears that most of these rhinos were the African species, *Ceratotherium simum* (Appendix A), although *Rhinoceros unicornis* was exhibited occasionally in Rome during the early years of the Empire (Gowers, 1950). There are no unequivocal descriptions of the Indian rhino in the classical literature until that of Strabo who may have been describing an animal given to Augustus by an Indian ruler and exhibited in Rome in 11 BC (Gowers, 1950).

After the final collapse of the Rome Empire and the sealing off of the East by the rapid spread of Islam, only descriptions of rhinos remained in Europe. Although several authors had described rhinos at first hand, their accounts were flavoured strongly with Ctesias' original, rather fanciful, description and so the rhinoceros changed its shape in most Europeans' imaginations to that of the fabulous unicorn. The tusks of the narwhal began to appear in Europe at this time, and they were attributed to the unicorn; as were the superstitions and beliefs associated with the one-horned rhinoceros from the East. The imaginary unicorn was believed to precede other animals to drinking places, and to test the water for poison by dipping its horn. Although rhinos were brought into Europe again during the sixteenth century, it was not until the nineteenth century that people stopped discussing seriously the existence of the unicorn. Alicorn, the pulverized tusk of the narwhal, was used extensively in European medicine and was recognised officially as a drug in England until 1741 (Guggisberg, 1966).

The first rhino to reach Europe after the fall of the Roman Empire was an Indian rhino sent in 1515 by Muzaffar, King of Cambaia in Western India, as a gift to King Manuel of Portugal (Fontoura da Costa, 1937). A few months after its arrival in Lisbon, King Manuel decided to give the rhino to Pope Leo X, but the ship carrying it was lost in the Gulf of Genoa, and the animal was drowned. Meanwhile a drawing of the rhino, possibly by a Portuguese hand, and a description by Valentin Ferdinand had reached Nuremberg, where Albrecht Dürer made his famous woodcut (Figure 1.1). Other woodcuts and engravings were made of the two rhinos that arrived in Europe during the sixteenth century, but Dürer's woodcut, although not wholly accurate, remained the standard representation of the animal and was copied many times during the next 200 years (Cole, 1953; Clarke, 1973).

Although an Indian rhino was on view in London between 1684 and

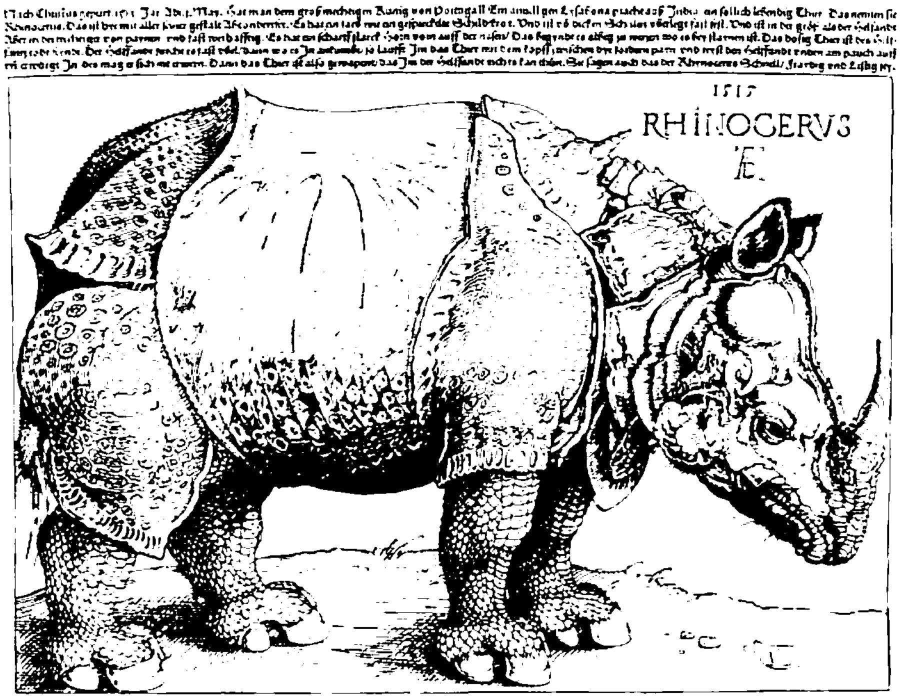

Fig. 1.1. Dürer's woodcut of 1515, first edition. British Museum.

1686 (de Beer, 1955), the first detailed scientific description of the species was published nearly 60 years later by Parsons (1743). The animal described by Parsons was brought to London in 1739: it was the second Indian rhino recorded in England and the fourth in Europe (Clarke, 1973). Several other Indian rhinos were on view in the zoos of Europe and North America from the eighteenth century onwards (Reynolds, 1967; Rookmaaker, 1973) but the first African rhino to be brought to Europe after the fall of the Roman Empire arrived in London only in 1868 (Sclater, 1876). Owen's (1862) treatise on the anatomy of the Indian rhino remains the most complete reference work for the species, although Cave (1962, 1964, 1969, 1976) and Cave and Aumonier (1964) have made extensive investigations of certain aspects of its anatomy.

There are several reports of Indian rhinos being tamed and even trained by man. Schenkel and Lang (1969) quoted early accounts of rhinos being used to pull ploughs in Assam and there are also reports that rhinos were used in war by the ancient Kings of India and Assam (Guggisberg, 1966). Butler (1847) noted an abundance of rhinos in Assam during the early nineteenth century, and wrote that tamed rhinos were often grazed with domestic cattle and sold for up to 300 rupees each. Pollok and Thom (1900) later reported that a washerman in Gauhati, Assam, had a tame rhino that carried the laundry on his delivery rounds. Recent experiences with Indian rhinos in zoos (Lang, 1961) and circuses (Reynolds, 1967) confirm that they can be tamed and trained, but they can also be dangerous and unpredictable. It was a long time before the Indian rhino was bred in captivity. The first recorded captive birth was in Kathmandu in 1826 (Hodgson, 1834) and the next was in Calcutta in 1925 (Gee, 1953a). Successful breeding was not achieved in Europe until 1956 (Lang, 1961), but there have been at least 36 births in zoos since then (Lang *et al.*, 1977), and much has been learned about the reproductive and maternal behaviour of the Indian rhino in captivity (Lang, 1961, 1967; Buechner *et al.*, 1975; Buechner and Mackler, 1975; Mackler, 1975).

Various hunters, amateur naturalists and tea-garden managers have written about the Indian rhino in the wild. The earliest accounts are by Babur, the first Moghul Emperor, who hunted rhinos with horses and elephants (Lamb, 1962). The later Moghuls, in particular Jehangir (1605-1627) were all keen hunters and naturalists, and recounted many stories of their hunts for rhinos and other animals (Ali, 1927). More recent hunts were described by Smythies (1942) and Prasad (1975) in Nepal, and by the Maharajah of Cooch Behar (1908) in India.

Manners-Smith (1909) gave an account of the distribution and abundance of the Indian rhino in Nepal and Bihar (Section 1.3.2) but the first study of the species in the wild was by Bengt Berg, a Swedish photographer. Berg (1933) visited the Jaldapara sanctuary in West Bengal for six weeks in 1932 and collected some interesting information on the movements and feeding habits of the rhino. Gee (1953a, 1953b, 1959, 1963) made observations on the rhinos of Assam and Nepal, and summarised what was known of their ecology and behaviour. Ullrich (1964) studied rhinos for three weeks in the Kaziranga National Park, Assam, concentrating mainly on their social organisation, and Schenkel and Lang (1969), on the basis of a one week visit to Kaziranga, questioned some of Ullrich's conclusions.

Apart from the reports mentioned above, there are various more recent publications on the distribution and numbers of rhinos, that are referred to in Sections 1.3 and 1.4. Few of these reports are concerned with ecology or behaviour, but Caughley (1969) discusses the deterioration of the rhinos' habitat in Chitawan, and Brahmachary *et al.* (1969), Lahan and Sonowal (1973) and Lahan (1974) have written briefly on feeding, population size and social behaviour respectively.

1.3 Past and present distributions of the Indian rhino

When drawing conclusions from a study of the ecology and behaviour of any species, it is important to consider whether the environment of the study area is different from the environment to which the species is primarily adapted. Where changes in environment have occurred, there must be a time lag before selection can produce ecological and behavioural adaptations more suitable to the new circumstances. Is the habitat at Chitawan, then, typical of that in which the species evolved? To answer this question (also discussed in Section 2.2), and to demonstrate the massive reduction in the rhinos' range, I consider here the past and present distributions and habitat types of the species.

1.3.1 Prehistoric distribution and habitat types

The genus *Rhinoceros* can be traced back to the pliocene of northern India: fossils of *R. palaeindicus* are found in the Siwalik beds with those of a vertebrate fauna including large predators, that lived on the alluvial plains of the Siwalik river (Wadia, 1966). A mosaic of grassland and woodland is thought to have covered the long broad valley of the Siwalik river which flowed from Assam to the Punjab and the Sind (Pilgrim, 1919). The climate was warm, water was abundant, and the valley floor was well fertilised by silt carried down by the rivers from the newly formed Himalayas (Ooi, 1959; Wadia, 1966).

R. kendengicus, a close relative of *R. unicornis* (Hooijer, 1946), occurred in a similar environment in Java during the mid-Pleistocene, when Java was part of the mainland of the Sunda shelf, and probably consisted of a mosaic of forested hills, scrub and alluvial grasslands (Medway, 1972). After a rise in sea level and climatic changes which led to a predominance of rain-forest vegetation, *R. kendengicus* and many other large mammals died out in south-east Asia. *R. unicornis*, on the other hand, remained widespread in India during the Pleistocene. There are fossil and semi-fossil remains in northern India, the Narbada valley of central India and near Bunda and Madras (Lydekker, 1924) (see Figure 1.2). All these remains are associated with alluvial deposits, indicating that the Indian rhino was originally an animal of marshes and river-banks, as recorded in the earliest literature (Section 1.2).

1.3.2 Historical distribution and habitat types

The accurate representations of the Indian rhino found at Mohenjodaro (Section 1.2) indicate that the species occurred as far south and west as the present Sind Province in 2000 BC. Rhinos were distributed widely on the flood plains of the Indus, the Ganges and the Brahmaputra until relatively recently. The Indian rhino still occurred near the present Pakistan-Kashmir border in 1398 when Timur is known to have hunted it (Guggisberg, 1966). The first Moghul Emperor, Babur, hunted rhinos at Nowshera near Peshawar as late as 1519 (Leyden, 1826; Ali, 1927) (see

Fig. 1.2. A map showing some places referred to in the text.

Figure 1.2). Babur, who wrote between 1505 and 1530, described the rhino's distribution in Pakistan as including the jungles of Peshawar and Hashnagar and those between the rivers Sind and Bereh. He also mentioned that rhinos were found on the banks of the river Saru in the Ganges plain. A Turkish admiral who travelled overland from Lahore to Constantinople in 1556 also reported seeing rhinos near Peshawar (Guggisberg, 1966).

The extent of the historical distribution of the Indian rhino to the east is complicated by confusion in the literature between *R. unicornis* and *R. sondaicus* (described in Appendix A). Camper (1772) first suggested that there were two species of *Rhinoceros* but it was not until 50 years later that Desmarest, in 1882, gave the first scientific description of the Javan rhinoceros (*R. sondaicus*). Confusion about the identity of the Javan species of *Rhinoceros* and its distribution persisted until about 1930 (Guggisberg, 1966). Thus, early records of *R. unicornis* in southern Burma, Malaya and Indochina (Helfer, 1838; Cantor, 1846) were probably *R. sondaicus* (Blyth, 1863). Pollok and Thom (1900) reported *R. unicornis* from the Arakan and Tennasserim provinces of Burma, but such reports have never been confirmed. It is possible that *R. unicornis* occurred in north-west Burma adjacent to the Tirap Frontier District, Arunachal Pradesh until early in this century (Talbot, 1959) but, apart from that, it was found almost certainly only within the present borders of India and Bangladesh (Figure 1.3).

Figure 1.3 shows the estimated distribution of *R. unicornis* in the fifteenth century, based on historical records and the habitat types known to have been present at that time. The human population of India has increased rapidly since the fifteenth century, and more and more land has been cultivated; in particular the lush, fertile flood plains favoured by Indian rhinos. Habitat destruction made hunting easier, as rhinos were deprived of the shelter of grasslands and forests. The combination of habitat destruction and hunting led to a rapid decline in the numbers of rhinos: Blanford (1888) reported that, by the late nineteenth century, the Indian rhino was confined to the Nepal terai, the Bhutan Duars, the Teesta Valley of West Bengal and the Brahmaputra Valley in Assam.

Hewitt (1938) stated that there were rhinos in Uttar Pradesh near Nepal's western border until the 1870s, but the last one was shot in

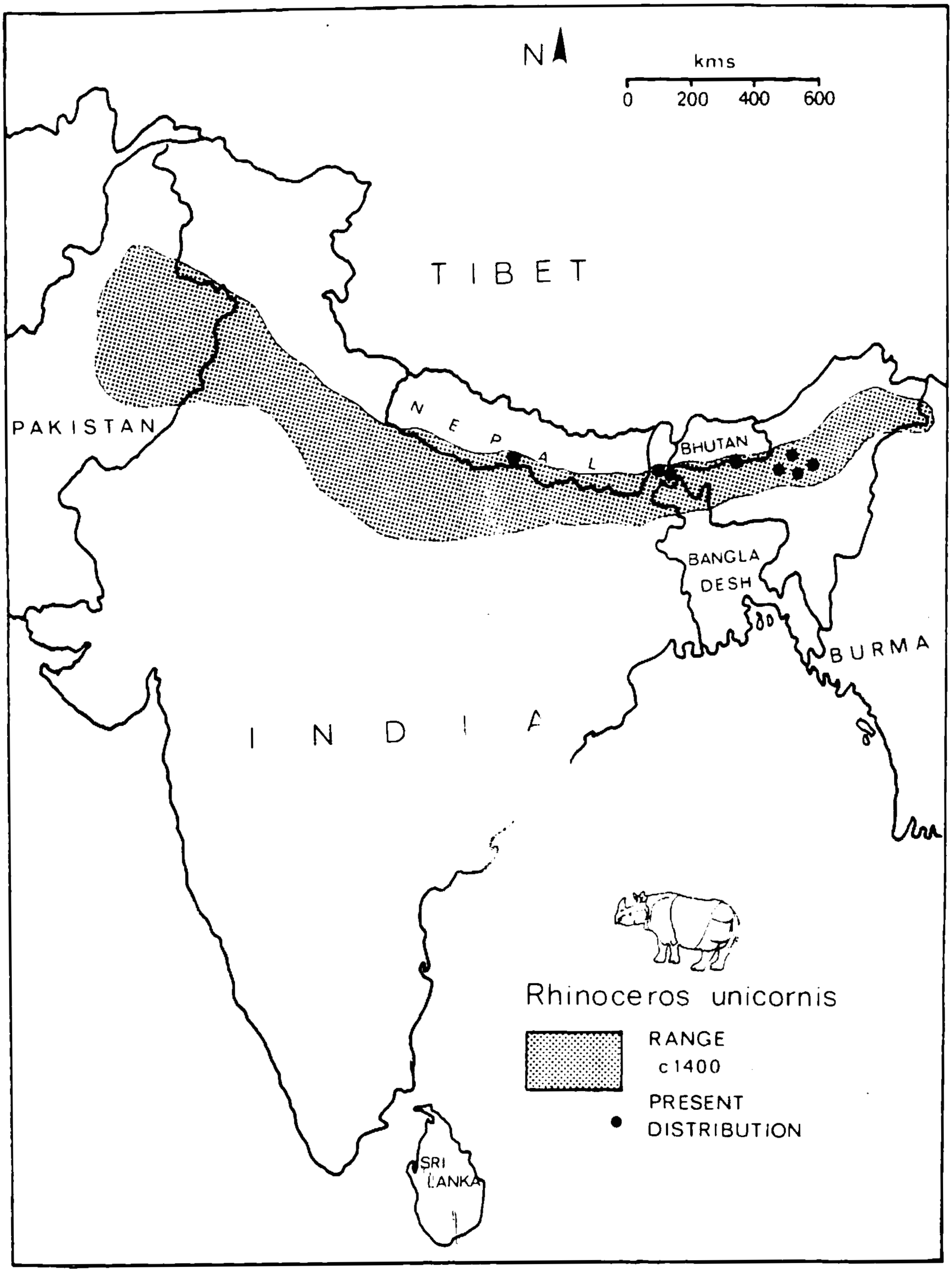

Fig. 1.3. The estimated distribution of R. unicornis *during the fifteenth century compared with the present distribution.*

Philibit district in 1878. After that time the western limit of the rhino's distribution was probably Nawalpur, just to the west of Chitawan in the Nepal terai (Figure 1.2). According to Lydekker (1924), Indian rhinos occurred in the Rajmahal hills, Bihar until about 1850. Manners-Smith (1909) described the range of the rhino in Nepal and Bihar; they were particularly numerous in Nawalpur and Chitawan but also occurred on the banks of the Bagmati, north of Muzaffurpur, Patharghatta, the Sun Kosi Valley, Purnea and Morang (Figure 1.2). The abundance of rhinos in the Nepalese terai, especially around Chitawan, was due to the small human population of the area and its strict protection by the Nepalese rulers as a hunting preserve (Smythies, 1942). A short history of the Chitawan Valley follows in Section 1.4.

Whereas the Nepalese rhino populations were relatively well protected in the nineteenth century and the early twentieth century, the Indian populations were hunted much more relentlessly in the decreasing areas of forest and grassland jungle which they inhabited. Butler (1847) considered that almost every military officer in Assam became a "keen and skilful sportsman". Colonel F.T. Pollok shot 44 rhinos in Assam and wounded "fully as many as he killed" (Pollok and Thom, 1900), and the Maharajah of Cooch Behar (1908) shot 207 rhinos between 1871 and 1907 in West Bengal and Assam. Just after the turn of the century, the Government became very concerned at the rapid decline in the numbers of rhinos, and all rhino hunting in India was prohibited in 1910. A number of reserves were created with the aim of ensuring the survival of the species, but illegal poaching still continued, as the price of rhino horns rocketed. The rhino survived largely due to the efforts of forest officers such as E.O. Shebbeare in Jaldapara Reserve and A.J.W. Milroy in Kaziranga Reserve. The population in Kaziranga has increased from an estimated 12 individuals in 1908 to more than 600 in 1978.

The historical distribution of the Indian rhino, from Sind to northern Burma, was typified by alluvial plain grasslands and woodlands. The rivers of these plains have changed courses frequently and often rapidly: in the third century BC, the Indus flowed more than 80 kms to the east of its present course, and the Brahmaputra has shifted 100 kms to the west within the last 100 years (Wadia, 1966). Obviously, the habitats of the alluvial plains were subject to considerable perturbations as a result of changes in river courses and successional changes in the vegetation. Similar processes continue in Chitawan to the present day (described in Section 2.1).

1.3.3 Present distribution and habitat types

The Indian rhino is confined now almost entirely to reserves and national parks in Nepal, West Bengal and Assam. A few survivors occur in forested areas around reserves and national parks, and there are occasional reports of rhinos wandering far from any reserves in Assam (P. Lahan, M. Oliver, pers. comm., 1975). Table 1.1 and Figure 1.4 show the present distribution of the species and the estimated numbers in each protected area and its immediate environs.

Table 1.1. Estimates of the numbers of R. unicornis *throughout its range.*

Name of protected area	Estimated number of rhinos
Nepal	
Chitawan (National Park)	270 - 310
West Bengal	
Jaldapara	30 - 40
Gorumara	*c*5
Assam	
Kaziranga (National Park)	*c*600
Laokhawa	*c*40
Manas	*c*40
Orang	25 - 30
Sonai Rupai	*c*15
Elsewhere (incl. Pobitora, Kukurata and Raja Mayang Reserves and unprotected areas)	*c*25
TOTAL	1050 - 1105

Estimates for protected areas include rhinos in the immediate environs. Sources for estimates are given in the text.

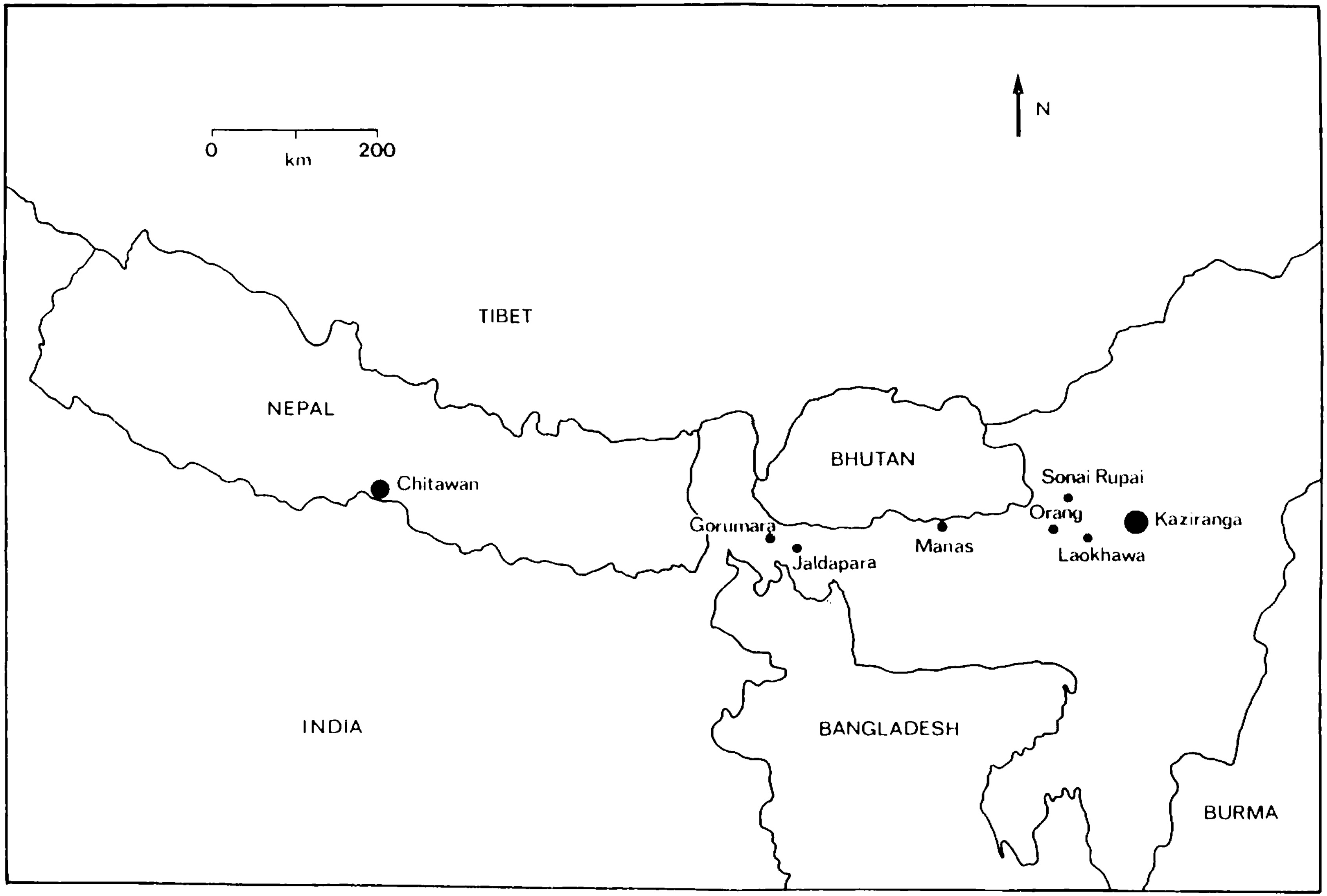

Fig. 1.4. The major Indian rhino reserves and national parks.

Brief descriptions of each protected area are given in Appendix C, with the exception of the Chitawan Valley which is described fully in Section 2.1. The Indian rhino is associated still with mixed riverine woodlands and grasslands which are subject to rapid changes in topography and vegetation as a result of changes in river courses (see Section 1.3.2).

1.4 A brief history of the Chitawan Valley and its rhino population

The Chitawan Valley, in which the study was carried out, is one of the interior valleys of the Himalayas known as *duns*, that are aligned parallel to and between the outer ranges of the Himalayan foothills. The Chitawan *dun* lies between the Siwalik and the Mahabharat Ranges near the southern border of Nepal. It is drained by the Rapti River which flows for 103 kms from east to west along the valley floor to join the Naryani River which originates beyond the Himalayas (see Figure 2.1). The valley is about two kms wide in the east, but it broadens to about 21 kms along the Naryani River in the west.

The Chitawan *dun* has been long famous for its wildlife and forests. Oldfield (1880) and Burkhill (1910) stated that much of the valley was put out of cultivation deliberately by the Government of Nepal at the beginning of the nineteenth century, to form a barrier of malarious forest as a defence against invading armies. Until the 1950s, the valley contained over 2600 km^2 of forest, swamps and grassland, and harboured a rich and varied fauna. Human disturbance was only slight: there were almost no settlements apart from a few small villages cleared from the jungle by an ethnic group called the Tharus, the oldest known inhabitants of the region, who had developed some degree of tolerance to malaria (Phillips, 1925 in Caughley, 1969). Sal forest (*Shorea robusta*) covered the hill slopes, and the valley floor was a constantly changing mosaic of riverine forest and grassland. The Rapti River meandered across the valley, destroying forest and grassland during the monsoon floods and building up soil elsewhere. Abandoned river beds became swamps and lakes, and prickly thickets of climbing palms filled the drier woodlands. Elephants, rhinos, tigers, leopards, bears, wild pigs, buffalo, gaur and five species of deer were abundant in Chitawan (Oldfield, 1880).

Members of the Rana family, Nepal's hereditary Prime Ministers, hunted in the valley during the cool winter months. They invited foreign royalty and used hundreds of riding elephants to pursue tigers and rhinos (Plate 3). The largest bag recorded this century, taken during the 1937-8 season, included 38 rhinos and 120 tigers (Smythies, 1942). However, hunts were infrequently in the same area, and the animal populations suffered little, despite the large numbers shot in some years (Caughley, 1969). Rhino-hunting was the strict prerogative of the ruling family and its guests, and originally there was a death penalty for poaching (Oldfield, 1880).

During the early 1950s, after the fall of the Rana regime and catastrophic floods in the hills, some desperate hill-farmers descended to the lowlands in search of fresh lands to cultivate. A malaria eradication scheme subsequently enabled thousands of the overcrowded hill-people to settle in the fertile Chitawan Valley (Spillet and Tamang, 1966). Vast areas of land were cleared for agriculture, a road was built and bazaars sprang up along its route. By 1959, the whole length of the valley was settled and 70% of the forests and grasslands had disappeared (Caughley, 1969). The U.S. Agency for International Development estimated that the human population of Chitawan rose from 36,000 to 100,000 between 1950 and 1960. Some of these people were later resettled in areas adjacent to Chitawan, and the official census total for Chitawan district was 55,000 in 1961 (H.M.G., 1964).

Poaching of rhinos for the valuable horn became widespread during the 1950s, despite the protection afforded them by a network of Rhino Guard-posts manned by 130 armed men of the Forest Territorial Service. According to Talbot (1959), at least 72 rhinos were poached during 1954, and similar numbers during the previous few years. At least 60 rhinos were killed during 1958 (Gee, 1959), and poaching continued, being particularly prevalent between 1959 and 1961 (Spillet and Tamang, 1966). Willan (1965) guessed that there were 800 rhinos in Nepal in 1950, Stracey (1957) guessed 400 in 1957 and Gee (1959) guessed 300 two years later. It should be emphasized that these guesses were not based on systematic counts or calculations. However, they do illustrate a rapid decline in the rhino population.

Concerned at the rapid decline of the forest areas and in particular of the revered rhinoceros, His Majesty's Government created the Mahendra Deer Park in the north-west of the valley, and proposed the establishment of a Wildlife Sanctuary south of the Rapti River in the lower half of the valley for a trial period of 10 years (Gee, 1959). However, the Mahendra Deer Park (see Figure 2.5) did not include the largest concentration of rhinos, and there were human settlements in both the Park and the proposed sanctuary. Further steps to preserve the rhinoceros were taken in the early 1960s when the western end of the valley south of the Rapti was declared a sanctuary, and in 1964, when settlements were cleared from the Rapti's southern bank. Poaching and habitat destruction continued, although at a slower rate: swamp deer and buffalo disappeared from Chitawan, and Spillet and Tamang (1966) guessed that there were only 100 rhinos in 1966. The human population rose to 185,000 by 1971 (H.M.G., 1974), and new areas were still being cleared for agriculture.

Caughley (1969) and H.R. Mishra carried out a helicopter census in

June 1968, and estimated the rhino population to be between 81 and 108. In a similar census in late May 1972, Pelinck and Upreti (1972) estimated a total of between 120 and 147 rhinos. Although both these results were probably underestimates (discussed in Section 3.9), the rhino population has increased during the last 10 years, particularly since the establishment in 1973 of the 544 km^2 Royal Chitawan National Park, which includes the original rhino sanctuary (Figure 2.6).

His Majesty's Government of Nepal, with the help of the Food and Agriculture Organisation of the United Nations, the World Wildlife Fund and the Fauna Preservation Society, has equipped the National Park and trained the staff. Poaching and encroachment of the boundaries by villagers have been almost completely controlled, and the Park has recently been extended by 350 km^2 (Section 7.2.2).

1.5 Summary

1. The general aim of the study was to provide information on the ecology and behaviour of the endangered greater one-horned rhinoceros (*Rhinoceros unicornis*), that would be useful in making plans for its conservation.
2. No detailed scientific study of this species had been carried out previously.
3. The greater one-horned or Indian rhino has been associated always with alluvial plain habitats.
4. The Indian rhino once ranged from the Indus Valley to the Burmese border. However, as a result of habitat destruction and hunting for the valuable horn, rhinos are found today only in the Brahmaputra Valley of Assam, in two small reserves in West Bengal and in the

Chitawan Valley of southern Nepal. The total population numbers less than 1,200 individuals.

5. Before 1950, the Chitawan Valley consisted of 2,600 km^2 of forests and grasslands where a great variety of wild animals lived. The ruling family of Nepal organised lavish hunts for tiger and rhino, but both species were well protected.

6. A resettlement programme in the 1950s destroyed large areas of forests and grasslands in the Rapti Valley. Poaching was rife for a while and the rhino population was almost wiped out. Stricter protection of both habitat and animals was enforced during the 1960s and led to the establishment of the Royal Chitawan National Park in the lower half of the valley in 1973.

2. STUDY AREAS AND GENERAL METHODS

2.1 Study areas

2.1.1 Location and topography

The study was carried out in the lower half of the Chitawan *dun*, mainly on the flood plains of the Rapti, Reu and Naryani Rivers. Parts of these flood plains and the surrounding hills form the Royal Chitawan National Park, henceforward referred to as the park. The broad topography of the area is illustrated in Plate 1 which is a photograph taken in April 1975 from a NASA[1] satellite 920 kms above the earth. The names of places mentioned in the text are shown on a sketch map (Fig. 2.1) and a vegetation map (Fig. 2.2).

The Chitawan *dun* is a synclinal basin within the Siwalik Range, closed to the south by the Dauney Hills, the Someswar Hills and the Churia Hills, and backed to the north by the Mahabharat Range. From Lothar, the Rapti flows westwards for 55 kms to its confluence with the Reu and the Naryani. It hugs the southern side of the valley near the base of the Churia Hills: the southern flood plain varies from one and a half to five kms in width, whereas the northern flood plain is between three and 15 kms wide. The Reu flows 35 kms north-west to its confluence with the Rapti; its valley is a miniature *dun* enclosed by the Someswar Hills to the south and the Churia Hills to the north. The Naryani flows south-west for 30 kms from a gorge in the Mahabharat to the Rapti confluence and then flows westwards for a further 25 kms along the base of the Someswar Hills before turning south through a very narrow gorge in the Siwaliks between the Dauney and Someswar Hills. The Naryani is very broad, consisting of a large number of channels and islands with a total width of up to four kms. Its widest

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[1] National Aeronautics and Space Administration.

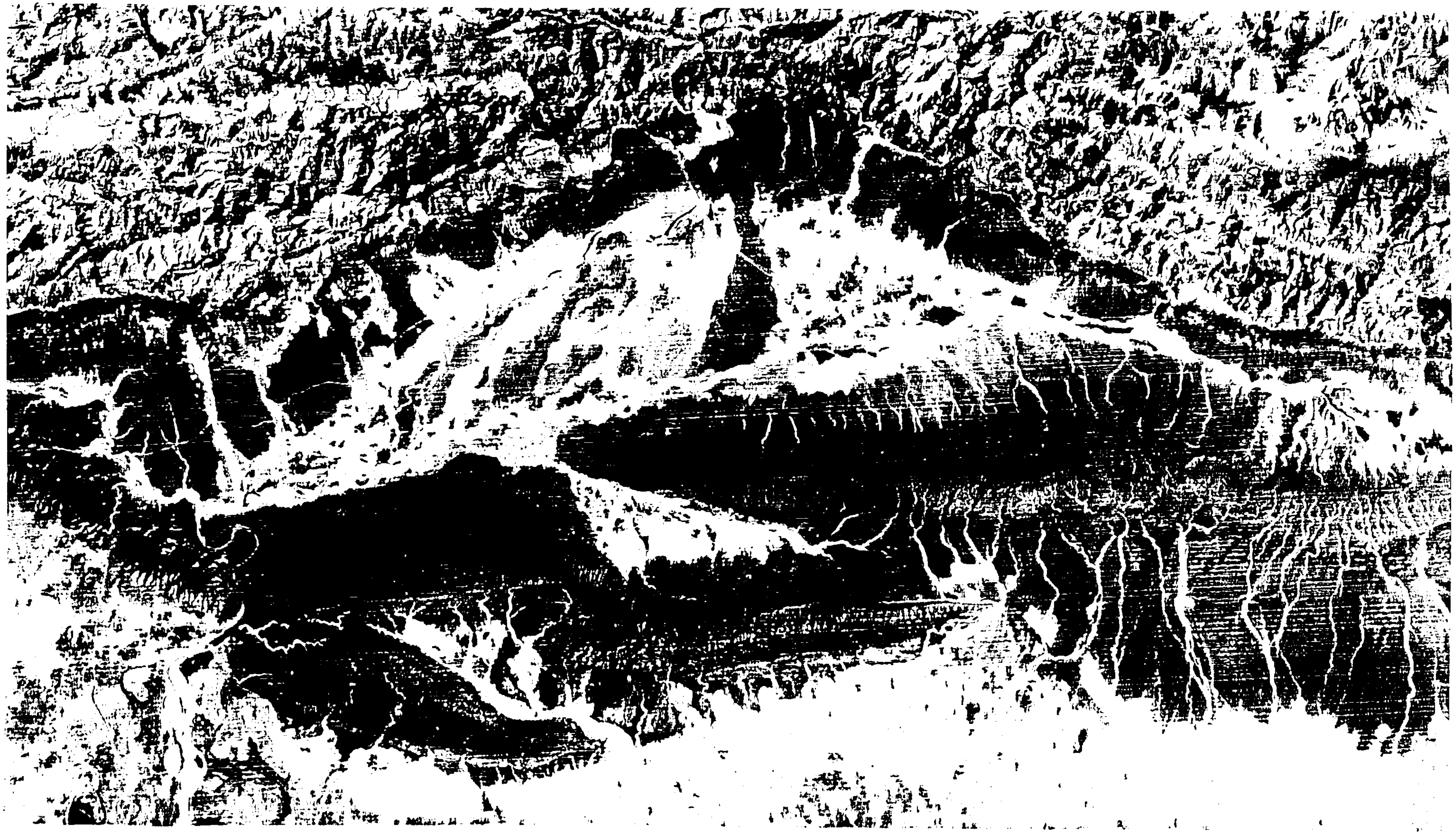


Plate 1. A photograph of the Chitawan Valley taken from a N.A.S.A. satellite in April 1975.

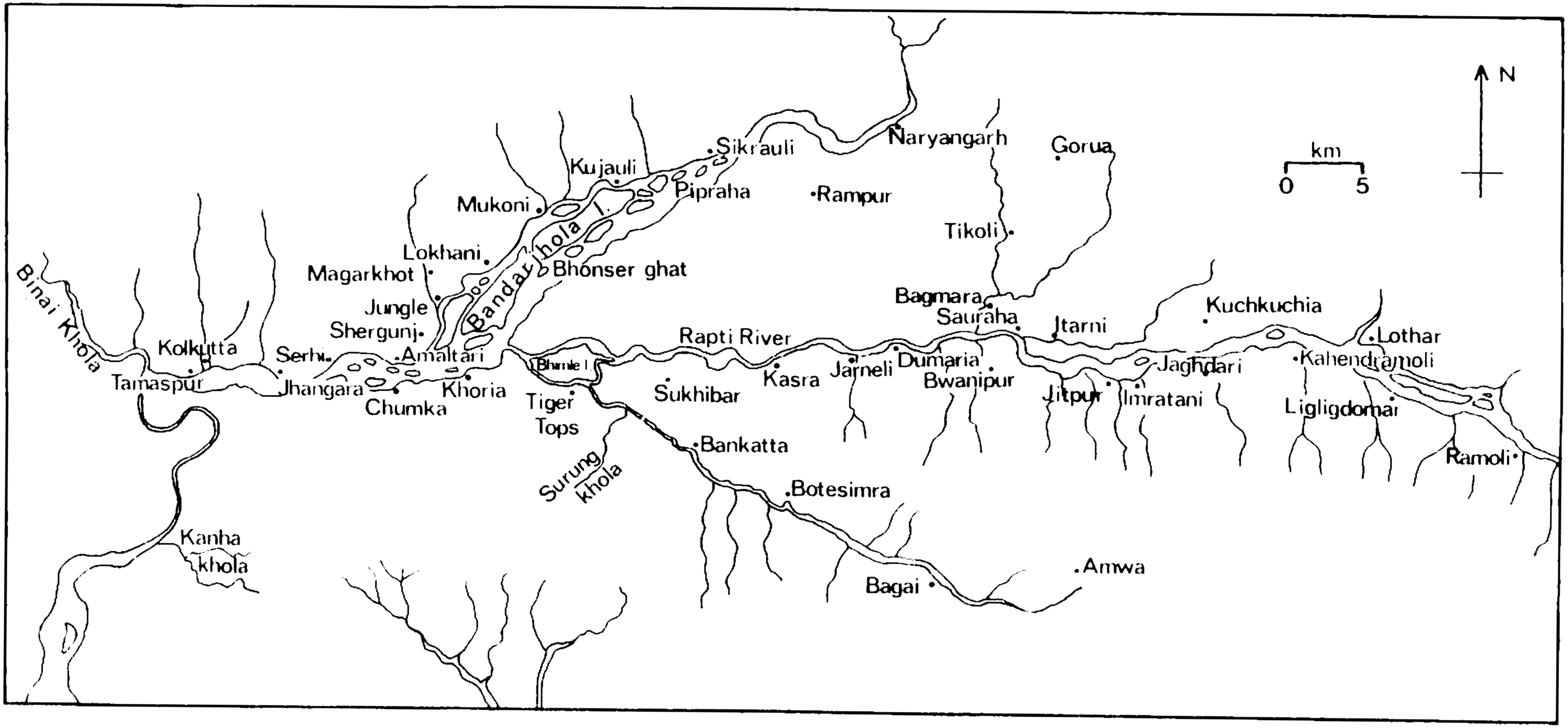


Fig. 2.1. A sketch-map of the Chitawan Valley showing places mentioned in the text.

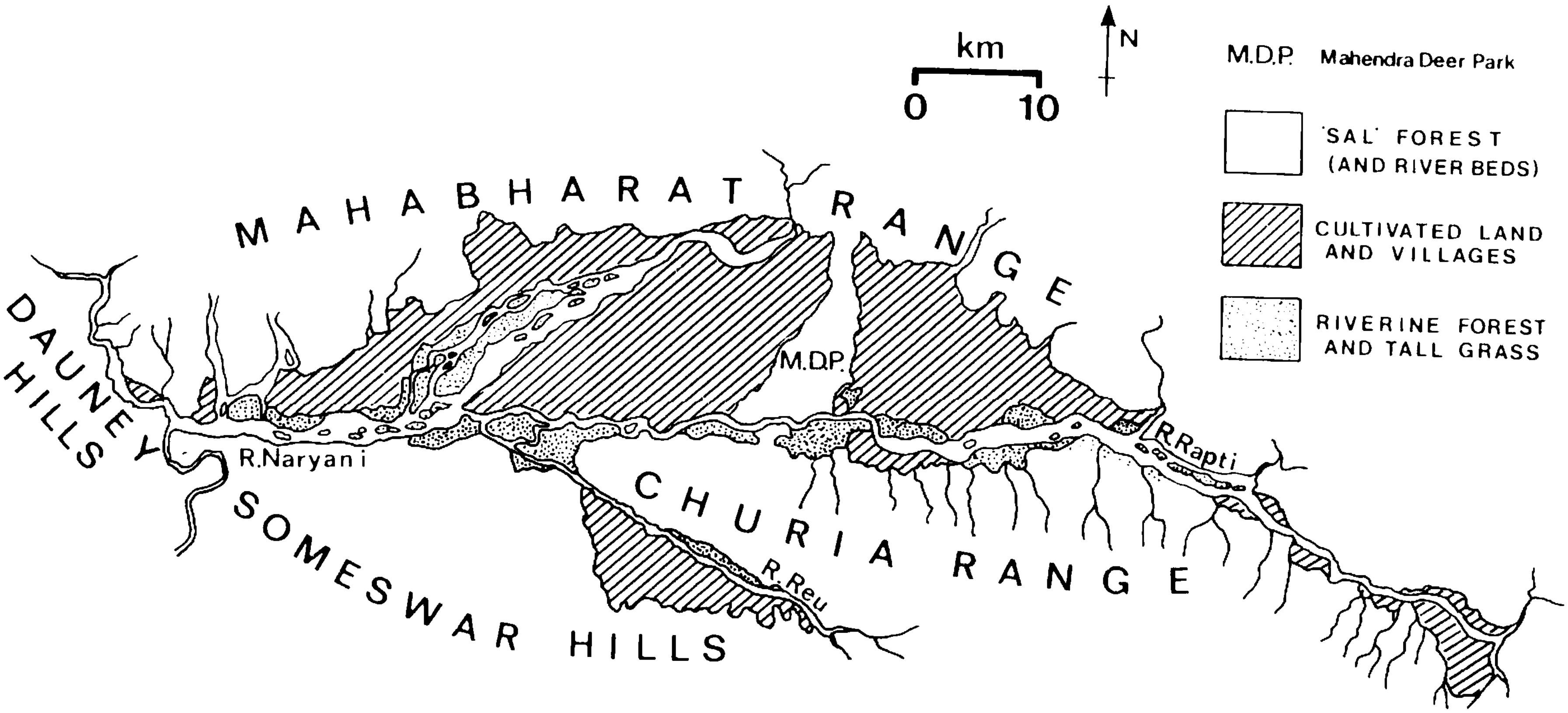


Fig. 2.2. A map of the Chitawan Valley showing the distribution of the major vegetation types.

point lies a little upstream of its confluence with the Rapti.

The altitude of the flood plain varies from 200 metres a.m.s.l. at Naryanghat to 120 metres a.m.s.l. at Tamaspur. The Churia Hills extend westwards between the Reu and Rapti Rivers as a forested ridge with a maximum height of 815 metres, which gradually drops in the west to about 130 metres a.m.s.l. near Sukhibar, where it joins the combined flood plains of the Reu and Rapti Rivers. The gentle lower slopes of the Churias are dissected by numerous stream-beds which flow north to the Rapti and south to the Reu. The main ridge varies in width from a knife-edge to a plateau about 100 metres across. On the other hand, the Someswar Hills are a complex mass of steep-sided ravines and sharp ridges, with no uniform direction of drainage. They rise to a maximum height of about 500 metres along a broken, eroded ridge which also forms the international boundary between Nepal and India. The Dauney Hills close the synclinal basin in the far west by running south-east to north-west and rejoining a northern branch of the Siwaliks.

2.1.2 Geology and soils

The Mahabharat Range consists of severely eroded pre-Siwalik quartzites, phyllites and sandstones (Berry *et al.*, 1974). The Siwaliks are characterized by outwash deposits carried from the north: all the rocks are of Pliocene or Pleistocene, fluviatile origin, and consist mainly of sandstones, conglomerates, quartzites, shales and micaceous sandstones (H.M.G., 1968; Hagen, 1969). The Siwaliks show a distinctive fault pattern that has produced steep cliffs on the south-facing slopes which have a poorer vegetation cover than the northern slopes.

The flood plains consist of a series of ascending alluvial terraces laid down by the rivers and subsequently raised by Himalayan uplift (Berry *et al.*, 1974). The terraces are composed of layers of boulders and gravels set in a fine silty matrix. There is a general tendency for the soils to be progressively *heavier* or finer textured, the greater the distance from hills and water courses. There is a rough gradient from the higher-lying boulders and gravels to sands and silts and then to the low-lying silt loams and silty clay loams (Berry *et al.*, 1974). However, shallow streams have meandered so extensively over the valley floor that sandy levées can be found even in the low-lying areas, and there is considerable local variation in soil types across the valley floor.

2.1.3 Climate

The climate of Chitawan is subtropical with a summer monsoon from mid-June to late September, and a relatively dry winter. Fig. 2.3 shows the maximum, minimum and mean monthly rainfall that I recorded at Sauraha for the years 1973 to 1975. The mean annual rainfall over this period was 2,411.6 mm, 92% of which fell between May and September.

There is a marked increase in rainfall in May before the monsoon, when sporadic thunderstorms and hailstorms are frequent, and high winds cause severe damage to trees and houses in the valley. The heavy monsoon rains are by no means continuous. Periods of one to three days of almost continuous rain (up to 163 mm per day) are interspersed by much drier periods. I recorded 15, 15 and 12 dry days respectively in the three wettest months (July, August and September) of 1973.

Fig. 2.4 shows the mean daily maximum and minimum temperatures, with ranges, recorded in the shade at Sauraha between 1973 and 1975. Temperatures normally reached a maximum in May (up to 38°C), becoming slightly lower, but with a smaller daily range, during the monsoon, and falling progressively until January (minimum recorded: 6°C).

Humidity is high all the year round, with early morning readings of 100% relative humidity being recorded frequently at Sauraha during the

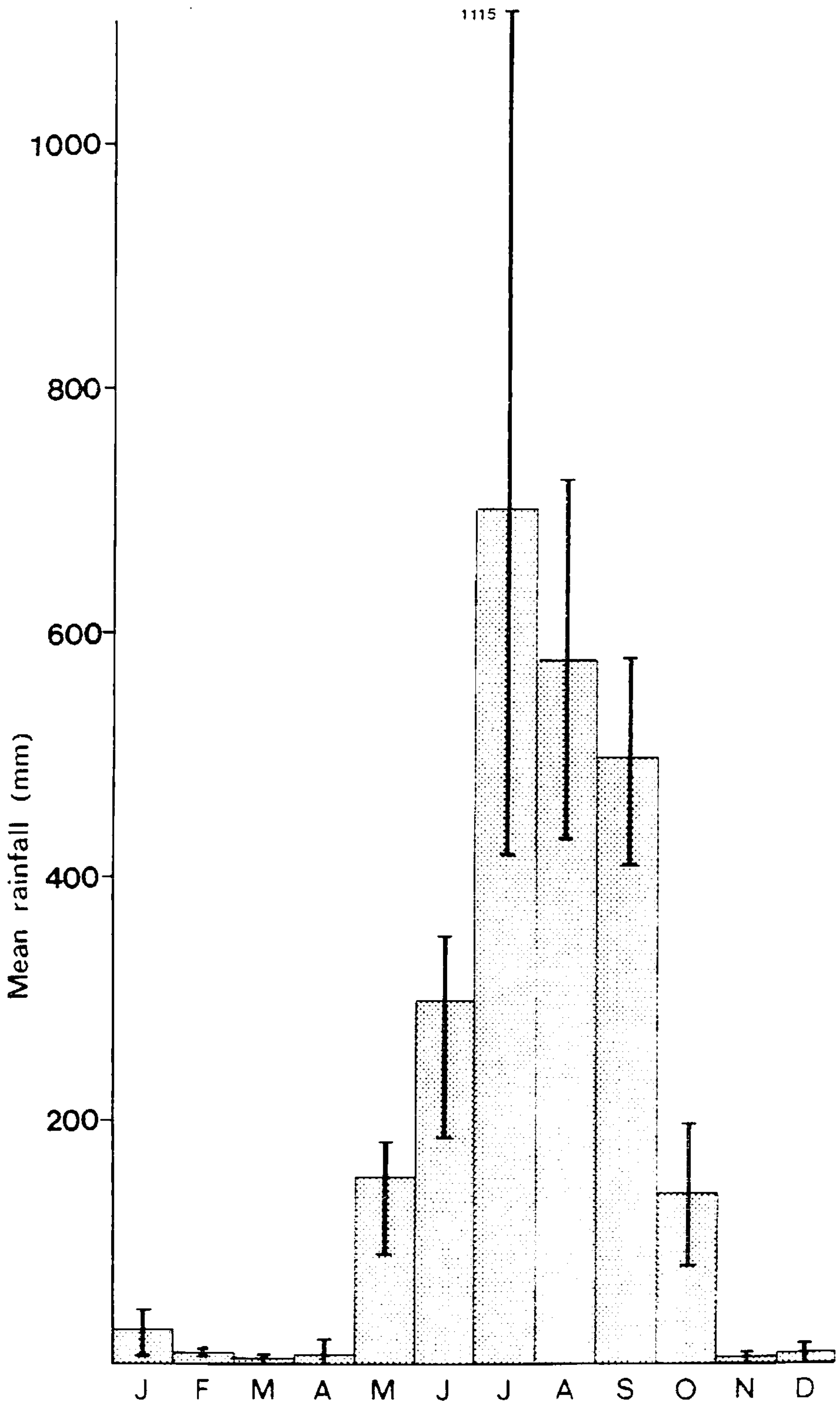


Fig. 2.3. Mean monthly rainfall, with ranges, at Sauraha, 1973 to 1975.

monsoon (June to September) and in December and January (see Fig. 2.5). The winter mornings are characterised by heavy mists which persist for

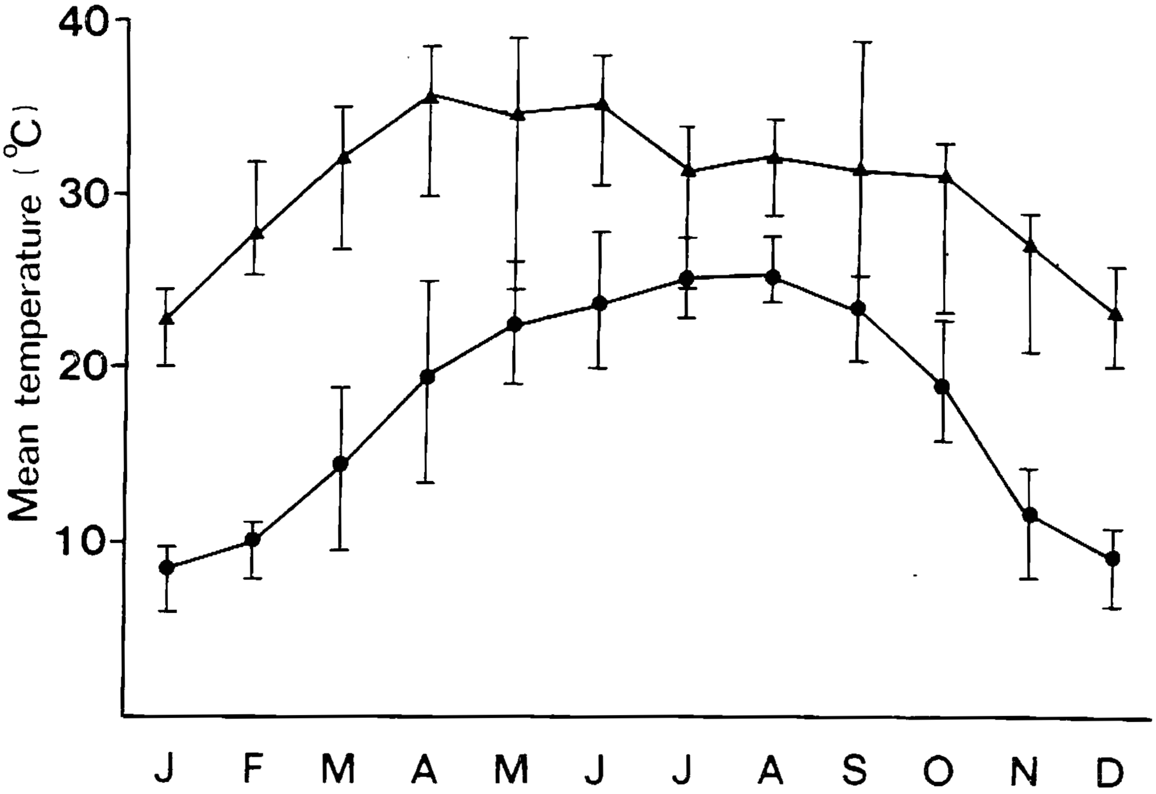


Fig. 2.4. Mean daily maximum and minimum temperatures, with ranges, at Sauraha, 1973 to 1975.

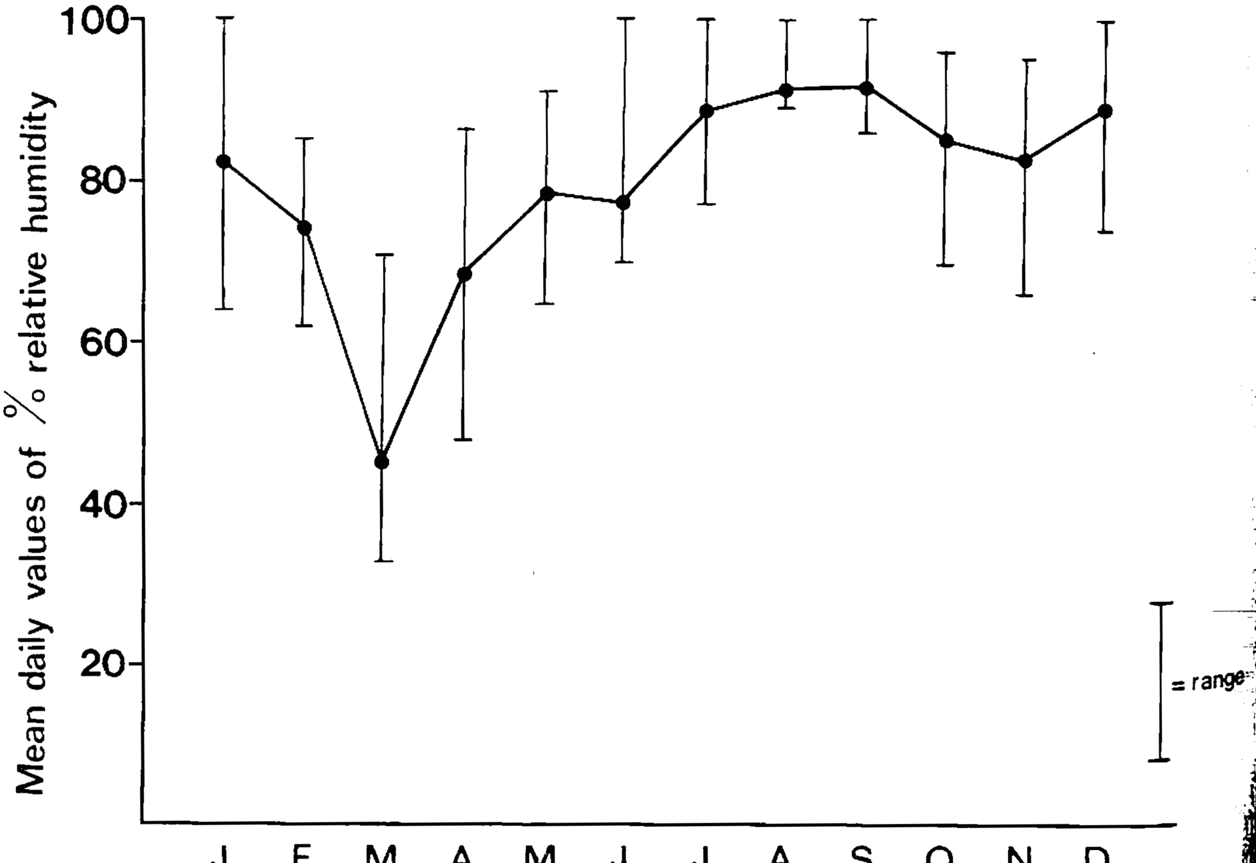


Fig. 2.5. Mean daily (07.00-10.00 h) values of percentage relative humidity at Sauraha, 1973 to 1975,

several hours after dawn, particularly in the lower half of the valley. Dry, cool, northerly winds blow from the Himalayas during the winter: there is little cloud cover, and insolation is high. From February to May, the prevailing wind is from the west and south-west, and temperatures rise, while humidity reaches a minimum in March. The wind swings further round to the south-east with the arrival of the monsoon in mid-June.

Rainfall, temperature and humidity vary considerably over short distances within the valley. The mean annual rainfall at Sauraha (1973-1975) was nearly 300 mm higher than that recorded in the centre of the valley at Rampur between 1958 and 1966 (shown in Appendix L). Although records kept at Tiger Tops during the study were incomplete, it appeared that the rainfall was lower there than at Sauraha, although it rained on more days. The mean maximum temperatures at Tiger Tops were lower than at Sauraha in all months, and the mean minimum temperatures were higher from July to February, and slightly lower from March to June. A much wider range of temperatures was recorded at Rampur - 0°C to 45°C (data in Appendix L). Such variations presumably arise from differences in locations relative to the hills, the rivers and the forest.

2.1.4 Hydrology

The Siwaliks and the Mahabharat Range are generally of low permeability, and the high monsoon rainfall runs off in numerous ephemeral streams, and in rivers which swell to many times their dry season sizes.

Drainage outside the park is complicated by extensive cultivation and irrigation. Drainage on the flood plains within the park is generally good. In the dry season, standing water is confined to small lakes or *tals* which are found throughout the park, generally on old river-courses. During the monsoon, however, extensive areas of grassland and forest become inundated, and may remain waterlogged for long periods. The river-beds become like quicksand in some places, and often cannot be crossed by elephants or rhinos for long periods.

Streams and rivers frequently change courses on the valley floor where they pass through easily erodable soils. I observed several major changes in the course of the Rapti during the study period, and the numerous ox-bow lakes on the valley floor indicate past river-courses. The Naryani, Nepal's third largest river, flows during the dry season in a series of deep clear channels between exposed shingle and boulder beds and sandbanks. However, during the monsoon the water is highly charged with sediment, and whole islands are washed downstream by the turbulent water. When in spate, all the rivers and streams carry large loads of sediment which are deposited when the floods recede, sometimes burying the river-bank vegetation under more than a metre of mud.

Springs flow from the edges of forested terraces after the monsoon, but they dry up progressively during the winter. However, there is sufficient water near the surface for the tall grasslands to grow up during the dry season after being burned in January and February (Sections 2.1.5.3 and 2.1.5.8). The ground dries up much more in the cultivated areas, where the water-level in the village wells drops considerably during the dry season,and little grows before the May rains.

2.1.5 Vegetation

The climax vegetation of the *terai* region of Nepal is considered generally to be sal (*Shorea robusta*) forest. However, floods, fires and riverine erosion combine to maintain a continually changing mosaic of grasslands and riverine forests in various stages of succession (Plate 4). Such habitat types are restricted now almost entirely to the park. Most of the Chitawan *dun* has been cleared for cultivation (Section 1.4), and many uncultivated areas have been transformed into open woodland, scrub or short grassland by extensive tree-felling and the grazing of domestic stock. The Siwaliks and the Mahabharat remain covered by sal forest, but much of the old Mahendra Deer Park is now more like woodland, with widely spaced trees and sparse undergrowth.

Bolton (1975) published the only account of the vegetation of the park, based largely on information and specimens collected by J.L. Fox and myself. I collected plants both in and around the park, and my collection of at least 385 plant species (listed in Appendix D) is the most comprehensive one recorded from the area.

I used aerial photographs (H.M.G. Dept. of Hydrology, April 1973; flying height, 3,500 m), satellite photographs (*e.g.* Plate 1) and my plant identifications to classify and map the vegetation types of the park and its immediate surroundings (see Figs. 2.2, 2.6, 2.8 and 2.9). I classified the uncultivated areas into six main classes of vegetation, and distinguished variations within them, which are described below. The six classes are: (a) sal and hill forest, (b) riverine forest, (c) tall grassland, (d) short grassland and river-banks, (e) permanent lakes, (f) scrub. Some of the forest types that I distinguished are the same as those described by Stainton (1972). I have used the nomenclature of Hara *et al.* (1978).

2.1.5.1 Sal and hill forest

Sal (*Shorea robusta*) commonly grows to about 25 metres in Chitawan, either in pure stands or with rather few associated tree species, *e.g.* *Terminalia bellirica, Garuga pinnata, Bridelia retusa, Anogeissus latifolius, Buchanania latifolia* and *Dillenia indica*, and creepers such as *Bauhinia vahlii* and *Spatholobus parviflorus*. *Terminalia* species (*T. bellirica, T. alata, T. chebula*) dominate the sal in places, and form *Terminalia* Woodland (Stainton, 1972) with associates such as *Lagerstroemia parviflora, Syzygium cumini, Adina cordifolia, Saurauia nepaulensis* and

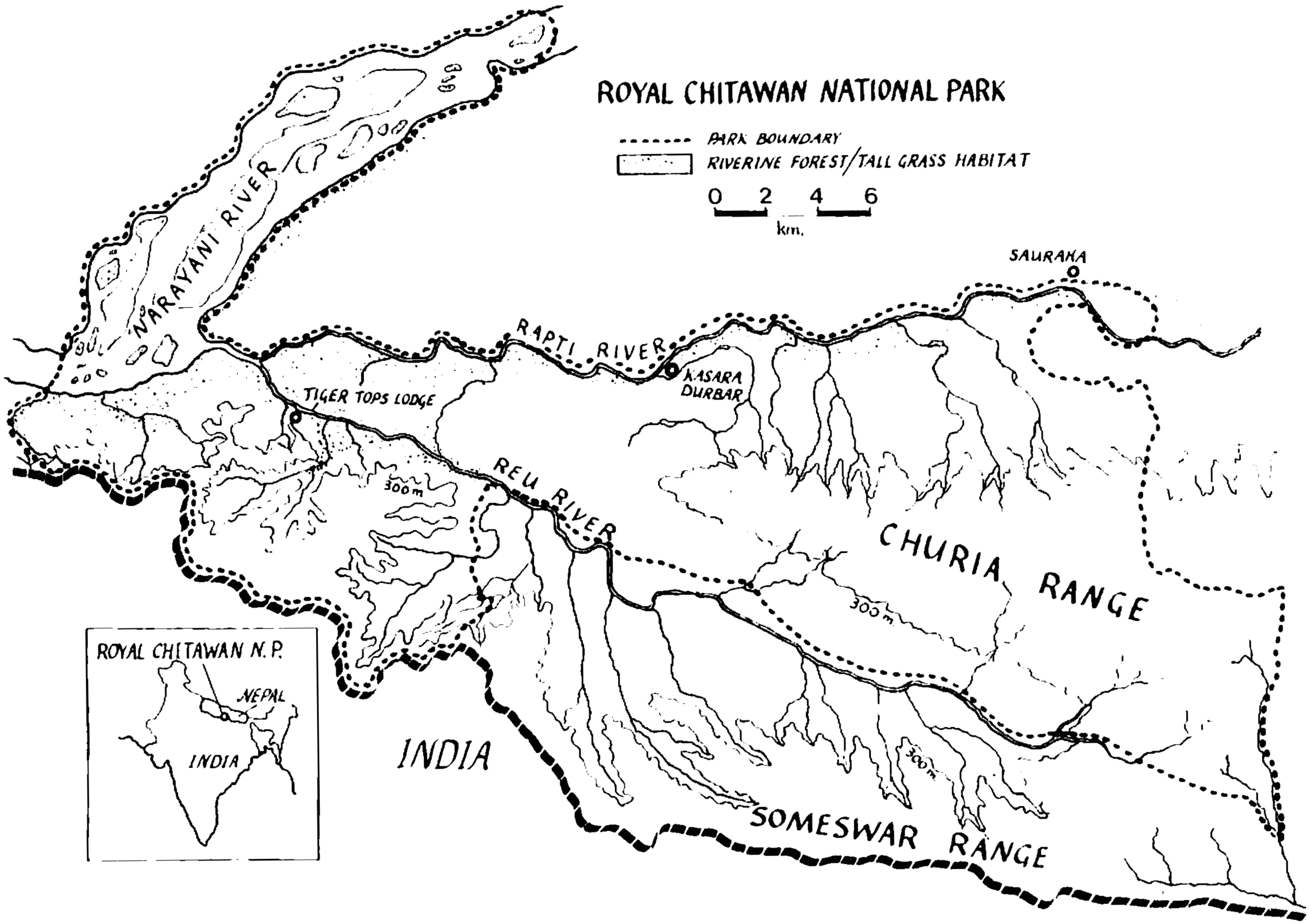


Fig. 2.6. Map of the Royal Chitawan National Park.

Schleichera trijuga. Sal forest and *Terminalia* Woodland grow extensively on the hills, and within them there are patches of forest along the water courses which include species such as *Macaranga denticulata, Ficus glomerata, Aegle marmelos, Xeranphis spinosa* and *Mallotus phillippensis.* This association is similar to Subtropical Deciduous Hill Forest (Stainton, 1972) but differs in its species composition. The chir pine (*Pinus roxburghii*) occurs with sal on some of the drier ridges of the Churias.

I have not mapped the distribution of the different types of sal and hill forest. The purest stands of sal occur on the lowlands around Kasra in the centre of the park. Undergrowth is sparse there during the dry months, but saplings come into leaf during the monsoon, and grasses such as *Themeda villosa* grow prolifically, reaching a height of five to six metres in clearings. Monocotyledons such as *Hedychium spicatum* and *Zingiber capitatum* occur in the undergrowth, and *Phoenix acaulis* palms are common in the hills. Bamboos (*Dendrocalamus strictus*) are common on the moist north-facing slopes of the Churias, and they form thickets in some localities.

2.1.5.2 Riverine forest

The term riverine forest has been used rather loosely to describe a wide variety of tree associations which occur along watercourses (Dinerstein, 1976). I distinguished four main types of riverine forest associations:

(a) Khair-sissoo

Khair (*Acacia catechu*) and sissoo (*Dalbergia sissoo*) associations dominate the banks of the Rapti and Naryani Rivers on recent alluvium. One of these species normally greatly outnumbers the other: khair is the most common species in the drier regions. There is often a dense undergrowth of *Pogostemon bengalensis* and a variety of other shrubs, herbs and grasses. The Khair-sissoo association is a colonizing vegetation type which, if successful in stabilizing the river-side gravel, ultimately produces conditions favourable to other tree species.

(b) *Bombax - Trewia*

Bombax ceiba and *Trewia nudiflora* are the two most common tree species in another riverine forest type which represents a later stage in succession and appears as a distinct strip between the khair-sissoo and the sal forests. It is a type of Tropical Deciduous Riverine Forest (Stainton, 1972), and includes species such as *Bauhinia malabarica, Butea monosperma, Ehretia laevis, Litsaea monopetala* and *Careya arborea.* Understory shrubs include *Callicarpa macrophylla, Clerodendron viscosum* and *Phyllanthus emblica.* There is a great variety of tree species in undisturbed areas, but selective felling and stock-grazing have transformed many areas into open scrub. Grasses are sparse except in clearings and at the forest edges where tall species, such as *Vetiveria zizanoides, Saccharum munja* and *S. spontaneum*, and shorter species, such as *Cynodon dactylon, Setaria pallidefusca, Paspalidium flavidum, Chrysopogon aciculatus* and *Digitaria setigera,* occur.

(c) *Eugenia* Woodland

Almost pure stands of *Eugenia jambolana* (now called *Syzygium cumini*) occur in damp places along the banks of the Naryani and its old courses. This is another type of Stainton's (1972) Tropical Deciduous Riverine Forest. I did not make a detailed collection of associated understory species, but they include *Colebrookia oppositifolia* and *Murraya koenigii.*

(d) Tropical Evergreen Forest

In a few places such as Bagmara to the north-east of the park, I found associations similar to the Tropical Evergreen Forest described by

Stainton (1972). This type of forest differs from the other riverine associations in the greater density of its understory and in the large number of climbers such as *Calamus tenuis*. The trees, whose height does not exceed 20 metres, include *Litsaea monopetala*, *Syzygium cumini*, *S. operculatus*, *Mangifera indica*, *Aesandra butyraceae*, *Baccaurea sapida*, *Duabanga grandiflora* and *Albizzia* spp., as well as some species of strangling *Ficus*.

2.1.5.3 Tall grassland

I distinguished four main types of tall grassland:

(a) *Themeda villosa*, as already mentioned (Section 2.1.5.1) forms a tall grass cover up to six metres high in clearings in the sal forest, especially on old river-courses.

(b) *Saccharum - Narenga* associations grow as mixed and pure stands up to eight metres high (Plate 5), with the dominant species varying according to locality. *Saccharum spontaneum*, as described in Section 2.1.5.4, is one of the first species to colonize newly created sandbanks. *S. spontaneum*, *S. munja*, *Erianthus ravennae* and *Narenga* spp. are all characteristic of later stages in the succession. Shorter grasses grow under the tall grass canopy, and climbing grasses such as *Apluda mutica* are also common. Trees such as *Bombax ceiba*, *Trewia nudiflora* and *Bauhinia malabarica*, and shrubs such as *Colebrookia* and *Callicarpa* spp., are present in varying abundance.

(c) *Arundo - Phragmites* associations form dense stands up to more than seven metres high along stream beds on the flood plain and around lakes (see Section 2.1.5.5). *Arundo donax*, *Phragmites karka*, *Saccharum* spp., *Typha elephantina* and numerous tall species of *Cyperus* are the most frequent components.

(d) *Imperata cylindrica* grows prolifically in areas within the park which were occupied by villages prior to evacuation in 1964. *Saccharum* spp. also occur in these areas, but they are sparsely scattered and *Imperata* is dominant, especially where the villagers cut it for thatching. *Imperata* is very variable in height but can grow up to two metres or more.

There are some other less common types of tall grass associations. The aromatic *Cymbopogon* spp. grow in some dry sandy locations on the edge of taller *Saccharum* stands, and *Vetiveria zizanoides* is common at the edges of riverine forest. *Arundinella* spp., *Neyraudia reynaudiana, Thysanolaena maxima* and *Thyrsia zea* are also common in mixed stands of tall grass.

The tall grasslands dry out during the winter, and can burn between December and April. Burning is carried out by the park staff as a deliberate policy in most areas (see Section 2.1.5.8). However, regrowth is rapid, and much of the grass reaches two or three metres in height before the May rains (Section 2.1.4).

2.1.5.4 Short grassland and river beds

For most of the year, the major rivers of Chitawan flow as small channels within a vast bed of sandbanks that change their configuration each year during the monsoon floods (Section 2.1.4). A wide variety of plant associations occur on the river-beds over the year:-

(a) During the dry months, various short grasses and herbs grow on the exposed sandbanks. They suddenly become much more prolific as the rain starts in May. *Polygonum plebujum, Persicaria* spp. and sedges such as *Cyperus, Kyllingia* and *Mariscus* spp. (see Appendix D) are very common around standing pools of water, and aquatic plants such as *Hydrilla verticillata, Ceratophyllum demersum* and *Utricularia aurea* occur in the pools. *Tamarix dioica* is a common shrub, especially in dry areas.

(b) Some areas, particularly higher areas near the riverine forest remain covered with short grasses such as *Cynodon dactylon* and *Chrysopogon aciculatus* all the year round. Short grasses such as these, *Eragrostis japonica* and *Brachiaria ramosa* are quick to germinate and grow both at the start of the rains and during and immediately after the monsoon when a fall in water level exposes silt-beds. These are all low, sometimes creeping grasses which rarely exceed 30 cms in height.

(c) *Saccharum spontaneum* and, to a lesser extent, some other *Saccharum* species grow prolifically at the beginning of the monsoon, reaching a height of up to three metres. Low-lying stands of *Saccharum* are destroyed by repeated flooding early in the monsoon.

In areas near the edge of the park, short grassland is maintained by the grazing pressure of domestic stock. The main species which occur in these short grass swards are a stunted form of *Imperata cylindrica, Chrysopogon aciculatus* and *Cynodon dactylon: Saccharum* spp. rarely establish themselves in such areas.

Later in this report, I use the term short grassland to encompass short grassland away from the rivers as well as the three vegetation types of the river beds described above. If the use of the term short grassland appears unsuitable for vegetation which includes grass three metres high, it should be remembered that this is indeed short when compared with the tall grasslands of up to eight metres in height described in Section 2.1.5.3. Furthermore, for most of the year, the grass on the river-beds is much shorter than three metres.

2.1.5.5 Permanent lakes

A large number of permanent lakes or *tals* occur in the park, mostly on old river-beds (Section 2.1.4). Many flow slowly during the dry season but they are all flooded during the monsoon, and rivers frequently flow along their old courses, joining series of isolated *tals*. The vegetation around the edges of the *tals* is usually the *Arundo-Phragmites* association described in Section 2.1.5.3. *Bombax ceiba* and *Trewia nudiflora* are common trees on the raised terraces along old river-courses (Section 2.1.5.2). Within the *tals*, aquatic plants are numerous and very prolific. Submerged and floating forms included *Pistia stratiotes, Lemna perpusilla, Hydrilla verticillata, Utricularia aurea* and *Ceratophyllum demersum.*

2.1.5.6 Scrub

The grasslands and forests at the edge of the park and over most of the valley have been considerably modified by man and his domestic stock. Much of the riverine woodland has been selectively felled for the best tree species for building houses and boats. Cattle and buffaloes have reduced many areas to low scrub with a short grass cover of persistent species such as *Imperata cylindrica, Chrysopogon aciculatus* and *Cynodon dactylon,* and unpalatable shrubs such as *Calotropis gigantea, Colebrookia oppositifolia* and *Clerodendron viscosum. Trewia nudiflora* is the most common tree species but it is continually lopped for cattle fodder by the villagers.

There is a great variety of types of scrub resulting from different degrees of modification by human and domestic stock, of different riverine forest and grassland associations.

2.1.5.7 Cultivated land

Local variation in soils and drainage (Sections 2.1.2 and 2.1.4) result in a varied pattern of cultivation. Fig. 2.7 shows the cultivation pattern in the traditional areas of neighbouring Nawalpur, after Berry *et al.* (1974). The pattern around Sauraha seemed to be very similar to this.

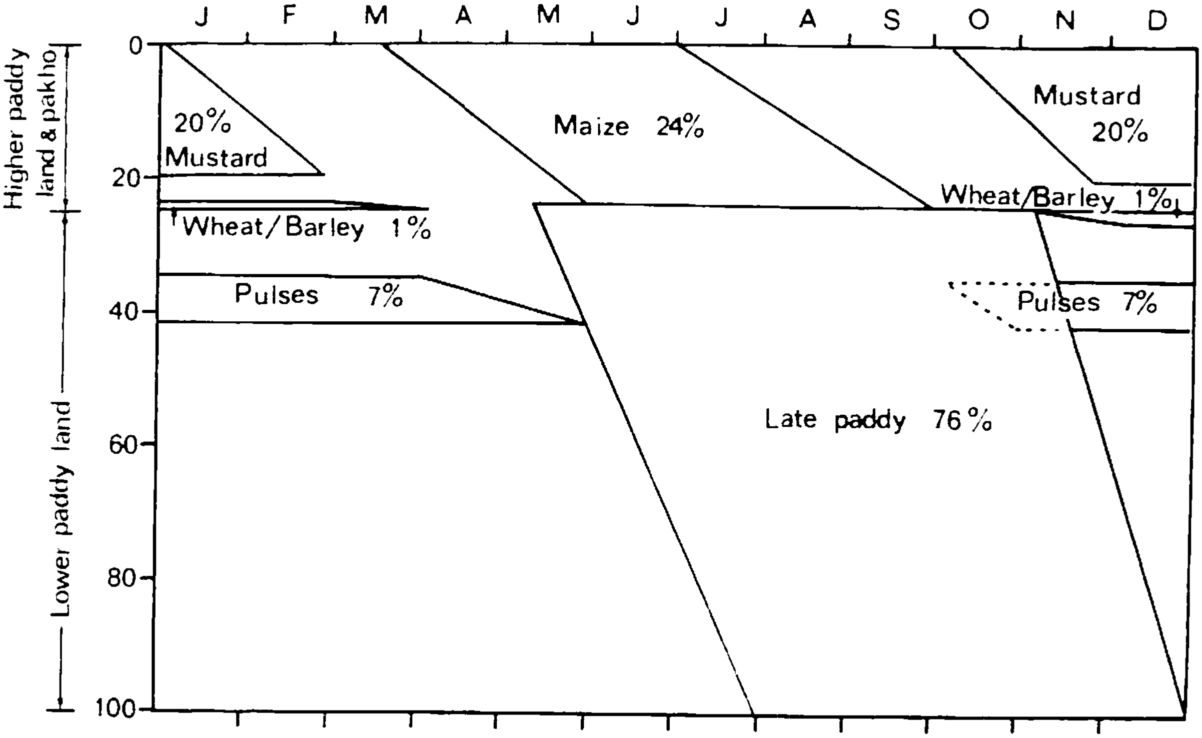


Fig. 2.7. Cropping pattern for traditional areas of Nawalpur.
Source: Berry et al. *(1974).*

Low-lying land (*khet*) normally produces an annual crop of rice (*Oryza sativa*) which is often not harvested until December. Pulses (*e.g. Cajanus sativa*) are grown on some of the earlier harvested fields and these are harvested as late as April. The higher and drier land (*pakho*) is frequently double-cropped. Maize (*Zea mays*) is planted before the monsoon and harvested from July to September, and early varieties of rice grown on some of the higher ground are also harvested by September. The major crop on the higher ground during the winter is mustard (*Brassica* sp.), although wheat (*Triticum arvense*), barley (*Hordeum vulgare*) and millet (*Paspalum scrobiculatum*) are also grown - usually on slightly wetter ground. Minor crops grown near the houses include tobacco (*Nicotiniana tabacum*), chillies (*Capsicum annuum*), bananas (*Musa balbisiana*), spinach (*Brassica* sp.) and cucumbers (*Cucumis sativus*).

Many species of short grass, sedges and herbs grow in the crops and in the fields outside the crop-growing seasons. The more common species include *Capillipedium assimile*, *Dactyloctenium aegyptium*, *Echinochloa colona*, *Eleusine indica*, *Heteropogon contortus*, *Imperata cylindrica*, *Desmostachya bipinnata*, *Cyperus* spp., *Scirpus* spp., *Chenopodium album*, *Alternanthera sessilis*, *Cynoglossum glochidiatum* and *Euphorbia hirta*.

2.1.5.8 Fire

Fires occur in the grasslands and in the sal forest between January and April. Most fires are lit either by local villagers or by park staff, although there are reports of fires which started spontaneously. Fallen sal leaves provide the fuel in the sal forest, as there is little undergrowth during the dry season. Dead wood, small saplings and shrubs also burn if the fire is hot enough, as it often is when fuelled by a patch of dry grass.

Early grassland fires are cool and have little effect on shrubs and trees. Later fires burn when the grass is much drier, and penetrate the edges of some of the riverine forest. Fires certainly reduce the number of species of trees and shrubs in the grasslands: *Bombax ceiba* is particularly fire resistant (Troth, 1976). The regrowth of grasses after burning is very rapid (Section 2.1.5.3) - particularly so if there are some early rain showers.

Burning is not a recent factor in the ecology of Chitawan: man has been burning grasslands in Asia for thousands of years and there is also considerable evidence of natural fires caused by lightning (Wharton, 1968; Ashton and Ashton, 1972; Kozlowski and Ahlgren, 1974).

2.1.6 Fauna

Nepal lies in the zone of overlap between the southern Oriental fauna and the northern Palearctic fauna. This geographical position has led to a very large bird population: half of the total number of bird species recorded in south and south-east Asia occur in Nepal (Fleming *et al.*, 1976). Over 500 bird species have been recorded in Chitawan.

The mammal fauna of Nepal is more limited, and that of Chitawan is restricted to the Oriental fauna. I consider below the large mammals which occur in the same habitat types as the rhino. Scientific names are listed in Appendix E and descriptions of these mammals were given by Prater (1971).

Among ungulates, hog deer are the most abundant, although rhinos constitute the bulk of the biomass (Seidensticker, 1976; Laurie, unpubl. data). Hog deer are predominantly grazers, and are rarely found in scrub or forest. They are usually solitary or in small groups. Next in abundance and biomass are the chital or spotted deer which frequently graze in the tall grasslands but also browse in riverine forest and the lower sal forest, and graze on short grasses at forest-edges and on open river-banks. Unlike hog deer, chital also live in scrubby areas outside the park, and feed on cultivated crops at night. Chital are more gregarious than hog deer, some herds numbering over 150 individuals.

Wild pigs, the next most abundant of the ungulates, are even more ubiquitous than chital. They occur in all habitat types, including the sal and hill forest, but are most in evidence on the flood plains and in scrubby woodland adjacent to cultivated land. The diet of wild pigs includes grass, roots, browse, fruits and the carcasses of other animals - they commonly feed from tiger kills. In cultivated land, wild pigs raid the maize crop in particular. Typical groups are made up of a number of females with their young from various litters.

The sambhar are the largest of the deer in Chitawan: they live at low density in all habitat types, either solitarily or in groups of 2-10 individuals. Sambhar eat a wide variety of plants, favouring young grass shoots when available and feeding extensively on submerged or floating aquatic vegetation. Barking deer, the smallest deer in Chitawan, are commonly seen in ones, twos and threes in riverine forest and the lower sal forest, especially near open river-banks. They are mainly browsers although they also graze short grass on the river-banks. Though more numerous than the sambhar, they constitute a smaller part of the biomass (Seidensticker, 1976; Laurie, unpubl. data).

Next to the rhino, the largest of the wild ungulates resident in Chitawan are the gaur or wild cattle which live mainly in the Churia and the Someswar hills but visit the plains during the dry season when food is scarce in the burned sal forest. Gaur are mixed grazers and browsers that live in herds of up to 30 individuals, although adult bulls are often solitary. Wild elephants now visit Chitawan rarely though 30 years ago they were very common. The swamp deer and the wild buffalo have both disappeared within the last 20 years.

It is important to note that, along the park borders, the biomass of the domestic ungulates is more than twice that of the wild ungulates; whereas, in the centre of the valley, the biomass of the domestic stock more closely approximates that of the wild ungulates (Seidensticker, 1976). The domestic stock is mainly cattle and buffaloes but there are also some sheep, goats and pigs.

Among carnivores, there are about 30 tigers distributed throughout the park and a few more in surrounding areas. Chital are their most important prey (Sunnquist and Tamang, 1976), but the tigers also take rhino calves (Section 3.8.1). Leopards are widespread within the park and most numerous on the flood plains and in the lower hill forests. There are about 50-60 sloth bears within the park: they travel widely and feed on termites, ants and fruits (Laurie and Seidensticker, 1977).

Other predators include the Indian fox, the jackal, the striped hyaena, the wild dog, the jungle cat, the fishing cat and the smooth Indian otter. Gangetic dolphins live in the Naryani, but they are endangered by a barrage at the Indian border which restricts their movements.

The mammal with the greatest impact on the vegetation of the valley is undoubtedly man. There are almost 200,000 people living in the Chitawan valley, but only about 20,000 of these are within easy reach of the park. Man's greatest impact on the vegetation has been as a cultivator, a stock-keeper and a builder of wooden and grass houses (see Section 2.1.7). Poaching within the park is not extensive although deer and wild pigs are often trapped in the fields during the maize and rice growing seasons. Wild pigs are often captured as piglets and reared for the pot. Tigers and leopards are trapped or poisoned occasionally.

Reptiles and amphibians recorded in Chitawan include the marsh crocodile or mugger, the gharial, two species of monitor lizards, the starred tortoise and several species of lizards, snakes and frogs.

2.1.7 Current influences of man on the rhinos and their habitats

Uncultivated land is an important resource for the people of Chitawan. It provides grazing and fodder for their domestic stock (Section 2.1.6), fibres for rope-making, timber and grass for building, firewood for cooking, and fruits, shoots, fish, molluscs and crustaceans for human consumption. Stock-grazing and collection of forest produce are controlled to a certain extent outside the park and almost totally prohibited within the park.

However, domestic stock are grazed up to the edge of and sometimes within the park, particularly in the north-east, and there are illegal incursions by villagers to collect forest produce. The cutting of grass (*Imperata cylindrica*) for thatching is permitted in certain areas for two to four weeks per year. It is difficult to police such cutting, and unauthorized cutting of timber and canes of *Saccharum* spp. and *Narenga* spp. takes place. Furthermore, areas are burnt to facilitate the cutting of the canes.

Such activities have far-reaching effects on the habitat, and cause considerable disturbance to the wild animals (discussed in Section 7.1.2). Visits to the park by tourists have small effects at present on the ecology of the region, but will have to be monitored carefully (discussed in Section 7.2.1). Cultivation and stock-grazing have transformed vast areas of grassland and riverine forest within a relatively short time. Crop-raiding by rhinos is a serious problem, and a rhino-fence at Sauraha has been only partially effective in controlling it (see also Sections 4.3.7 and 7.2.1).

Poaching of rhinos has been controlled almost entirely (shown in Sections 3.8 and 7.1.1). However, the threats to the rhinos of a vastly decreased area of suitable habitat and a fast increasing human population are very serious. The protection, conservation and management of the rhinos and their habitats are discussed fully in Section 7.

2.1.8 Areas selected for intensive study

After a month spent exploring the park and its surroundings, I decided to make the Sauraha area in the east of the park my main study area. The reason for this choice was mainly that I found it easier to observe rhinos at Sauraha: unlike other areas I was able to see at least one rhino at Sauraha on almost every trip I made to look for them.

However, I did not want to limit investigations to Sauraha which is adjacent to the cultivated land and thus inevitably influenced by humans and domestic stock. I wanted to make comparative observations in an area further from the park boundary, and therefore I chose the Tiger Tops area as a subsidiary study area.

Figs. 2.6, 2.8 and 2.9 show the vegetation types in the Sauraha and the Tiger Tops areas. I built two thatched huts in the Sauraha area, and the larger one became my headquarters. On trips away from Sauraha, I either camped out, or stayed in guard posts or at the Tiger Tops Jungle Lodge.

2.2 The adaptation of the Indian rhino to its present habitats in Chitawan

The present riverine forest and grassland habitats of Chitawan are probably similar to those in which rhinos have been living for two million years (Sections 1.2, 1.3 and 2.1). However, most of the diverse large mammalian fauna of the Pliocene became extinct in the early Pleistocene, and the Indian rhino is one of the few species which survived the Pleistocene glaciations (Wadia, 1966). Thus, although the climatic and vegetational conditions are probably typical of those in which *R. unicornis* evolved, there are now fewer large herbivores to compete with the rhino, and predators are also reduced in numbers and diversity.

Man has been the most significant addition to the fauna since the Pliocene, and his greatest impact has been as a cultivator. He has cultivated most of the alluvial plain habitat of south Asia, and his herds of domestic cattle and buffalo have transformed areas of woodland into short grassland with scattered trees and scrubby undergrowth. The cultivated land and the scrubby border areas between cultivation and alluvial grassland or forest are relatively recent habitat types in the evolutionary history of the Indian rhino. Their present importance to the rhinos of Chitawan will become clear.

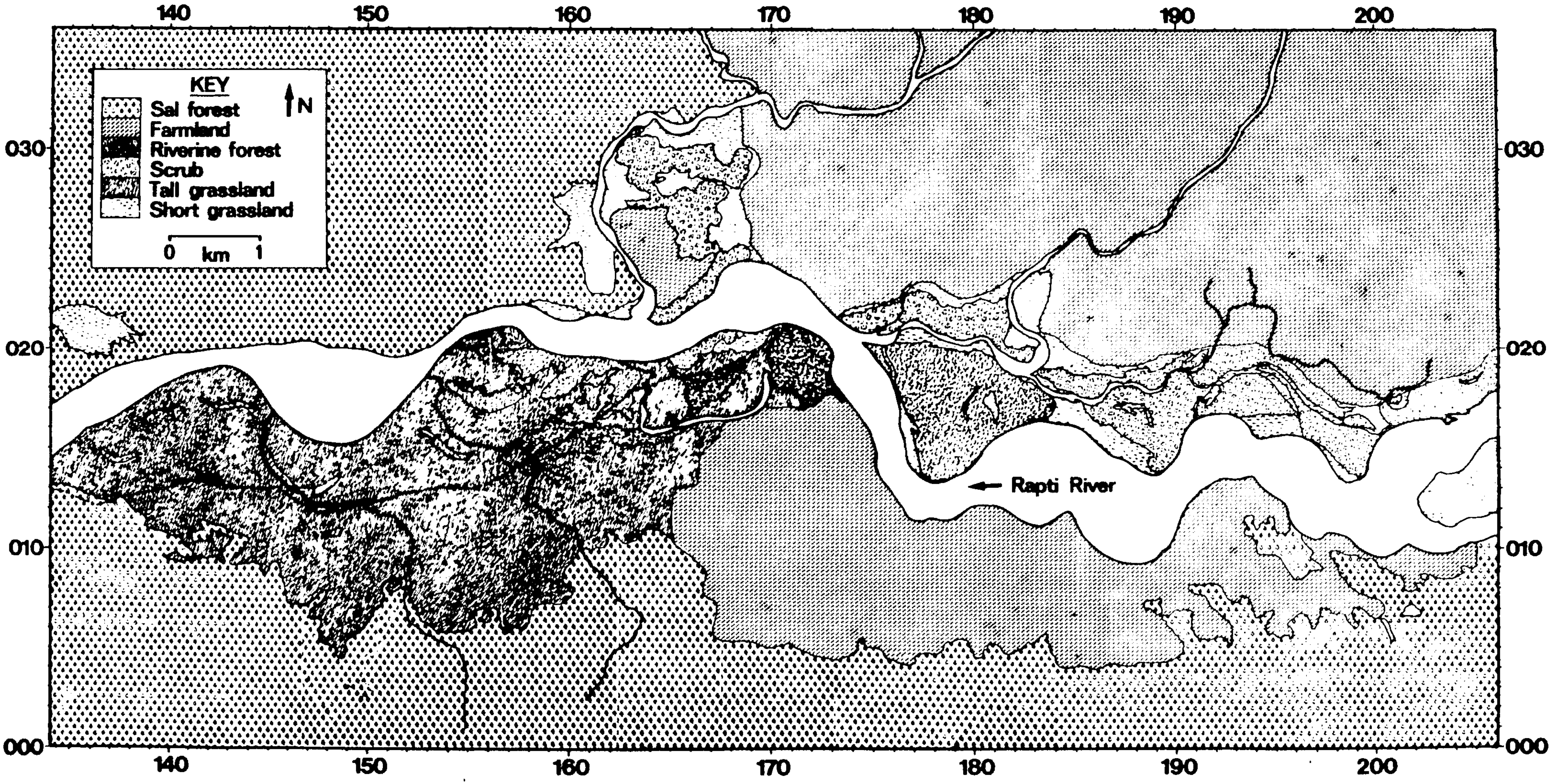


Fig. 2.8. A map of the Sauraha study area, showing the distribution of the major vegetation types.

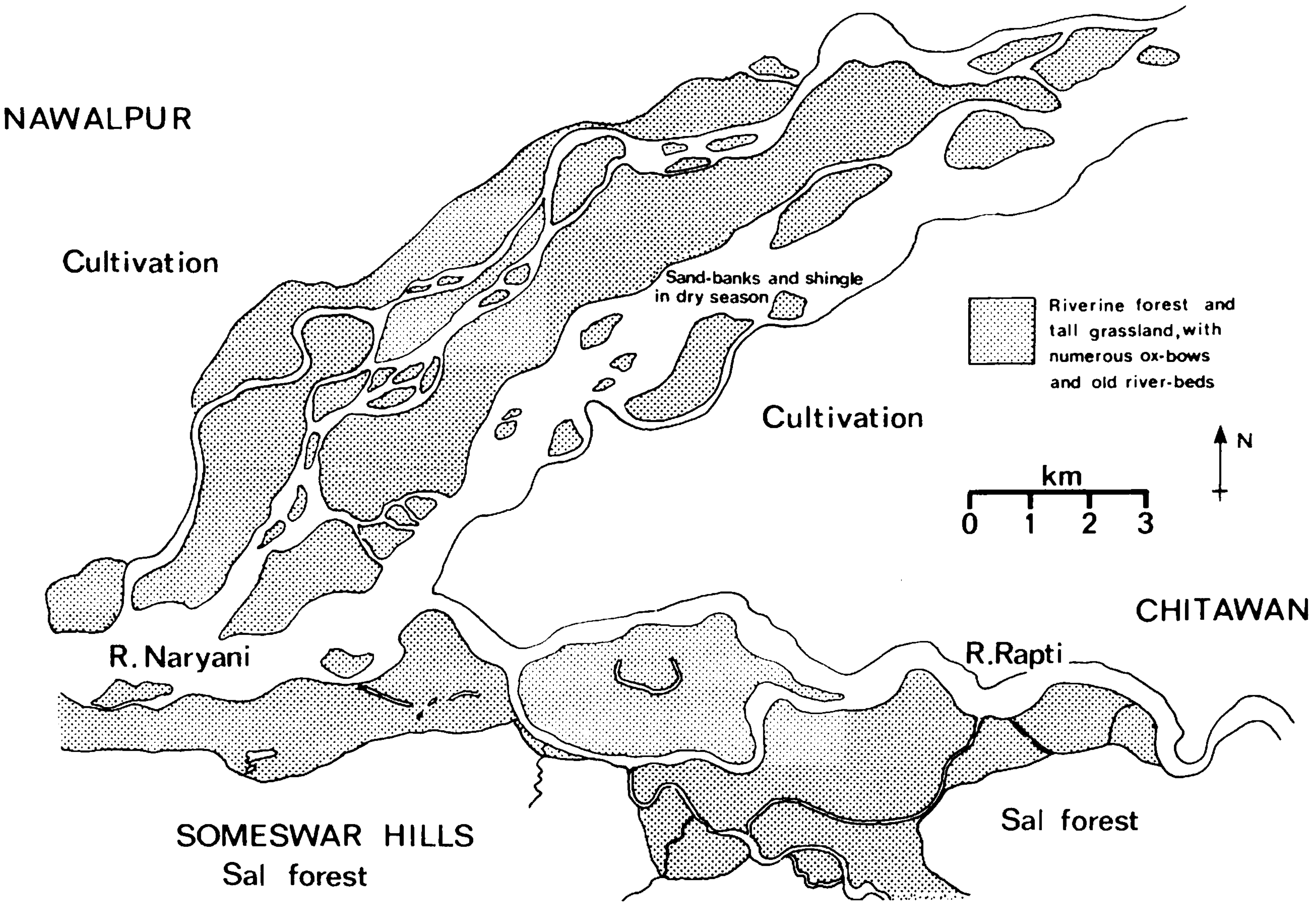


Fig. 2.9. A map of the Tiger Tops area, showing the distribution of the major vegetation types.

2.3 General methods of observation

The tall grasslands and dense woodlands made observation difficult, especially during the monsoon when much of the study areas were flooded I observed rhinos on foot, from elephant back and from machans: the habitat type, the season and the information being sought determined the observation method used.

Elephants were the easiest and safest form of transport in the thick grasslands and swamps of Chitawan (see Plate 6). I spent over 2,000 hours on elephant back during the study. Most of this time was taken up in searching for rhinos and determining which rhinos were present in a particular area. Elephants were not so convenient for prolonged observation of individuals,because they inevitably moved and started to feed, thus scaring away the rhinos being watched. Observation distances in thick grassland were obviously small; it was usually impossible to see a rhino at more than 10 metres distance,and then it was normally frightened and either ran off or remained nearby, alert and disturbed. In more open grassland and along river-beds, observation distances increased up to 200 metres and disturbance of the rhinos could be avoided. When searching an area,I stood on the back of the elephant holding a rope for support, thus attaining an eye height of about 4.5 metres on a moving platform. Any movement in the grass,or mynah birds flying up from rhinos' backs,could be spotted immediately,and the driver of the elephant directed to the spot.

For prolonged observations of individuals, the elephant was unsaddled and allowed to feed. Lying on her back and guiding her to keep downwind of grazing rhinos, I was able to remain undetected by the rhinos for periods of up to two hours.

Although elephants were invaluable in reaching areas dangerous or impossible to visit on foot, they were impractical for observation of animals in woodland areas. The noise of their passage and the cutting of branches by the driver scared many rhinos and other animals before I could see them. It was more convenient to travel on foot in these areas. There were usually trees nearby for escape from aggressive rhinos; and careful progress, listening for sounds of rhinos feeding, moving or breathing, enabled me to approach very close to rhinos. I often climbed a tree downwind of any rhinos found, and observation distances in these cases were usually between 20 and 40 metres, although the rhinos sometimes came nearer and stood beneath the tree. The most extended observations were made from machans built in trees or on the ground. The highest machans were about 15 metres above the ground, and from these I could survey wide areas without being detected by rhinos. Successful use of the lower ones depended upon the wind direction: they were excellent for close up photography and most were situated at wallow edges or in short grass clearings with good visibility. I built several machans in some clearings, and used the one which was downwind of the clearing on any particular occasion. Observation distances from machans varied from less than one metre to over 600 metres.

Observations were aided by the use of 9 x 40 or 7 x 50 binoculars. I used a 22 x 60 telescope on a tripod in open areas and from the high machans. A Rank image-intensifying device was found invaluable at night in open areas, and was sometimes used in conjunction with an electric torch in the absence of starlight or moonlight.

Table 2.1 shows the number of sightings of rhinos and the number of rhino hours of observation made on foot, from machans, from elephant back and from camp, cars, aircraft or boats. Although the number of sightings made on foot, from elephant back and from machans are roughly equal, 60% of the rhino hours of observation were made from machans, 28% on foot and only 9% from elephant back. The average number of hours of observation per

Table 2.1. Rhino sightings classified according to observation methods.

Observation method	Number of sightings of rhinos	Number of rhino hours of observation	Average number of hours of observation per sighting
Foot	2298 (35.9%)	874 (28.0%)	0.38
Machan	1888 (29.5%)	1873 (59.9%)	0.99
Elephant	1949 (30.4%)	281 (9.0%)	0.14
Camp, car, aircraft or boat	266 (4.2%)	98 (3.1%)	0.38
Total	6401	3126	0.49

sighting for each observation method is also shown in Table 2.1. Observations from camp account for most of the other methods. Whenever rhinos walked past my camp - usually at night - I followed them for as long as possible. A few observations were made from aircraft, cars,dug-out canoes and a rubber dinghy.

The duration of observations varied from brief glimpses of a few seconds up to 33 hours. It was difficult to follow individual rhinos for long periods without being detected. When rhinos detected my presence they normally moved away immediately or remained alert and inactive for periods of up to 30 minutes before resuming their previous activities or moving off. Fig. 2.10 shows the frequencies of different observation durations. It can be seen that 57% of observations were 10 minutes or shorter in duration. Most of the long observations were made from high machans or at night when rhinos came out into the open and I could follow them more easily from a distance.

Observations were of two general types. Either I recorded information on the individuals present, the time and the place, and moved on, or

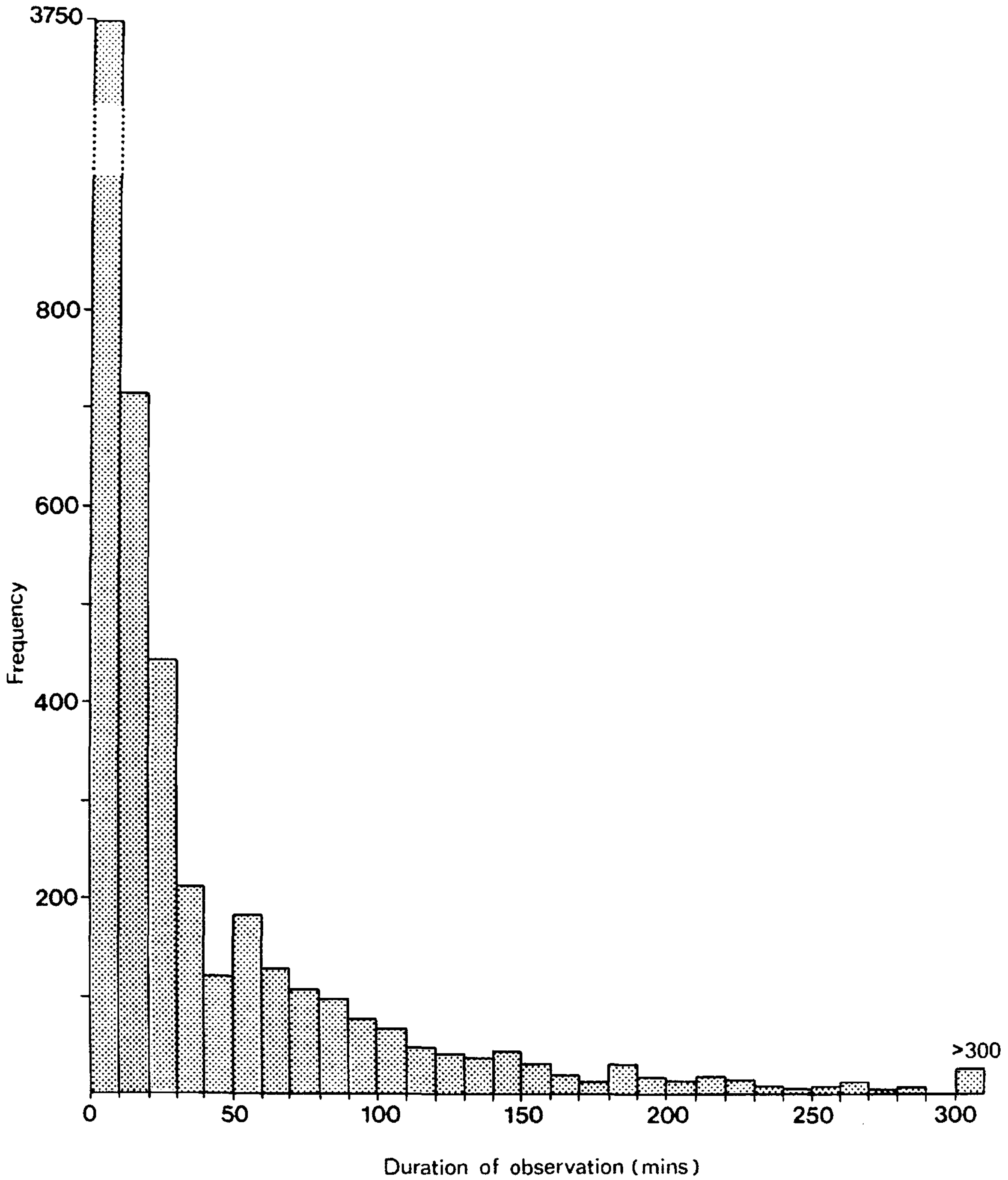


Fig. 2.10. Frequency distribution of the durations of rhino-observations.

I observed and followed selected individuals for longer periods. Standard information recorded for each sighting included the following:-

(1) Date, time, location, weather, observation method and distance, wind strength and direction.

(2) Age and sex of rhinos present and their identity

or distinguishing characters leading to identification (sex and age classification and identification methods are described in Sections 3.1 and 3.2).

(3) Initial activity of rhinos and all subsequent activities with timings and details of food plants eaten.

(4) Details of interactions between rhinos and any behaviour associated with communication - mostly sounds and scent marking.

(5) Time of the end of the observation, *i.e.* when either I or the rhino left.

During these observation periods I gave priority to recording social behaviour, over other activities. Thus, during observation periods from machans, I concentrated my attention on interactions between individuals and attempted to follow individuals which were courting or fighting, if they passed out of sight from the machan. Similarly, when on foot or on elephant back, I followed interacting individuals. If I heard obvious sounds of rhinos fighting, I hurried in the direction of the fight to try to find out what was happening.

Certain individuals were selected for more detailed study on some occasions. Further details of the methods used and the data collected are given at the beginnings of Sections 3, 4 and 5. I used a notebook and pencil to record data, and sometimes a tape-recorder at night in machans. I transcribed the data into a large notebook and elaborated on some of the details as soon as possible after returning from the field. Observations were entered under the day on which they were made. Standard information on time, location, sex, age and identity was duplicated on cards. Summaries and references to the notebooks were entered under the behavioural and feeding headings, and the cards thus provided a method of indexing the notebooks and were used later in the analysis of the data.

2.3.1 Distribution of searching effort and observation time

There was enormous variation in visibility over the study area and throughout the year due to the seasonal changes in vegetation described in Section 2.1. I spent longer in the places which I had learnt were good for finding and watching rhinos at a particular time of the day and the year. I visited the less good areas regularly but less frequently, because it was more profitable to collect information by watching rhinos than to sit in areas where I saw very few rhinos, in order solely to distribute my searching time equally around the study area. Figs. 2.11, 2.12 and 2.13 show the percentages of searching or field time (n = 6,992 hours) and the percentages of observation time (n = 3,126 rhino hours, which corresponded to 1,182 man hours) in each habitat type, month and time of the day for the whole study period. There is considerable variation between different months, hours of the day and habitat types. I explain in the relevant sections how I overcame the effects of differences in the distributions of searching effort and observation time.

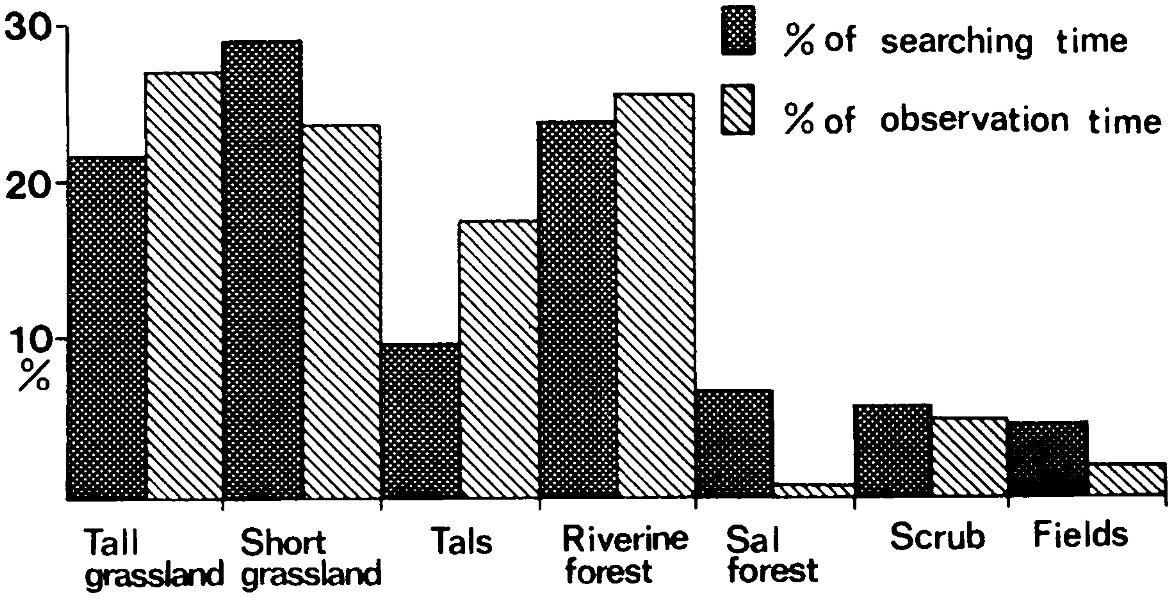


Fig. 2.11. The distribution of searching time and rhino-observation time over the major habitat types.

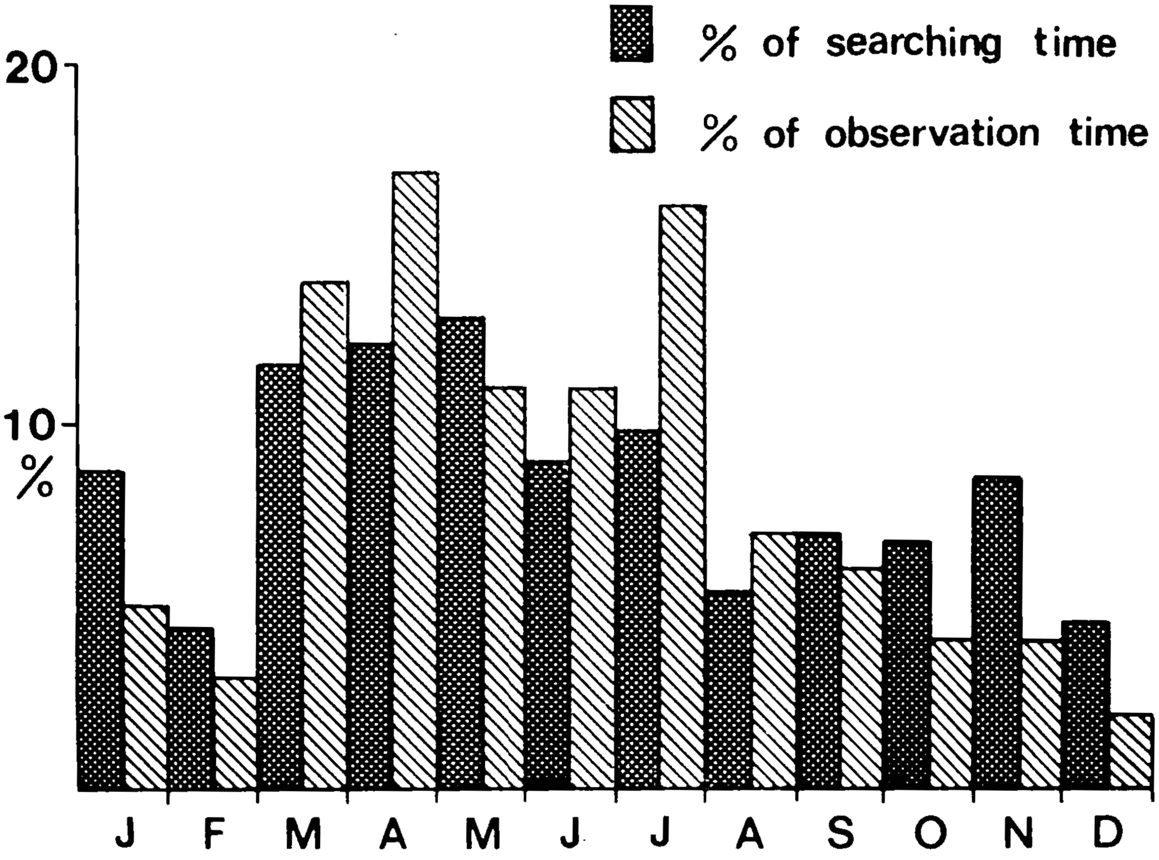


Fig. 2.12. The distribution of searching time and rhino-observation time according to the time of year.

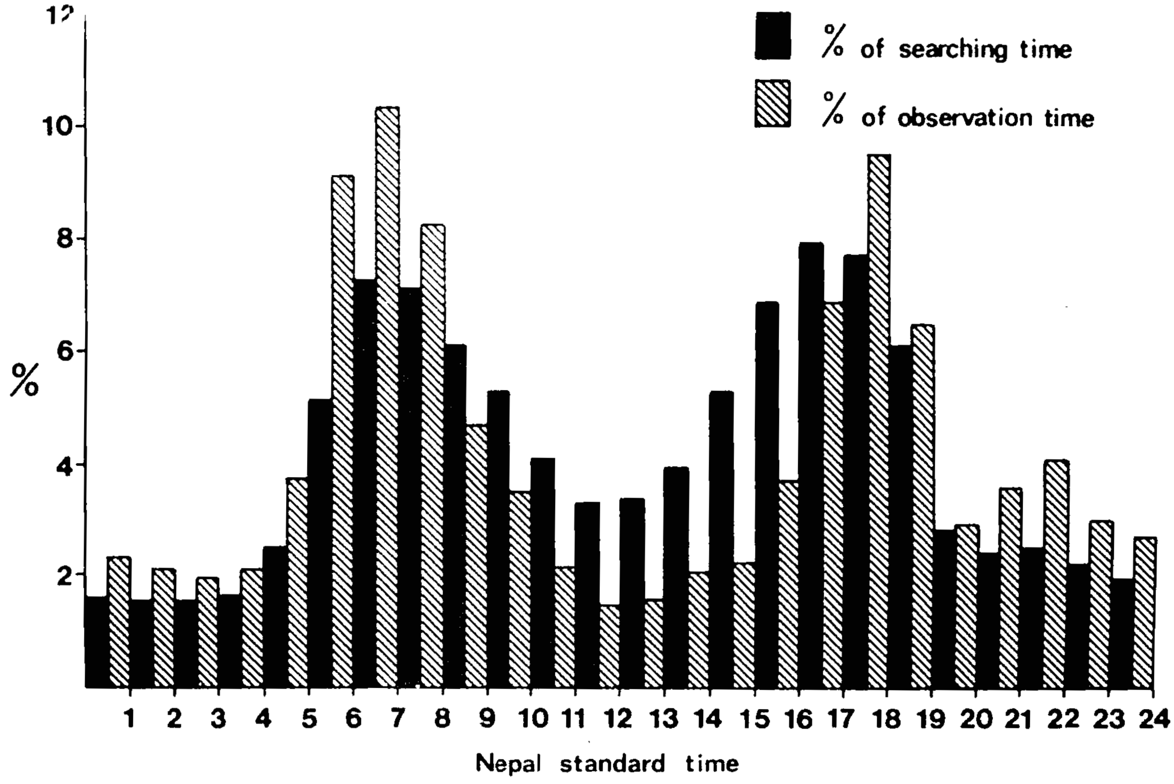


Fig. 2.13. The distribution of searching time and rhino-observation time according to the time of day.

2.3.2 Reactions of rhinos to observers

Disturbance of rhinos by the observer often reduced the duration of observations and affected the behaviour of the rhinos in various ways. Rhinos reacted to the observer in some way on 38% of the 6,323 observations made on foot, from elephant back or from a machan or camp. Although there were an enormous variety of reactions to disturbance, I have summarized them in eight main categories:-

1. Silent alert (n = 53)

   The rhino stood still and silent for several minutes, after an initial snort on a few occasions (n = 14).

2. Turn in alarm (n = 84) (Plate 7)

   The rhino suddenly started or turned in alarm and then stood in the same place.

3. Sudden flight (n = 1,185) (Plate 8)

   Sudden flight away from the observer, sometimes accompanied by sounds such as snorts, honks and humphs (described in Section 5.3.1).

4. Charge (n = 117) (Plate 9)

   The rhino suddenly charged head down towards the observer. It usually veered off to one side at the last moment, or stopped and turned round before running off. It sometimes stopped again a short way off to look back (n = 10) or to walk (n = 13).

5. Curious advance (n = 122)

   The rhino advanced inquisitively towards the observer, often sniffing the ground and the air. Afterwards it normally ran or walked away (n = 96) or stayed very close and would not move away (n = 26).

6. Run and look back (n = 197)

   A hesitant flight often preceded by a long look at the observer and broken by repeated pauses in which the rhino turned to look back towards the observer. The rhino snorted occasionally and went on again in short bursts of trotting.

7. Walk away (n = 520)

   A quiet but quick walk away from the observer, often preceded by a long look at him.

8. Ignore observer (n = 102)

   The rhino continued its previous activities, apparently unconcerned about the presence of the observer. It was clear from its initial brief glance towards me that the rhino had detected my presence.

The above classification of reactions is inevitably incomplete, and many combinations of two types of reaction have been classified under their ultimate component. Thus, silent alertness and sudden turns in alarm often preceded the other reactions: the only reactions classified in these two categories are those which did not include any other components.

Table 2.2 shows the frequency of detection of the observer by rhinos for the various methods of observation and also the frequency of the eight types of reaction to the detection of the observer. There were significant differences between the observation methods in the number of times the observer was detected by rhinos. The detection rate was lowest in machans and highest on elephant ($\chi^2 = 854.2 \quad p < 0.001$). There were also significant differences in the types of reactions to the observer ($\chi^2 = 32.8$ $p < 0.01$); for example, the greater tendency to sudden flight from an observer on elephant back than from one on foot or in a machan.

There were consistent individual and sex and age differences in the reactions of rhinos to observers. I was eventually able to predict the reaction of different rhinos to my presence and adjust my observation distance accordingly. Table 2.3 shows the numbers of reactions of the

Table 2.2. Reactions of rhinos to the observer for different observation methods.

Observation method	Number of observations			
	Elephant	Foot	Machan/Camp	Total
Reaction type				
Silent alert	34 (2.9%)	10 (1.1%)	9 (3.0%)	53
Turn in alarm	40 (3.4%)	31 (3.5%)	13 (4.3%)	84
Sudden flight	581 (49.4%)	470 (53.3%)	134 (39.8%)	1185
Charge	58 (4.9%)	49 (5.6%)	10 (3.1%)	117
Curious advance	55 (4.7%)	49 (5.6%)	18 (6.0%)	122
Run and look back	103 (8.8%)	69 (7.8%)	25 (8.4%)	197
Walk away	254 (21.6%)	169 (19.2%)	97 (29.9%)	520
Ignore observer	50 (4.3%)	34 (3.9%)	18 (5.5%)	102
Number of observations when observer detected	1175	881	324	2380
% of total observations	60.3	38.3	15.6	37.6

Overall $\chi^2 = 32.8$ $p < 0.01$

Table 2.3. Reactions of rhinos to the observer, classified according to the rhinos' sex and age classes.

Class	Number of observations				
	A♂	A♀	S	C	Total
Reaction type					
Silent alert	12 (3.7%)	17 (2.4%)	7 (1.1%)	14 (2.3%)	50
Turn in alarm	10 (3.2%)	29 (4.1%)	16 (2.6%)	28 (4.7%)	83
Sudden flight	81 (25.0%)	310 (44.0%)	388 (62.9%)	309 (51.4%)	1088
Charge	19 (5.9%)	77 (10.8%)	6 (1.0%)	13 (2.2%)	115
Curious advance	40 (12.5%)	35 (5.0%)	15 (2.4%)	29 (4.8%)	119
Run and look back	12 (3.7%)	54 (7.7%)	70 (11.3%)	48 (8.0%)	184
Walk away	78 (24.0%)	169 (24.0%)	107 (17.4%)	151 (25.1%)	505
Ignore observer	71 (22.0%)	14 (2.0%)	8 (1.3%)	9 (1.5%)	102
Number of observations when observer detected	323	705	617	601	2246
% of total observations	38.5	37.8	43.5	38.1	39.4

different types by rhinos of each of four age and sex classes. (I describe in Section 3.1 how I determined the sex and age of rhinos.)

Sub-adults detected the observer more than adults did ($\chi^2 = 11.7$ $p < 0.001$). Sub-adults also took to sudden flight and repeated running and looking back significantly more frequently than adults. Calves ran away more than adult females did: the latter tended to charge towards the observer more than any other classes did. Adult females also ran away more frequently than adult males which were more curious, and often walked up to the observer or ignored him completely. In general, young animals displayed a greater tendency to flee than did older animals, particularly males. This tendency was also noted in agonistic interactions between rhinos (described in Section 5.4.2).

2.4 Summary

1. The study was carried out in and around the Royal Chitawan National Park in the lower half of the Chitawan Valley of southern Nepal. The climate is monsoonal with a mean annual rainfall (1973-1975) of 2,400 mm, 92% of which falls between May and September.
2. Most of the valley floor is under cultivation. The hillsides are forested with deciduous or semi-deciduous tree species, *e.g.* sal (*Shorea robusta*), and the low-lying areas along the rivers in the National Park are a mosaic of riverine forest types and tall grasslands up to eight metres in height. There are rapid and very marked seasonal changes in climate and vegetation.
3. Fires, annual floods and frequent changes in river-courses maintain a high diversity of early successional vegetation stages on the valley floor. The activities of man and his domestic stock increase the habitat diversity where the park meets the cultivated areas, but the

present forest and grassland habitats are probably similar to those in which the Indian rhino evolved.

4. In addition to the Indian rhino, the large mammal fauna of the park includes four species of deer, wild pig, gaur, tiger, leopard and sloth bear.

5. The tall grasslands and dense woodlands of Chitawan made observations difficult. Two areas were selected for intensive study, and rhinos were observed on foot, from elephant back and from machans. Rhinos were seen on 6,401 occasions and watched for a total of 3,126 rhino hours (1,182 man hours).

6. Rhinos reacted to the presence of the observer on 38% of occasions. There were eight main types of response to disturbance but the most frequent was rapid flight.

3. POPULATION

Methods

3.1 Individual identification

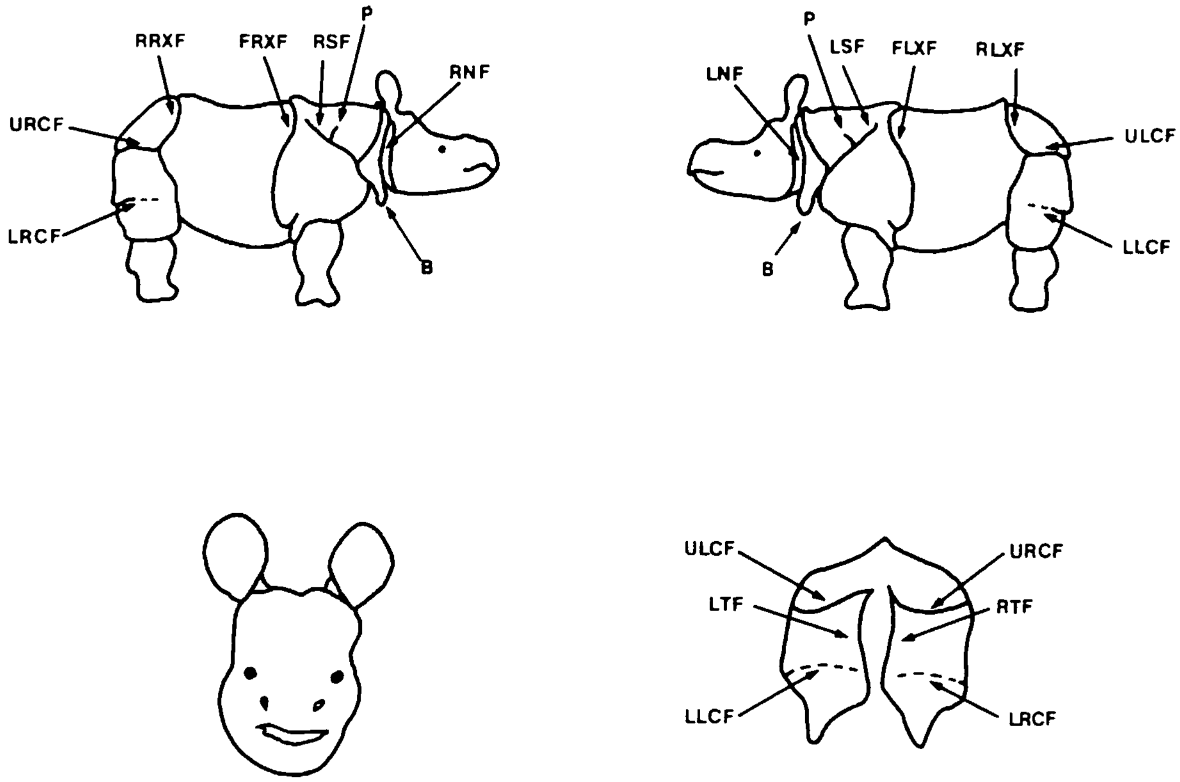
I needed to be able to identify individual rhinos in order to estimate the numbers in the population and to study the movements and behaviour of individuals.

With experience, it can be seen that individual rhinos vary considerably in their appearance. The most obvious differences between individuals are in the characters listed and described below.

(1) Arrangement of skin folds.
(2) Irregularities in skin folds.
(3) Scars.
(4) Arrangement of tubercles on the rump.
(5) Ear nicks.
(6) Tail length.
(7) Horn length and shape.

The arrangement of the skin folds was used to classify individuals into a number of distinctive types. Fig. 3.1 shows the main skin folds and the names given to them. The shoulder-fold in a few individuals extends across the back of the neck just anterior to the front cross-fold. The 'prongs' on the shoulder-fold vary in number and length and are sometimes absent altogether. The neck-folds also vary in number. The lower corner-folds are absent in young animals and their arrangement on the rump varies between individuals. The nature of the junction of the corner-folds and the rear cross-folds also varies, and in some cases the rear cross-fold is split above the corner-fold.

Rhinos commonly develop bumps and irregularities on the folds as they grow older (Plate 10). Some of these result from wounds,but many seem to



KEY

LRCF:	Lower right corner-fold	LLCF:	Lower left corner-fold
URCF:	Upper right corner-fold	ULCF:	Upper left corner-fold
RRXF:	Rear right cross-fold	RLXF:	Rear left cross-fold
FRXF:	Front right cross-fold	FLXF:	Front left cross-fold
RSF:	Right shoulder-fold	LSF:	Left shoulder-fold
RNF:	Right neck-fold	LNF:	Left neck-fold
P:	Prong	B:	Bib

Fig. 3.1. Outline drawing used to record identifying features of rhinos in the field.

grow spontaneously. The most common positions for these bumps are on the cross-folds; particularly on the rear cross-folds near the corner-folds. One cow had such a long pendulous bump on her rear left cross-fold that it bounced up and down as she walked. None of these bumps changed appreciably in appearance during the study period.

Other marks appear on the skin during a rhino's life. Scars from old wounds make up the bulk of these,but there are also raised areas near the folds, similar to those described for the folds themselves. The tubercles on the skin are also arranged in individually distinctive patterns, but these are often obscured by mud and were only useful at close range. I used tubercle patterns mainly to distinguish between young animals which had not developed individually distinctive fold patterns, horn and ear shapes.

Horns, ears and tails vary considerably in length and shape in older animals. For horns, the rings and grooves in the surface, the degree of curvature and the length are the most distinctive features. Ears acquire nicks, the sizes, shapes and positions of which are individually distinctive. The same is true of tails: it was quite common to see individuals which had lost parts of their tails. In addition to those features described above, there were less definable characteristics such as the distance between the ears, and the general shape of the head, which, with practice, were also reliable identification marks.

It was important to record several identifying features for each individual. This reduced the chance of finding two rhinos with the same recorded features, and also enabled me to identify each individual from several angles. In thick vegetation I often caught only a glimpse of a rhino, but was nevertheless able to identify it if I knew the characteristics of its two flanks, rump, folds, horn and ears. There were two rhinos which I could identify without even seeing them, as they had individually distinctive vocalisations.

I tried to take photographs of each individual to show its identifying features. However, photography was often impractical, especially in tall grass areas or at night; although I did obtain some good identification photographs with the image intensifier on moonlit nights (Plate 11). These photographs were supplemented by drawings and descriptions of each individual's identification marks. I used outline drawings of the front, rear and side views of rhinos (Fig. 3.1) to record each individual's features in the field. Identification cards were made later for each identified individual (Plate 2). All rhinos registered in this way were assigned a number, and most were also given names suggestive of their main identifying features. A chart, extracts from which are reproduced in Fig. 3.2, was updated regularly to show the combinations of characters being used to identify each individual. Reference to this chart helped me to distinguish between individuals which had some duplicated features.

Brief glimpses of a rhino were often insufficient for positive identification. All identifying characters seen on such occasions, and the absence of marks from the parts of the body seen, were recorded on cards with an 'X' prefix to the number. In many cases I later matched up these individuals with previously identified individuals, or recognised them as new individuals when I subsequently identified them at a later date, under better observation conditions.

It was more difficult to identify calves and young animals,without close observation. However, very young calves were almost always with their mothers,and there was no need to pay much attention to their individual identifying features. I made a special effort to identify older calves so that I could follow them after they left their mothers. As the rhinos grew older, they gained more prominent marks which were useful for identification. With records of several identifying features for each rhino, I found it possible to recognise newly acquired features. The chart and identity cards were duly updated in such cases with new notes, photographs and drawings.

As it was difficult to identify young animals, I tried to mark some animals with self-attaching collars of plastic rope, similar to those used on red deer in New Zealand by Taylor (1969). These collars were set up as

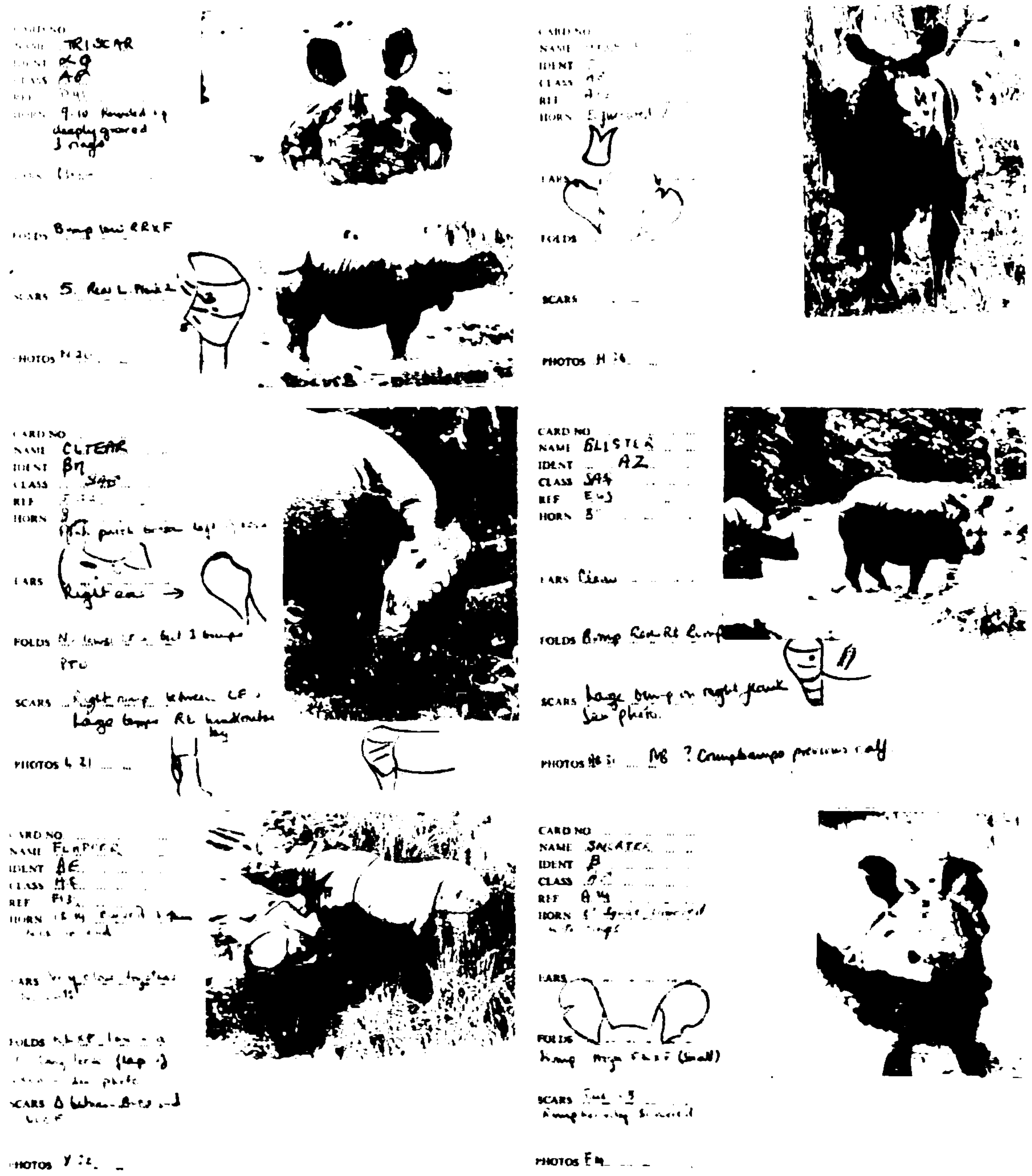
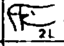
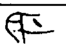


Plate 2. A selection of six rhino identification-cards. Further details and photographs were included on the backs of such cards.

snares on rhino paths in an area with a particularly high density of young animals which had left their mothers. I took care when designing the collars

1st OBS. No.	1st PHOTO No.	IDENT. LETTER	NAME	CLASS	HORN	R. EAR	L. EAR	RLXF L H	RRXF L H	RLXF/ULCF	RRXF/URCF	ULCF	URCF	TAIL	FLXF L H	FRXF L H	L. FLANK F R	R. FLANK F R	HEAD	NF	PRONG/SF	RUMP L	RUMP R
00013	A36	α 001	Stumptail	A♂	Gr 12"				B					6"								Scarred	
00024	B03	A 073	Curvy	A♀	C 12"		 F																
00025	B03	a₁ 074	Nosy	♂IC(4/72)	-															Split			
00055	C02	D 081	Shorthorn	A♀	RG 3"				B	Dent 		3S 										S 	
00126	D22	δ 004	Comer	A♂	Gr 8"			B B		B					B					Segment-ed (rt side)			
00128	D25	C 078	Thinhorn	A♀	RG 10"									½severed	B								
00130	D30	G 090	Gertie	A♀	Left tip 17" missing				B 2S					9"									
00131	D30	g₁ 091	Gilbert	♂IIC	5"										Double FXF							S 	
00137	E05	ϵ 006	Mr Plod	A♂	Gr 11"				B													S	
00138	E09	B 075	Bobbles	A♀	Gr/R 11"				3B S		B												
00139	E09	b₁ 076	Bubbles	♂IIIC	4"							See photo F12											
00642	H04	V 013	Mittenear	A♂	Gr 13"											B	S						
01224	-	AH 137	Mrs Pipplequick	A♀	 9"			B			B										2P		
01427	M12	AY 183	Sidestripe	S♀	 8"			2L	 2L	B+S				 B				 S			Long		
01575	-	AK 139	Fingers	A♀	 9"																		
01577	AA31	AJ 141	Crumplerump	A♀	 10"			Big B															B rt of tail-base
01634	S14	AE 130	Flapper	A♀	C 13"	Close together		Flap			B												
02047	AA02	88 056	Squarecut	A♂	Str 10" R												 2S						S 
02429	L21	δn 066	Cutear	S♂	5"													L.S 			2P	No LCF's 3B	S between CF's

Abbreviations of fold-names as in Fig. 3.1. Other abbreviations:-

Gr = Grooved C = Curved RG = Regrown R = Ringed Str = Straight F = Floppy B = Bump S = Scar L = Scar adjoining RXF

Fig. 3.2. Extracts from the chart showing identifying features of registered individuals.

to ensure that they would not stay on long enough to endanger the life of the growing animals. It proved difficult to make the collars small enough to stay on yet still effective in their self-attaching mechanism; and although seven individuals were marked with numbered tags in this way, they all lost their collars after periods of from one to eight days.

3.2 Sex and age classification

3.2.1 Sex determination

I determined the sex of rhinos by observation of

(a) external genitalia
(b) body-size and the shape of the head, horn and neck folds
(c) urination
(d) accompanying calves
(e) mammary glands.

Sex determination was easy during long observations in the open, but it was often difficult during short observations in dense vegetation, especially of young animals. From the external genitalia, it was easier to be sure of a positive determination for males than for females. The penis of a rhino is clearly visible from the side or from behind, especially when the rhino is walking. The female genitalia need closer examination and are only visible from the rear. Thus there is liable to be a bias towards males in the sex classification of young rhinos (discussed in Section 3.6.1). There is no such bias in the sex classification of adults, because they are sexually dimorphic in body size and in the shape of the head, horn and neck folds. Adult males are larger in stature and bulk than adult females (see Section 3.2.2). The horn is usually wider at the base in males than in females, and is more often broken off or worn down by rubbing on trees and bushes. Adult males also differ from adult females in having more deeply folded skin around the neck and a bigger 'bib' beneath the chin (Plates 12 and 13).

Observation of urination provided a very good determination of the sex of an individual and was especially useful in young animals which had not developed markedly sexually dimorphic characters. It was also useful at long distances and at night (see Plate 14). Direct observation of the mammary glands was useful on a few occasions in the cases of young pregnant females or females which had recently given birth.

Eventually, after repeated sightings of the registered individuals I was able to determine the sex of all the adults and sub-adults and all but 16 of the calves. Therefore, among the registered individuals there is little bias in sex classification; but there is some bias towards females in the sex classification of sightings of unregistered adults. This is because adult females have an additional sex-indicating character, particularly useful during brief or long distance observations, in having accompanying calves.

3.2.2 Age

I divided calves into four age classes by estimating their heights and areas in side view in relation to that of their mothers, and the development of their horns. When possible, measurements of the relative shoulder-heights and body-lengths were made on photographs of cows and calves near each other - side by side or one behind the other (*e.g.* Plates 15 and 16). Table 3.1 shows the four age classes of calves and the age in years to which they were found to correspond approximately.

Rhinos of various ages were measured photographically. A rhino in the open was photographed; when it had moved off a second photograph was taken, from exactly the same position, of a calibrated pole placed in the forefoot-print of the rhino (shown in Plates 17 and 18). With a tripod

Table 3.1. The age classification of calves.

Age class	Age (years)	Shoulder height (cms)	Side view area as a proportion of mother's	Horn length (cms)
1	0 - 1	60 - 100	$^1/_9 - ^1/_3$	0 - 2
2	1 - 2	100 - 120	$^1/_3 - ^2/_3$	2 - 5
3	2 - 3	120 - 135	$^2/_3 - ^3/_4$	5 - 8
4	> 3	> 135	$^3/_4 - ^4/_5$	> 8

All measurements are approximate.

for the camera and a stand to support the pole, the whole operation could be done single-handed; on other occasions an assistant helped by taking the pole to the footprint. I also measured rhinos by watching for branches which they just managed to pass beneath, and then measuring the height of the branch above the ground. The actual heights of the four age classes of rhino calf are shown in Table 3.1.

After calves had left their mothers they were classed as one of two age classes of sub-adults. Class 5 animals range in age from just under three to over five years. Their horns are less than 11 cms long (perpendicular measurement from tip to base), and they have very few cuts in the ears or skin, or prominent irregularities in the folds. The neck-folds are small and the bib does not protrude below the level of the chin (see Plate 19). Shoulder-height is generally between 135 and 145 cms (Table 3.2).

Table 3.2. The age classification of sub-adults.

Age class	Age (years)	Shoulder height (cms)	Horn length (cms)	Neck folds and bib
5	3 - 5	135 - 145	8 - 10	Very slight
6	5 - 9 (according to sex)	145 - 155	8 - 18	More pronounced

All measurements are approximate.

Class 6 includes all other sub-adults. They are slightly bigger - up to 155 cms at the shoulder - and are distinguishable from adults (Class 7) by their lesser height, the shallower folding around the neck, and shorter horns which rarely exceed 18 cms (Table 3.2 and Plate 20). Adults measured in Chitawan ranged in height from 160-183 cms (females, 160-170 cms; males, 170-183 cms), and their horns measured up to 45 cms (see Appendix M). Some adult females were undoubtedly shorter than 160 cms at the shoulder and would have been classed as sub-adults if they had not had accompanying calves. Those with accompanying calves were defined as adults, which is liable to cause a bias towards males in the sex ratio of sub-adults (discussed in Section 3.6.2).

I measured all dead rhinos which were found, and recorded details of their dentition (Laurie, unpubl. data). Also, when possible, I collected the lower incisors (shown in Plate 21) and later sectioned them longitudinally with a diamond saw for microscopic examination of the cementum and dentine layers. I found very distinct incremental lines in both the cementum and the dentine, although they were more distinct in the cementum (results in Section 3.8.2). Viewing of the sections in polystyrene dishes with polarised light produced birefringence patterns that helped in distinguishing the lines. Similar lines have been used to age many mammals in seasonal environments, *e.g.* seals (Laws, 1952), reindeer (Reimers and Nordby, 1968) and buffalo (Grimsdell, 1973; Sinclair, 1977).

3.3 Determination of population size

3.3.1 Registration of individuals

An attempt was made to identify, register and count all rhinos which used the study area. Possible errors in this method of estimating the population size include mistaken identifications and incomplete registration.

Mistaken identifications could be of two kinds. A single individual could be registered as two or more different individuals, or two or more individuals could be consistently confused and recorded as the same registered individual. One would eventually expect to detect such mistakes by finding impossible or unlikely movements indicated in the location records for each individual. Furthermore, in the event of the first type of mistake, one could find that a registered individual, seen consistently for part of the study period, 'disappeared' and was 'replaced' in the records by a similarly marked individual. I eliminated possibilities of mistaken identifications by regularly checking the chart of registered individuals (Fig. 3.2).

To demonstrate that most of the individuals which used the study areas were registered, the ratio of the number of new individuals registered to the total number of individuals seen is plotted in Fig. 3.3 for each month of the study period. Months were chosen as the unit of time for this and later analysis because they are of a convenient length - long enough for the numbers of individuals seen to be little affected by a few days per unit spent away from the area, and short enough to demonstrate changes through the study period. Months are particularly suitable units because they include a complete lunar cycle: many of the individuals could only be seen on moonlit nights along open river beds in areas where it was almost impossible to find them during the day due to the thickness of the vegetation.

The total number of individuals seen per month in Sauraha, shown in Fig. 3.4, did not decline, whereas the proportion of new individuals in the monthly totals very quickly dropped to a level of about 5% (Fig. 3.3). A continuous low proportion of new individuals would be expected as a result of births which occurred during the study period. Excluding all calves born during the study period, the rate of identification of new individuals

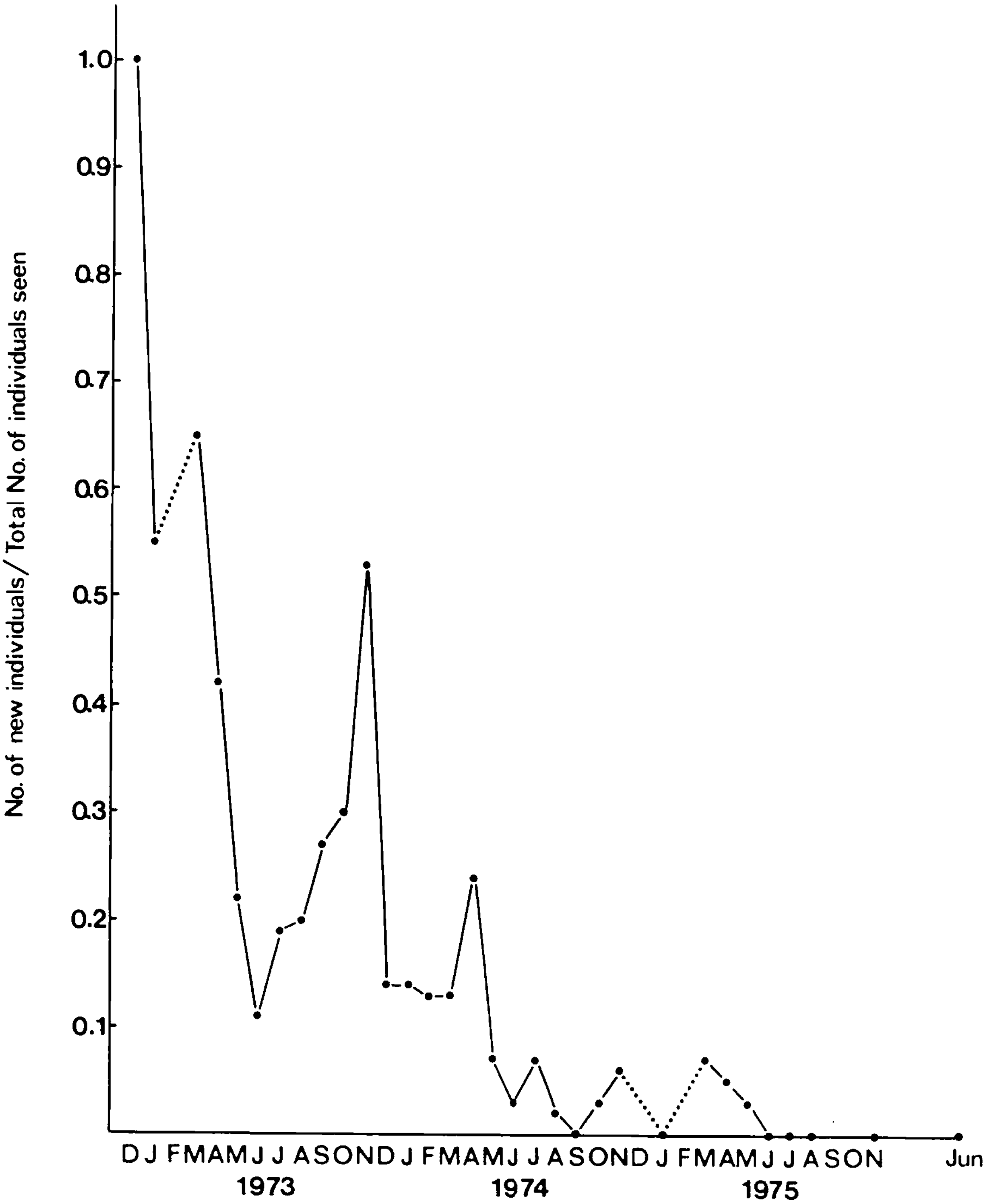


Fig. 3.3. The ratio of the number of new individuals registered to the total number of individuals seen in each month. Dotted lines indicate no data for those months.

fell to zero, as shown in Fig. 3.5 which is a plot of the cumulative total of identified individuals for each month of the study period in each study area.

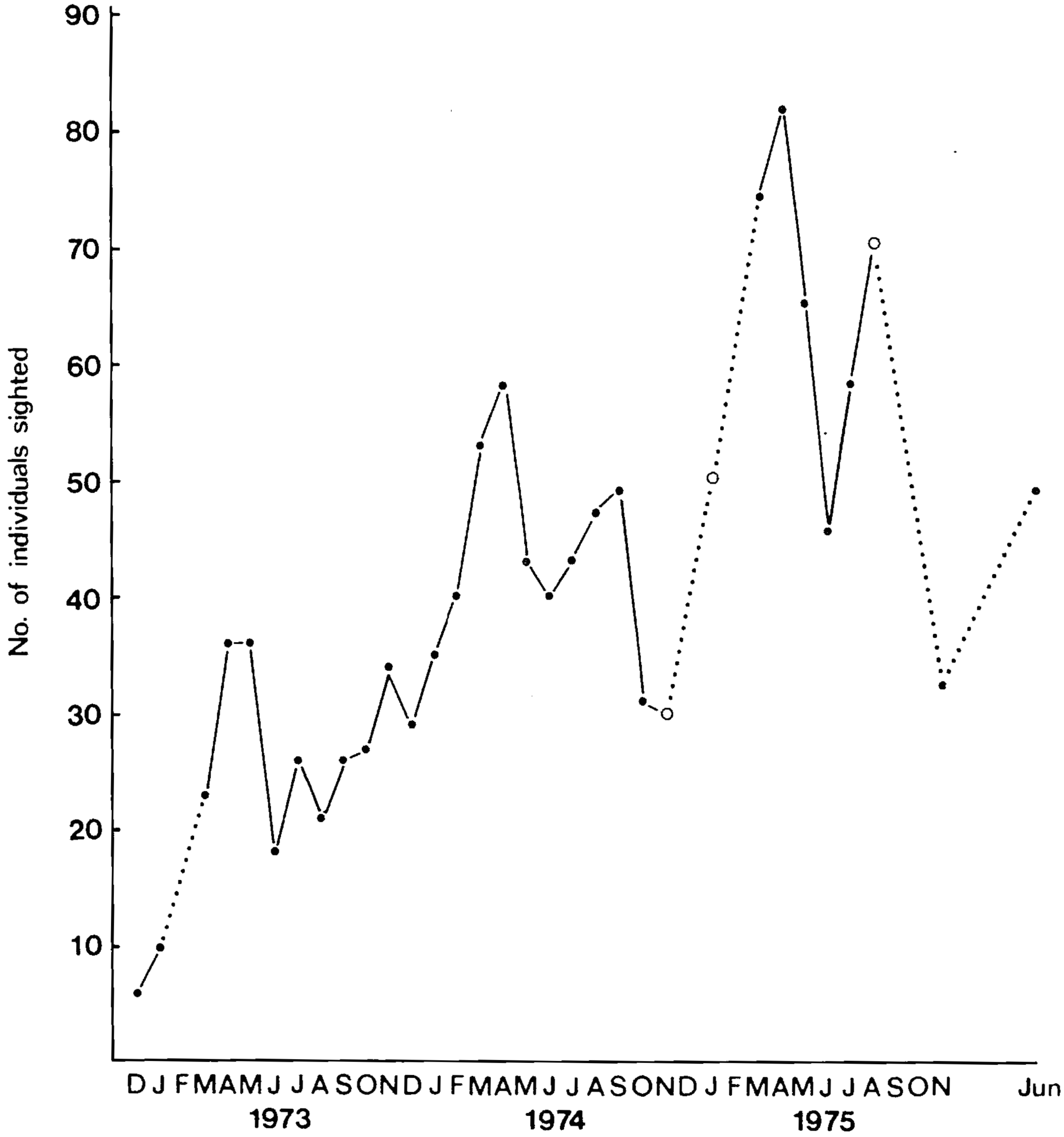


Fig. 3.4. The total number of individuals sighted in each month.

The periods of increased rate of identification of new individuals corresponded to annual periods of increased visibility in February and March after the grass fires, and to increased coverage of the western part of the Sauraha study area from November 1973 onwards. However, the general trend of the plot is to level off with time. At Sauraha the increases in rate of identification were less marked with each successive year of the

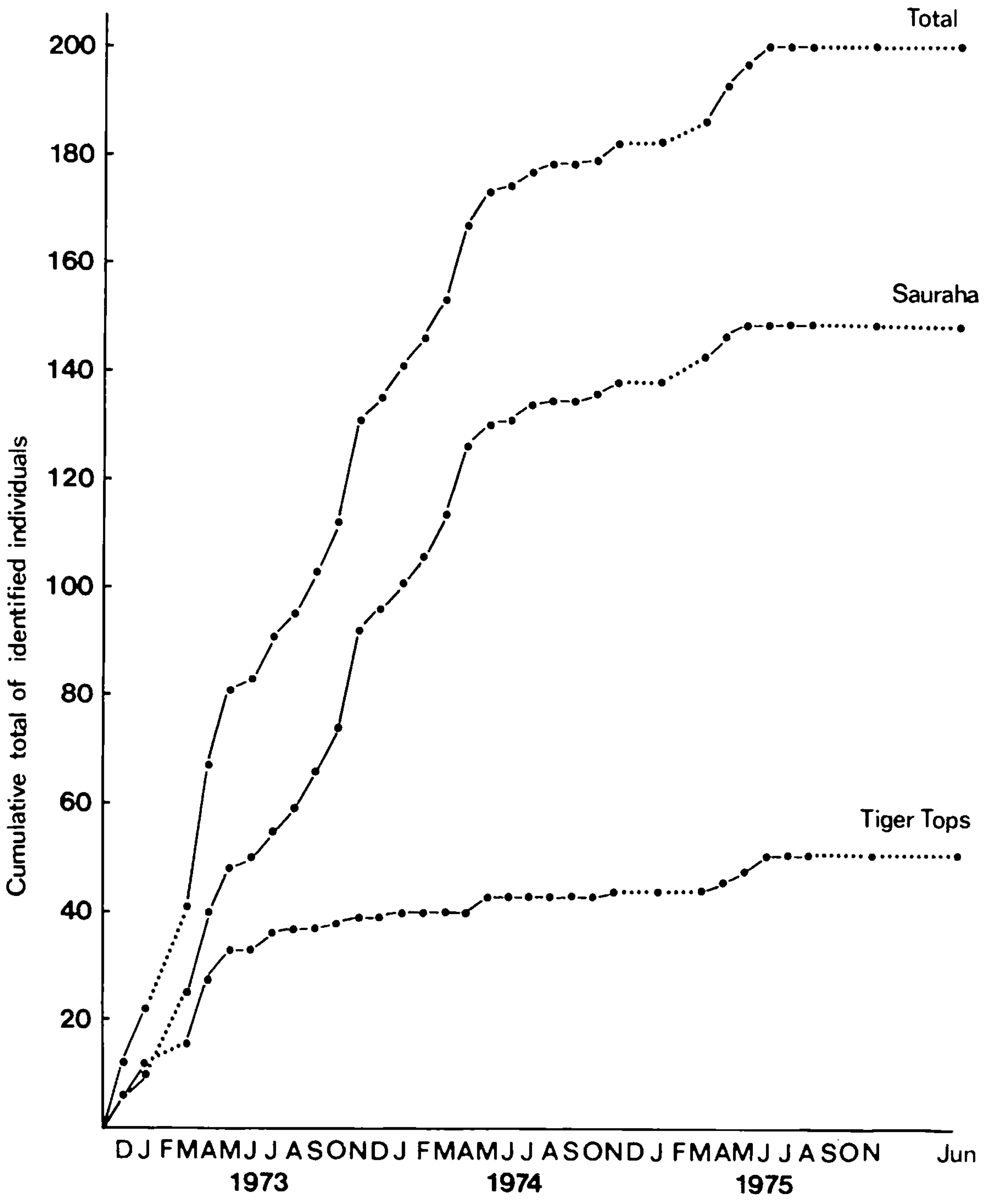


Fig. 3.5. The cumulative total of identified individuals over time, excluding calves born during the study period.

study. In the Tiger Tops study area, due to more time spent in the area in the third year, more new individuals were found there than in the second year. No new individuals were positively identified after June 1975, although 473 and 77 hours were spent in the field in the Sauraha and Tiger Tops areas respectively after that month. Some sub-adults identified later in the study were probably registered earlier as unidentified calves. This would be expected to increase the cumulative total of identified individuals, but despite this bias the curve flattens out for both Sauraha and Tiger Tops areas - an indication that I had identified almost all the rhinos which were resident for appreciable periods in the study areas.

However, there could be other explanations for the levelling of the curve in Fig. 3.5. For example, a decline over the study period in the time spent searching for rhinos or in the numbers of rhinos seen would have the same effect. In Fig. 3.4 it was shown that the decreased rate of registration cannot be explained by a decreased rate of rhino sightings. Fig. 3.6 shows the cumulative time spent in the field in each study area in each month. Together, these confirm that the decrease in the rate of identification of new rhinos is not due to a decrease in searching effort in the rhino areas. Although little time was spent in Chitawan after July 1975 the fall off in registration rate started a long time before that, and it can be assumed that most of the individuals in the population were registered.

3.3.2 Frequency of signs and sightings of rhinos

I estimated the population size of the study areas from the total number of registered individuals (Section 3.3.1), but I did not spend long enough in outlying areas to be able to register all the individuals present. Furthermore, because many of these areas were outside the park, the rhinos were more disturbed by the local people and observations were more difficult. Therefore, in the outlying areas, I estimated the rhino population size from the frequency of signs and sightings during short survey trips of from two to ten days duration. I made five such trips to the Naryani Islands and Nawalpur by boat, three to Kuchkuchia and Ligligdomar (the Katar region),

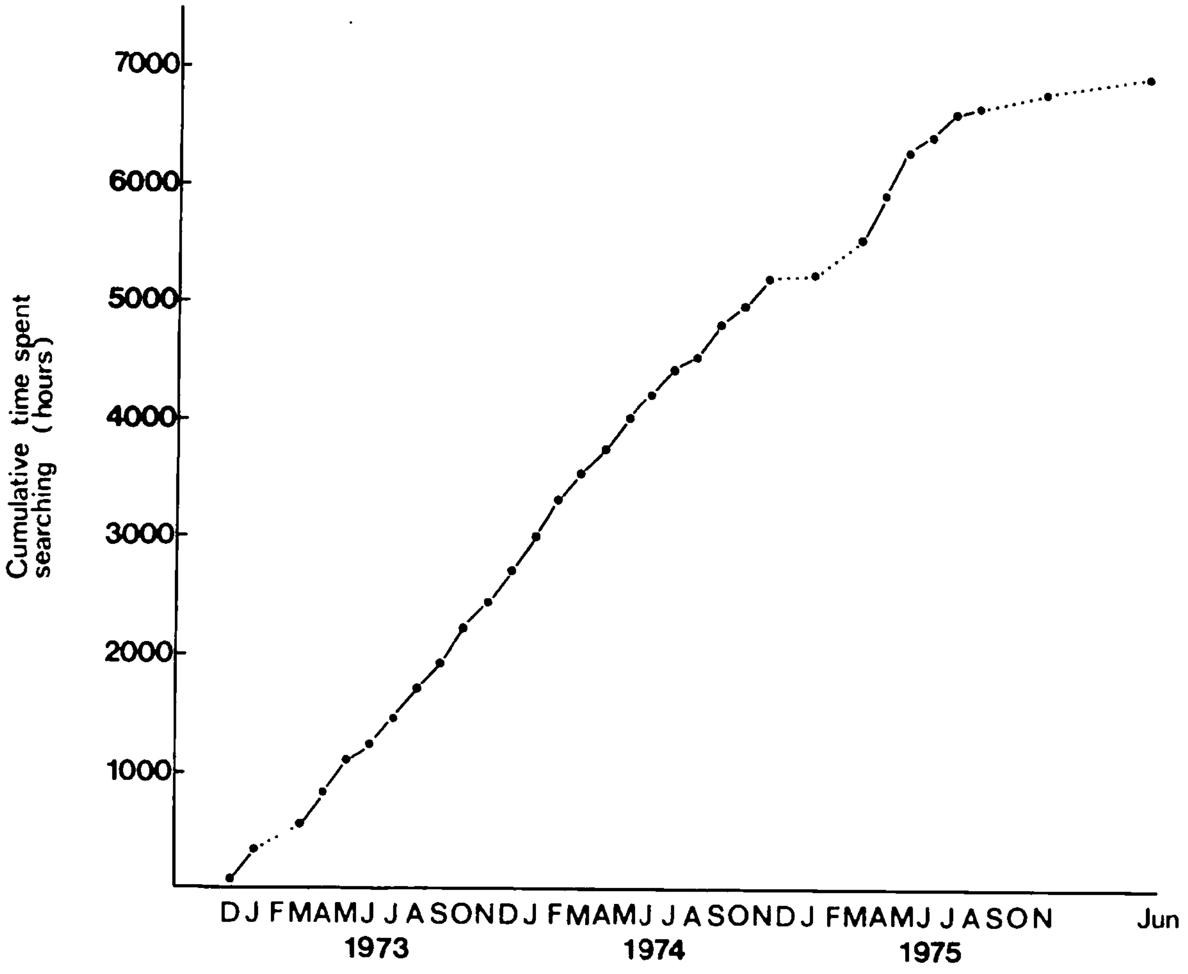


Fig. 3.6. The cumulative total of time spent searching for rhinos.

two to the Reu Valley and one to the Rani Khola region near Gorua, at the base of the Mahabharat Range (map in Fig. 2.1).

I used a combination of three different methods to estimate the numbers of rhinos in the outlying areas. Six rhinos were identified individually in these areas, and I also used a form of indirect registration of individuals from their footprint sizes. This method, similar to that used in Malaysia to census elephants (Olivier, 1978), provided only a minimum estimate of the number of rhinos which had visited the area; I could not distinguish between individuals with the same size of footprints unless, in the case of adult females, they had accompanying calves with different sized footprints.

All measurements were of the widths of the forefoot-prints which, although often obscured by the hindfoot-prints, are slightly larger than the latter, and thus could be expected to be easier to separate into size classes. The width of footprints varied considerably with the gait of the rhino and the nature of the ground surface - the feet of rhinos are particularly pliant. I measured differences of up to 10 cms in the widths of footprints of rhinos tracked through wet and dry areas. Footprints in some substrates shrink with time and in other substrates they grow larger with time. I therefore measured only recent footprints of walking individuals in firm sand or mud, and recorded the smallest of five from the same track (*i.e.* line of footprints). By allowing a margin of ± 2 cms when distinguishing between individuals' footprint widths, I was confident that I was not over-estimating the numbers of rhinos in any area.

I classified the indirectly registered individuals as to age and sex by referring to measurements of the footprint widths of rhinos of known sex and age classes in the Sauraha study area. There was considerable overlap in footprint size between adult males and females, between sub-adults and adult females, and between older calves and sub-adults. I therefore adopted the simple classification shown in Table 3.3.

Table 3.3. Sex and age classification of rhinos by footprint size.

Width of forefoot print	Sex and age class
> 30 cms	Adult male
24 - 30 cms	†Adult
20 - 24 cms	*Subadult or calf
12 - 20 cms	1st or 2nd year calf

† Those with a calf were assumed to be females.

* Those with an adult were assumed to be calves.

Further estimates of the number of rhinos using each area were made on the basis of the frequency of signs and sightings of rhinos. Signs included wallows, tracks (*i.e.* lines of footprints), dung and feeding signs. Rhinos defecate on communal dung-piles (described in Section 5.3.2) which were easy to count as I walked through an area, and I used the frequency of dung-piles as an index of the use of an area by rhinos. I calibrated this index by measuring the frequency of dung-piles in the study area where I knew the population size reasonably accurately. Dung-piles are encountered more commonly on rhino paths (Section 5.3.2) than off them, but this did not bias the frequencies measured on the survey trips because I walked approximately equal distances on and off rhino paths at each place. In the calibration counts in the study areas, the results of which are shown in Table 3.4, I measured the frequencies of dung-piles on paths and straight line transects separately and then took the means of the two frequencies for each area.

3.3.3 Aerial counts

Whenever possible, I took flights over the study areas and the surrounding regions in light aircraft (Pilatus Porter and Cessna 206). I attempted a total count of all the rhinos in the central part of the Sauraha study area on six occasions. All rhinos seen from the air were tallied and,on three occasions,the counts were compared with the estimated number of rhinos in the area flown over. The estimate was based on the number of individuals seen in the area over the previous eight days.

3.3.4 Transect counts on elephant back

Most of my elephant trips were along routes chosen for the high probability of meeting rhinos. This was the best method for identification and registration of the individuals in the area. A circuit of all the

Table 3.4. The numbers of dung-piles counted per kilometre.

	Distance (kms)	No. of dung-piles	Dung-piles/km
Sauraha			
1. Straight line transect	6	64	10.7
2. Straight line transect	8	54	6.8
3. Straight line transect	8	62	7.8
Total (Straight line transects)	22	180	8.2
4. Path	3	23	7.7
5. Path	5	61	12.2
6. Path	8	70	8.8
Total (Paths)	16	154	9.6
Tiger Tops			
1. Straight line transect	5	21	4.2
2. Straight line transect	6	34	5.7
3. Straight line transect	8	38	4.7
Total (Straight line transects)	19	93	4.9
4. Path	3	20	6.7
5. Path	4	23	5.8
6. Path	8	65	8.1
Total (Paths)	15	108	7.2

wallows in an area, for instance, was much more productive in rhino sightings than random wandering in the tall grass. However, I made several systematic straight line transects on elephant back, counting the number of rhinos seen and estimating the visibility on each transect. This is similar to the belt-transect method of Kelker (in Jarman, 1972) and was used by Seidensticker (1976) to census ungulates in Chitawan.

However, I found such great variability in the visibility and in the numbers of rhinos seen, and saw such a small total of rhinos away from open grazing areas and wallows that I abandoned the method and concentrated on finding, identifying and watching rhinos (discussed in Section 3.9.1).

Results

3.4 Numbers

3.4.1 Registered individuals in the study area

The rate of registration of new individuals within the study area fell to zero by the end of June 1975 (Fig. 3.3). I searched the study area regularly during the 2½ years before this date. Therefore, assuming that few individuals within the study area remained consistently elusive or invisible, an estimate of the population size in the study areas can be made from the numbers of registered individuals (Section 3.3.1).

There were problems in assessing the population size by this method because it took such a long time to register the population. Thus, changes in the population had taken place by the time the rate of registration fell to zero in June 1975. For example, some individuals had died between the time of their last sighting and June 1975; and some adult females had probably given birth without my knowing.

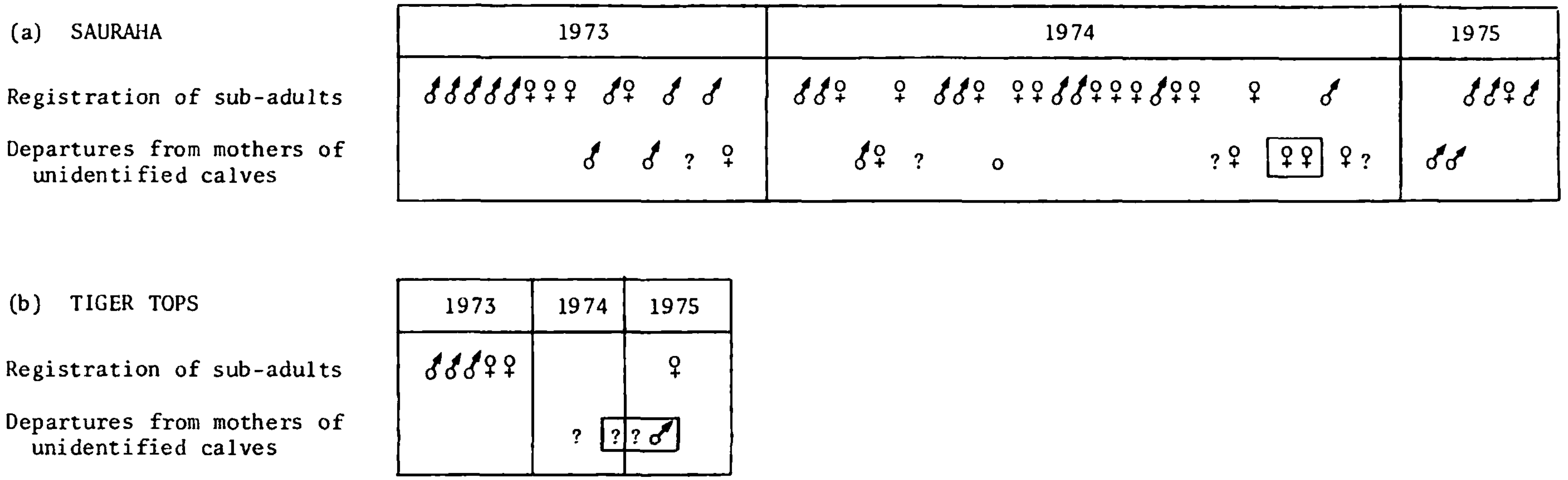
Table 3.5 shows the total numbers of registered individuals in each study area, and the various corrections which were made in estimating the population size. A total of 251 rhinos were registered within the study area up until June 1975. Seventeen of these individuals were known to have died during the same period and a further two individuals which were found in a decomposed state were assumed to have been previously registered. I have not corrected for possible unrecorded deaths but, as explained in Section 3.8.1, there were probably not very many.

Twenty calves were insufficiently identified to be followed after

Table 3.5. The estimated numbers of registered individuals in the study areas in June 1975.

	Sauraha	Tiger Tops	Total
A. Total number of individuals registered	189	62	251
B. Number of deaths among registered individuals	12	5	17
C. Number of deaths of unidentified individuals	1	1	2
D. Number of possible re-registrations of calves as subadults	14	1	15
E. Estimated number of undetected births	5	4	9
Total of registered individuals and calves in June 1975 (A-B-C-D+E)	167	59	226

leaving their mothers, and some of these calves may have been re-registered as sub-adults and thus counted twice. In order to show how many calves could have been re-registered, I compare, in Fig. 3.7, the time of registration of sub-adults with the times that unidentified calves left their mothers. I have treated each study area separately, as no movements of identified individuals were recorded between the study areas (Section 4.6). Fig. 3.7 shows that 15 calves could have been registered twice: therefore at least five of the 20 calves were not re-registered as sub-adults. There was no evidence that these five sub-adults died, and there was evidence (given below) of more sub-adults in the study area than I had identified. On many occasions I saw sub-adults which I confirmed were not already registered, but which I did not observe closely enough to be sure of positive identification on subsequent sightings. I was able to identify sub-adults positively on only 58% of 1,231 sightings; as against 85% of



? denotes sex not determined

☐ denotes calves which were definitely not re-registered as sub-adults because (i) the sex was wrong, or (ii) there were too many of them. All others may have been re-registered.

Fig. 3.7. The sequences in which sub-adults were registered, and unidentified calves left their mothers, showing the possible re-registrations of calves as sub-adults.

2,524 sightings of adults ($\chi^2 = 329.0 \quad p < 0.001$). Sub-adults were more difficult to identify in brief sightings than adults were, so a result of this kind would be expected even with no difference in the proportions of unregistered adults and sub-adults in the area. However, the adults which I was unable to identify were rarely confirmed as unregistered individuals. Therefore it seems likely that there were relatively more unregistered sub-adults than unregistered adults. Consequently, I have included the five sub-adults (Fig. 3.7) in the estimated population total for the study areas

In June 1976, nine cows with calves had not been seen for over three months, and on the evidence of other cows' intercalving intervals (Section 3.7.1), I assumed that they had given birth again since their last sightings. This assumption is supported by brief sightings of unidentified cows with newborn calves in the study areas.

Allowing for these corrections, the population estimates for the study areas are 167 at Sauraha and 59 at Tiger Tops. The calculations are shown in Table 3.5.

3.4.2 Numbers of rhinos in outlying areas

Table 3.6 summarizes the results of the surveys of signs and sightings in the outlying districts and shows the estimated numbers of rhinos which used each region. The detailed results are given in Appendix F. Places mentioned in Table 3.6 are shown on the map, Fig. 2.1. Obviously it was possible that some individuals moved between neighbouring areas and were counted twice. However, I have calculated the minimum number of rhinos which used each of five outlying regions,by taking into account the sex and age classes of the rhinos found there. There was little seasonal variation in the results of surveys which were carried out in May, September and November, but this was expected, as the number of sightings was very small and the freshness of the dung-piles was not taken into

Table 3.6. The numbers of rhinos estimated to be living in outlying areas.

LOCATIONS	Number of rhinos	Sex and age classes
West		
Sikrauli, Pipraha, Kujauli	1	A♂
Mukoni	4	A♂, A♀ + c, A?
Bhonser ghat	14	2A♂♂, 3A♀♀ + cc, 6S??
Lokhani	5	A♂, 2A♀♀ + cc
Jungle, Magarkhot, Shergunj	7	2A♂♂, 2A♀♀ + cc, S?
Amaltari, Serhi, Jhangara, Kolkutta, Tamaspur, Binai Khola	15	4A♂♂, 4A♀♀ + cc, 3S??
	46	
East		
Imratani, Jaghdari, Kahendramoli	7	3A♂♂, A♀ + c, A?, S?
Lothar, Ligligdomar	3	A♂, A♀ + c
Kuchkuchia	9	2A♂♂, 2A♀♀ + cc, 3S??
	19	
South		
Amwa, Bagai, Botesimra, Bankatta	4	2A♂♂, A♀ + c
North		
Gorua	2	A♂, A?
Tikoli	5	A♂, 2A♀♀ + cc
	7	
TOTAL	76	

account. In areas where I found no dung-piles the presence of a few temporary visitors could be deduced from tracks found, but these rhinos were assumed to have come from neighbouring areas and were not counted twice. An estimated total of 76 rhinos used the areas surveyed outside the study areas, distributed as shown in Table 3.6.

3.4.3 Estimation of total population size

Fig. 3.8 summarizes the population estimates for the study areas and the outlying areas. In order to make an estimate of the total population size it is necessary to consider the likelihood that rhinos registered in the study areas were also counted in the outlying areas.

The numbers of individuals seen in the Sauraha study area in each calendar month are shown in Fig. 3.9. No correction has been made for the different lengths of searching time in each month because such differences affected mainly the total number of sightings rather than the numbers of identified individuals seen. The notable peak in numbers of individuals seen in March, April and May is a result of both an increase in visibility after the long grass has burned, and an influx of individuals from the outer parts of the Sauraha study area to the central parts (shown in Section 4.6).

Fig. 3.10 shows the numbers of sightings per registered individual in the Sauraha study area. A large number of individuals were seen on only a few occasions each. It seems likely, from evidence presented in Section 4.6.2, that some of the very infrequently sighted individuals came into the study areas during the spring from the outlying areas. However, there are reasons for believing that it was definitely not a large number. Firstly, no movements of registered individuals were recorded between the two study areas, nor between the study areas and the outlying areas. I knew most of the individuals in the study areas and it is likely that I would have detected extensive movements of individuals between the study areas if they had occurred. Secondly, it is unlikely that all the 53 rhinos seen, for example, on fewer than five occasions in the Sauraha study area could have come from outside the study area, because there were only 30 rhinos recorded from the outlying areas nearest to Sauraha, and those in the Katar region, north of the Rapti, were separated from Sauraha by 11 kms

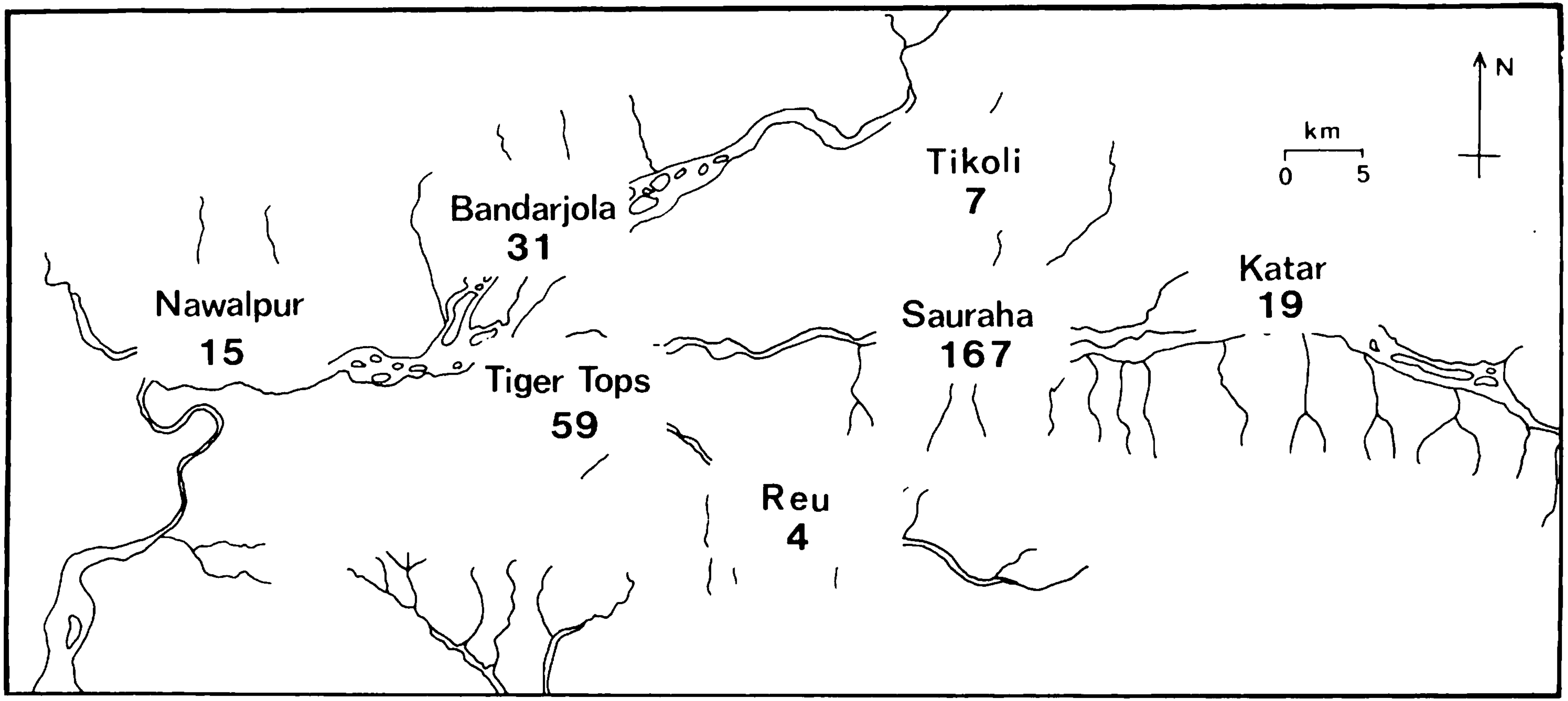


Fig. 3.8. A sketch-map showing the estimated numbers of rhinos in each of seven regions.

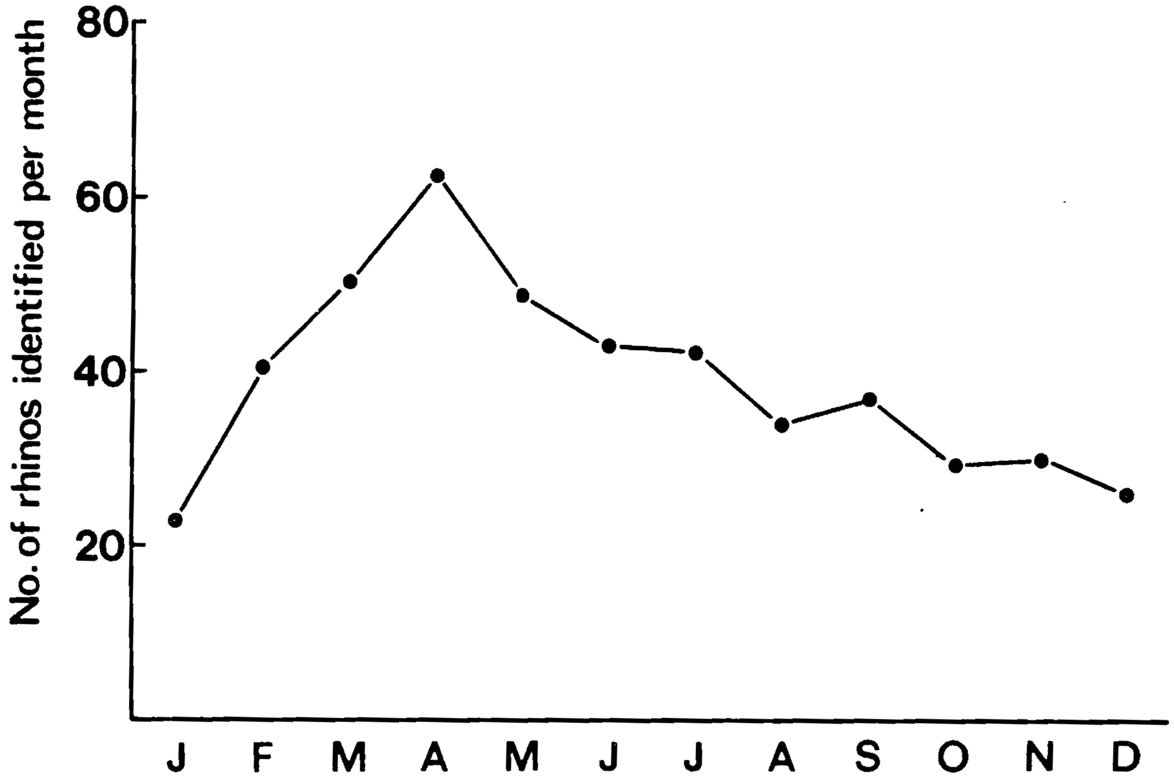


Fig. 3.9. The numbers of rhinos identified per calendar month, 1973 to 1976.

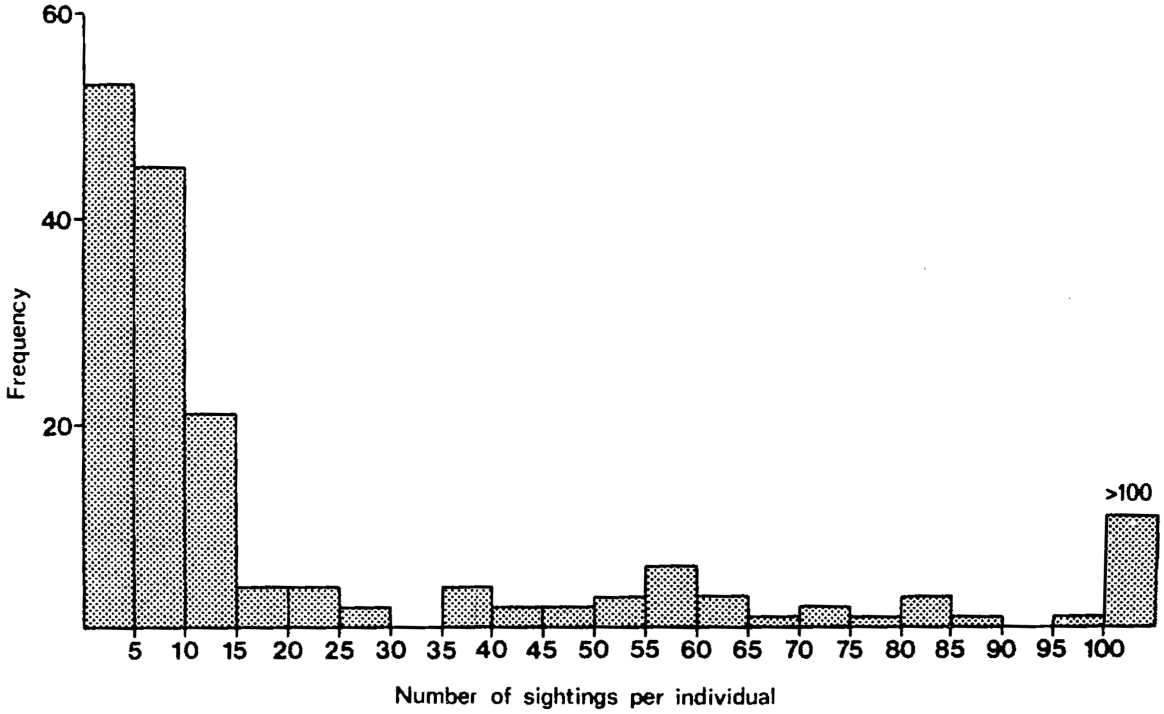


Fig. 3.10. The frequency distribution of the number of sightings per individual in the Sauraha study area.

of agricultural land.

As the 34 rhinos estimated in the Nawalpur and Katar areas are separated from the study areas by a wide river and by agricultural land, I have assumed that they were never registered within the study areas. Three of the remaining 42 rhinos estimated to live in outlying areas were registered in Bandarjola. I have no evidence that the remaining 39 rhinos were registered within the study areas or not. Therefore, the total population size, calculated by the steps in Table 3.7, should lie between 263 and 302 individuals. I had reports of a few rhinos from further east of Ramoli, and I therefore conclude that the total population in Nepal lay between 270 and 310 individuals in June 1975. The population trend is discussed in Section 3.9.3.

Table 3.7. Steps in the estimation of the total population size.

Number of rhinos registered at Sauraha and Tiger Tops	226
Number of rhinos estimated at Nawalpur and Katar	34
Number of rhinos registered on Bandarjola	3
Minimum estimate for total population	263
Number of rhinos estimated on Bandarjola and at Tikoli and Reu, which may have been registered within the study areas	39
Maximum estimate for total population of areas surveyed	302

Allowing for rhinos reported in unsurveyed areas east of Ligligdomar, the final estimate for the total rhino population is between 270 and 310 individuals.

3.4.4 Results of aerial counts

The results of counting carried out on six flights are shown in Table 3.8. A total count of the rhinos present was attempted using knowledge of their favourite haunts. For the three counts made on 7-9 June 1975, a check was made on the accuracy by comparing the totals counted with the number of rhinos seen in the same area from the ground over the previous and the following seven day periods. Fifty-seven different individuals were seen from the ground in the seven days previous to 7 June 1975, and 41 individuals were seen in the seven days following 9 June, making an average total of 49 rhinos. The maximum number of rhinos counted from the air was 15/49 = 30.6% and the lowest number counted was only 5/49 = 10.0% of this total.

Table 3.8. The numbers of rhinos counted from the air.

Flight No.	Place	Date (day, mth, yr)	Time	Duration (mins)	Area flown over (km^2)	No. of rhinos counted
1	Sauraha	20.7.73	09.30	20	4.2	4
2	Sauraha	22.5.75	06.00	60	14.0	3
3	Sauraha	7.6.75	07.00	15	7.0	13
4	Sauraha	8.6.75	07.00	20	7.0	5
5	Sauraha	9.6.75	07.00	20	7.0	15
4	Khoria	8.6.75	07.40	10	12.0	6
5	Kasra	9.6.75	07.30	15	15.0	1
6	Sauraha	14.8.75	10.00	15	4.2	4

This variability, and the low proportion of rhinos seen, makes counting of rhinos from fixed wing aircraft very inadequate. Rhinos and other species are difficult to see in the forest, tall grassland and swamps unless they are in a clearing.

3.5 Distribution and density

Fig. 3.8 shows the approximate distribution of rhinos in Nepal. Inspection of the vegetation maps, Figs. 2.2, 2.6, 2.8 and 2.9, shows that the rhinos' distribution coincides roughly with that of the riverine forest, scrub and grassland habitats of the alluvial plains. The sal forest supports only a low population of rhinos - in the vicinity of lakes and river-beds. The habitat preferences of rhinos are considered in detail in Section 4.3. Here, I consider the population densities of rhinos in different regions, using knowledge of habitat preferences to calculate both crude and ecological densities (Eisenberg and Seidensticker, 1976).

The calculation of population density requires knowledge of the number of animals and the area of the terrain which they inhabit. Having estimated the population size, the main problem lies in defining the area which the animals inhabit. Seasonal movements obviously affect population densities, but here I am concerned with overall population densities, and aim to include the annual ranges of the rhinos. However, even daily movements affect the calculation: should, for instance, the cultivated land, visited by rhinos during the night at certain times of year (Section 4.3), be included in the rhinos' range when calculating population density? Secondly, should any adjustment be made for the inclusion of large amounts of unsuitable habitat such as sal forest or sand-banks in the rhinos range?

In view of the above points, I have calculated two different population densities for each region; crude density and ecological density. Crude density refers to the total annual ranges of the rhinos including areas of less suitable habitat such as sal forest, but excluding agricultural land. Ecological density (Eisenberg and Seidensticker, 1976) refers only to the areas of most suitable habitat, *i.e.* riverine forest, grassland and scrub (see Section 4.3), again excluding agricultural land.

Table 3.9 shows the crude and ecological densities of rhinos in each of five regions. Note that I have treated Bandarjola and Tiger Tops as separate regions, although it is unclear how much movement of rhinos takes place between them (Section 3.4). The most densely populated region, Sauraha, is characterized by a wide variety of habitat types (Fig. 2.8) and easy access to agricultural land. Within the region, the tall grassland meets the short grass of the river-beds, the riverine forest and the scrub and scrubby woodland grazed by domestic stock. In Katar, Nawalpur and Bandarjola there is less tall grassland and there are fewer well vegetated tals, but a considerably higher proportion of scrub and scrubby woodland. At Tiger Tops, the habitat is more uniform tall grassland, riverine forest and tals; there is less scrub, and access to agricultural land is across the Rapti River.

Table 3.9. Crude and ecological population densities in each region.

Region	Crude density N^{o}/km^{2}	Ecological density N^{o}/km^{2}
Sauraha	1.79	4.85
Tiger Tops	1.02	1.74
Katar	0.38	1.12
Nawalpur	0.45	0.95
Bandarjola	0.43	0.77

Thus, high population densities appear to be associated with a high diversity of habitat types, and ease of access to agricultural land. The high number of rhinos living far from the tall grass habitat traditionally associated with the Indian rhino (Prater, 1971) indicates a certain adaptability in their feeding habits, which is examined in detail in Section 4.3 There is a clear correlation between rhino concentrations and water: rhino are never found far from water, and all concentrations are centred on suitable rivers, *tals*, streams or wallows (Section 4.4). Habitat preferences and differences in population densities between regions are discussed further in Section 4.7.

3.6 Sex and age composition

In Table 3.10 the 226 registered individuals (Table 3.5) are divided, according to study areas, into age and sex classes as at June 1975. I have taken June 1975 as the time for examining the population composition because no individuals were registered after that month and some individuals were not seen again after that month. I only spent four months in Chitawan between August 1975 and June 1976: as a result, many of the births and deaths during that period were not recorded.

3.6.1 Calf sex ratio

Of 51 registered calves, 26 were male, 16 were female and nine were not classified (Table 3.10). However, there was a methodological bias towards males in determining the sex of calves: male calves tended to be sexed more quickly than female calves (Section 3.2.1). With 18% of the calves unclassified, it is necessary to consider this bias before drawing any conclusions about the calf sex ratio.

As the chances of determining a particular calf's sex increased with the amount of observation time, I compared the sex ratio of registered calves seen on five or fewer occasions with that of calves seen on more than five occasions (Table 3.11). In order to enlarge the sample, I have included all rhinos registered as calves at any time during the study period - a total of 86. Although there is a significant bias towards males in the total numbers of calves sexed (χ^2 one sample test: $\chi^2 = 5.2$ $p < 0.05$), there is no significant departure from a one to one sex ratio

Table 3.10. The sex and age composition of the registered population of the study areas.

	Sauraha	Tiger Tops	Total
Adult males	29	16	45
Adult females alone	12	1	13
Adult females with calves	44	16	60
Sub-adult males	21	5	26
Sub-adult females	17	3	20
Sub-adults (sex unknown)	-	2	2
Male calves	21	5	26
Female calves	14	2	16
Calves (sex unknown)	4	5	9
Calves assumed to have been born	5	4	9
TOTAL	167	59	226
Adult sex ratio (% male)	34.1	48.4	38.1
Sub-adult sex ratio (% male)	55.3	62.5	56.5
Sub-adult and adult combined sex ratio (% male)	41.0	51.2	43.3
Adults as % of the population	50.9	55.9	52.2
Sub-adults as % of the population	22.8	16.9	21.2
Adult females with calves as % of the population	26.3	27.1	26.5
Adult females as % of the population	33.5	28.8	32.3
Adult males as % of the population	17.3	27.1	19.9
% of adult females with calves	78.6	94.1	82.4

among calves seen on more than five occasions (χ^2 one sample test: $\chi^2 = 0.1$ $p > 0.10$). Thus the inequality in the determined sex ratios of registered calves is a result at least partly of bias towards males in sexing calves, and there is no clear evidence to suggest that the sex ratio at birth is not one to one.

Table 3.11. Differences in the determined sex ratios of calves according to numbers of sightings.

	Calves seen on fewer than five occasions	Calves seen on more than five occasions	Total
Males	26	18	44
Females	9	16	25
Unclassified	14	3	17
Total	49	37	86

3.6.2 Sex ratio of sub-adults and adults

There was an excess of males over females among the registered sub-adults, although not a statistically significant one (χ^2 one sample test: $\chi^2 = 0.78 \quad p > 0.30$). It may have been at least partly a result of females being classed as adults as soon as they had given birth, whereas males of the same age were classed as sub-adults. Among adults, there were more females than males, as would be expected for the same reason. The sex ratio of the sub-adult and adult classes combined was 93 females to 71 males, a departure from a one to one ratio which is not quite statistically significant (χ^2 one sample test: $\chi^2 = 2.95 \quad p > 0.10$). However, there were differences in the sex ratios between the two study areas which are described below.

3.6.3 Comparison of the sex and age compositions of the registered populations of the two study areas

In the Sauraha area, the ratio of males to females among the adults and sub-adults combined, is significantly greater than one to one (χ^2 one sample test: $\chi^2 = 4.30 \quad p < 0.05$). In the Tiger Tops area there was a higher proportion of males - approximately one male to one female. There were several minor differences in the age and sex compositions of the two registered populations (Table 3.10), but the relative proportions of adult males, adult females, sub-adults and calves were not significantly different ($\chi^2 = 3.05 \quad p > 0.05$). Minor differences included a lower proportion of sub-adults in the Tiger Tops population and a higher proportion of adult males: also, a higher proportion of the adult females at Tiger Tops had accompanying calves.

3.6.4 Comparison of the sex and age classifications of registered individuals and of all sightings

Table 3.12 shows the numbers of sightings of rhinos in the two study areas up to June 1975, classified, as in Table 3.10, according to the rhinos' sex and age classes. I have compared the sightings and registration data in order to test the reliability of calculating population statistics from the sightings data which included repeated observations of the same individual.

There are no statistical differences between the sightings and the registration data in either the Sauraha study area ($\chi^2 = 6.2 \quad p > 0.05$ df = 5) or the Tiger Tops study area ($\chi^2 = 4.7 \quad p > 0.05$ df = 3). This implies that there was an approximately equal chance of encountering each of the sex and age classes of rhinos. This result is important for the study of grouping behaviour (Section 5.2), and is discussed further in Section 3.9.2.

3.6.5 Differences within the Sauraha study area in the distribution of the sex and age classes

There were differences in the distribution of the sex and age classes in the Sauraha area, which can be demonstrated by dividing the study area into two regions north and south of the Rapti River. This splits the study

Table 3.12. The sex and age composition of all rhino sightings in the study areas.

	Sauraha	Tiger Tops	Total
Unclassed	546	33	579
Adult males	677	96	773
Adult females alone	242	17	259
Adults (sex unknown)	62	15	77
Adult females with calves	1,367	48	1,415
Sub-adult males	401	25	426
Sub-adult females	370	17	387
Sub-adults (sex unknown)	390	28	418
Calves	1,367	48	1,415
Total	5,422	327	5,749
Total classed	4,876	294	5,170
% classed	89.9	89.9	89.9
Adult sex ratio (% males)	29.6	59.6	31.6
Sub-adult sex ratio (% males)	52.0	59.5	52.4
Sub-adult and adult sex ratio (% males)	35.3	59.6	36.8
Sightings of adults as % of total classed	48.2	59.9	48.8
Sightings of sub-adults as % of total classed	23.8	23.8	23.8
Sightings of adult females with calves as % of total classed	28.0	16.3	27.4
Sightings of adult females as % of total classed	33.0	22.1	32.4
Sightings of adult males as % of total classed	13.9	32.7	15.0
% of sightings of adult females with calves	85.0	73.8	84.5

area into a long grass and riverine forest region on the south bank and a short grass and scrub region on the north bank. Rhinos in both regions have access to cultivated crops and river-beds.

In Table 3.13 the rhino sightings in the Sauraha area are split into those from each region, and the sex and age compositions are compared. It

Table 3.13. The sex and age compositions of rhino sightings north and south of the Rapti River in the Sauraha study area.

	South	North
Not classified	354 (9.0%)	238 (11.2%)
A♂	538 (13.7%)	197 (9.3%)
Single A♀	179 (4.6%)	90 (4.2%)
A?	42 (1.1%)	20 (0.1%)
A♀+ c	1,127 (28.8%)	392 (18.5%)
S♂	133 (3.4%)	358 (16.9%)
S♀	245 (6.3%)	169 (8.0%)
S?	175 (4.5%)	264 (12.5%)
C	1,127 (28.8%)	392 (18.5%)
Total	3,920	2,120

$p < 0.001$ $\chi^2 = 581.1$ df = 8

is difficult to test such figures statistically because sightings are not strictly independent, but it is evident that there are quite large differences in the frequency of sightings of the different sex and age classes in each region. The most obvious differences are in the ratios of sightings of sub-adults to adults in the two regions. Sub-adults comprised 15.5% of the classified sightings on the south bank but 42.0% on the north bank. Furthermore, the sex ratio of the sub-adults was 35.2% male on the south bank and 67.9% male on the north bank. The proportion of unsexed sub-adults was about one third in both regions. The adult sex ratio was 29% male in both regions, but there was a higher proportion of sightings of single adult females on the north bank. These differences are further investigated in Section 4.6.

3.7 Births

3.7.1 Birth rate

As it was difficult to locate individual rhinos at will, I had to estimate the birth-dates of calves from their sizes. There were a total of 42 cows (adult females) whose breeding histories I knew from December 1972 to November 1975 by deduction from the ages of accompanying calves. During three years, these 42 cows produced 36 calves, two of which died soon after birth. This is an overall birth rate of one calf per female per 3.5 years or, adjusted for perinatal mortality (Section 3.8), one calf per female per 3.7 years.

I determined the exact interval between two births to the same cow for only three cows, because only three of 31 cows which I followed from December 1972 to June 1976 gave birth twice during those 3½ years. The inter-calving intervals were 36, 34 and 18 months respectively. In the latter case, the cow's earlier calf was killed by a tiger when it was a few days old, and the cow must have mated again within two months.

Fig. 3.11 shows the intercalving intervals for all registered cows that gave birth at least once during the study period. They are calculated from my estimates of the previous calves' ages. The median of 50 inter-calving intervals was 34 months and the maximum was 50 months.

3.7.1.1 Decline in birth rate with age

Two of the three cows which had inter-calving intervals exceeding 48 months appeared, from their scarred skins and folds and aged-looking horns, to be old individuals. Two of the three may have given birth and lost their infants without my knowing, but one of the older cows was seen so frequently that I would have noticed if she was pregnant. When she finally did give birth, she lost her calf within six weeks: I never found

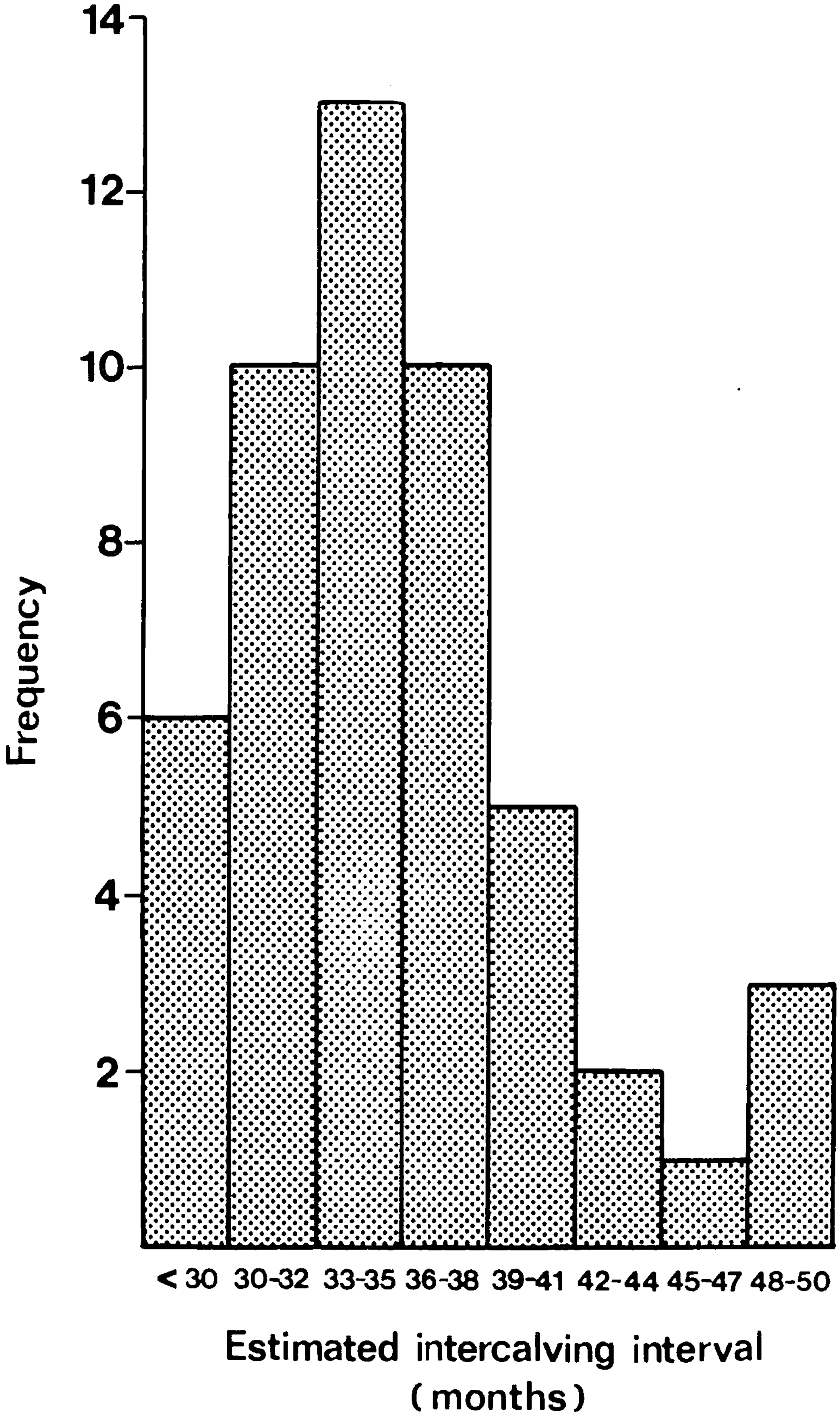


Fig. 3.11. The frequency distribution of estimated inter-calving intervals (n = 50).

the carcase, so the cause of death was not determined. One cow (F084) that died in November 1974 from a wound in her shoulder, had calved three years previously but was not pregnant at the time of death. Few cows, having calved three years previously, would not be pregnant, as can be seen from Fig. 3.11. I examined F084's tusks in section and found 26 clear lines in the cementum which indicates that she was at least 26 years old (see Section 3.8). Thus it is possible that the older individuals have longer inter-calving intervals and perhaps suffer a higher loss of calves.

3.7.2 Seasonality of births

Fig. 3.12 shows the estimated dates, to the nearest two months, of births of calves between 1972 and 1975. Calves known to belong to registered cows, and calves which could not be traced to particular individuals are all included. Records of the latter are based on guards' reports from outlying areas, and brief glimpses of small calves which could not have belonged to any registered cow known to have a young calf. Less time was spent in the field after August 1975, and consequently many of the cows which I expected to give birth during 1975 were not seen. I have partially corrected for this by including records of births not traced to particular individuals, but the low number of births recorded during 1975 and 1976 should not be interpreted as a drop in the birth-rate.

Table 3.14 shows the numbers of calves born in each two calendar months between 1972 and 1975. Although there are slight peaks in recorded births from November to February and July to August, the differences between the pairs of months are not significant. These data are compared with data for seasonality of oestrus in Section 5.5.1.

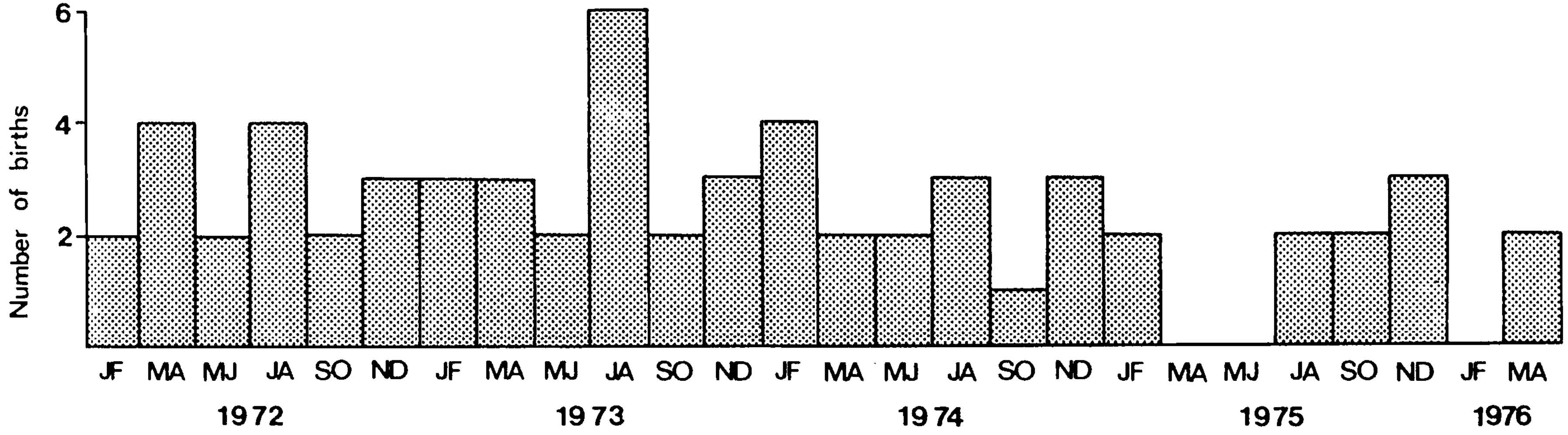


Fig. 3.12. The numbers of births recorded for each two month period, 1972 to 1976.

Table 3.14. The numbers of births recorded in each two calendar month period.

Months	Number of births recorded (1972-1975)		
	Sauraha	Tiger Tops	Total
January-February	7	4	11
March-April	4	5	9
May-June	5	1	6
July-August	11	4	15
September-October	7	0	7
November-December	8	4	12
Total	42	18	60

χ^2 one sample test: $\chi^2 = 6.67$ $p > 0.05$ df = 5 (Total).

3.7.3 Age at first reproduction

One female calf left her mother in December 1972 aged approximately three years, and had not given birth by June 1976 aged 6½ years. Another female calf left her mother in September 1973 and was still single in June 1976 aged just under six years. Five females were classified as Class 5 sub-adults (*i.e.* 3-4 years old) at the start of the study: they were followed until June 1976, by which time one had given birth, aged about six years, and one was about to give birth, aged about seven years. The other three were still single and at least 6½ to seven years old.

In June 1975 there were 17 registered sub-adult females, four of them in Class 5. If Class 5 accurately represents one year-class, and assuming for the moment no changes in mortality and birth rates, these 17 sub-adults represent 4.3 year-classes. Taking the median inter-calving interval of 34 months or 2.8 years as the average age of leaving the mother (a reasonable approximation: data in Section 5.6.2), this indicates that the average age at which females produce their first calf is 7.1 years (discussed in Section 3.9.3).

3.8 Mortality

3.8.1 Causes of mortality

Twenty-seven deaths were recorded during the study period. It is difficult to know what proportion of deaths were detected but, with over 200 rhino-guards distributed in 35 guard-posts throughout the rhinos' range, it was probably quite a high proportion. The causes of death were determined as far as possible, and the frequency of deaths from each cause are shown in Table 3.15.

Table 3.15. The numbers and causes of deaths recorded for rhinos of each sex and age class.

	Number of deaths recorded						
Class	A♂	A♀	S♂	S?	♂C	?C	Total
Cause of death							
Poaching	2	4					6
Tiger predation					3		3
Old age	1	3					4
Interspecific fighting	3	1	1		1		6
Abandonment by female					2		2
Accident in capture					1		1
Unknown (cause undetermined)	1	2		1			4
Unknown (disappeared)						1	1
Total	7	10	1	1	7	1	27

Poaching was confined almost entirely to the first year of the study.

The rate of poaching decreased sharply about that time: there were 17 cases discovered during the three years previous to the study (B.N. Upreti, pers. comm., 1973), but there has been only one recorded case in the five years since November 1973. The effects of previous heavy poaching on the population (Section 1.4) are discussed in Section 7.1.1.

Intraspecific fighting accounted for 28.6% of the deaths due to causes other than poaching. All sex and age classes were involved, but males were killed most frequently (described in Sections 5.4.2 and 5.6.4.2).

Predation by tigers on calves is the most likely form of death to go undetected. The fact that I recorded three such deaths implies that tiger predation is quite common. Calves also died if abandoned by their mothers - either from starvation or from attacks by adult males (described in Sections 5.4.2 and 5.6.2).

3.8.2 Mortality rates

(a) Calves

The deaths of seven first-year calves and one third-year calf were recorded during the study period (Table 3.15). Another calf (*c.* 18 months old) may have died after its mother was killed by poachers in July 1975. These data indicate a high calf mortality, especially among first-year calves. In order to calculate rates of mortality, I consider only those births and deaths recorded within the study areas.

Perinatal mortality accounted for two (5.6%) of the 36 births to registered cows followed throughout the study period (Section 3.7.1). Such deaths were difficult to detect unless the cow was seen frequently; and one was only detected because the calf was killed by a radio-collared tiger. Considering later calf mortality, four first-year calves and one third-year calf died out of a total of 59 calves born and assumed to have been born (see Section 3.4.1) during the study period. Assuming constant birth and mortality rates, this indicates a minimum calf mortality of 8.5% per annum, most of it occurring during the first year of life. Both the perinatal and the subsequent calf mortality rates given above are minimum estimates, as it is highly unlikely that all deaths of calves were discovered.

Seven of the eight dead calves were males (Table 3.15), but this does not differ significantly from an even sex ratio among the dead calves (Kolmogorov-Smirnov one sample test, $p > 0.05$). However, it is interesting to note that a higher mortality rate among male calves was also recorded in Kaziranga National Park. Records of 375 deaths of rhinos showed that 23% of all deaths were of calves and 61% of the 46 calves whose sex was determined were male (Assam Forest Dept. Records, 1965-1975) (discussed in Section 6.2.2.3.

(b) Sub-adults and adults

In order to calculate approximate mortality rates for sub-adults and adults, I again consider only those deaths recorded within the study area. Two sub-adults and 14 adults were found dead in the study area during 3½ years. Assuming the population composition for June 1975 (shown in Table 3.10), the minimum annual mortality rates for sub-adults and adults are 2.8% overall or 1.2% and 3.4% respectively. It has also been assumed that the population composition and the mortality rates are stable, although this is obviously not so. The implications of these mortality rates are discussed in Section 3.9.3.

(c) Longevity

I examined incremental lines in the cementum and the dentine of the procumbent lower incisors of eight individuals (Section 3.2.3). The clearest patterns of annuli were in the cementum on the outside of the root near the gums. It is not known how reliable such lines are in ageing Indian rhinos, but the incisors should be the most useful indicators of age because they are open-rooted and continuously growing throughout life (Laws, 1968). However, both resorption and wear may affect the results of studies using incremental lines.

Two of the incisors examined were from young rhinos estimated to be in their third or fourth years respectively. They showed two and three incremental lines in the cementum,which probably corresponds to one line per year in the permanent dentition. The deciduous incisors are probably shed during the first year of life.

Seasonal differences in food abundance or quality can be expected to result in one or more lines being formed per year (Sinclair, 1977). The marked dry and wet seasons of Chitawan (Section 2.1.5) suggest that one incremental line would be formed per year. Counting these lines should therefore be a guide to ageing rhinos although it is possible that the lines cease to form or are obscured after a certain age.

The incisors of six adults (three males and three females) indicated ages of between 10 and 26 years. Table 3.16 shows the indicated ages and the causes of death. M002 had worn molars which implied old age but the molars of F084 were less worn although she had a greater indicated age.

Table 3.16. Causes of death and ages indicated from cementum lines of six adult rhinos.

Individual	Died	Indicated age (years)	Cause of death
M002	Aug. 1975	22	? Senility
M041	Nov. 1973	12	Poached
M062	Apr. 1975	10	Fight with A♂
F084	Nov. 1974	26	Suppurating wound
Not identified	May 1975	17	Unknown
Not identified	Mar. 1974	14	Unknown, perhaps poached

These results are discussed in Sections 5.6.4 and 6.2.

3.9 Discussion

3.9.1 Problems of counting rhinos

The nature of the habitat in Chitawan (Section 2.1.5) and the small rhino population (Section 3.4.3) makes aerial counting of rhinos and counting by transects very inefficient (Sections 3.3.4 and 3.4.4). Stationary rhinos can remain undetected by an observer on elephant back passing within 30 or 40 metres, and two counts along the same route can produce widely different totals of rhinos. The results of aerial counts are also very variable. Even using knowledge of their favourite haunts, and by trying to find as many rhinos as possible, I counted a maximum of one fifth of the total number known to be in the area, and the count varied on successive days from 3% to 20% of that total (Section 3.4.4).

Counts from helicopters are undoubtedly more reliable than counts from fixed wing aircraft, as small clearings and wallows can be examined in greater detail. However, despite the advantages of the helicopter, I suspect that the results of both the 1968 and 1972 aerial counts (Section 1.4) were underestimates, particularly as they were carried out in May and June when the grass is generally high and visibility is poor (Section 2.1.5).

Identification and registration of each individual is the most accurate method of censussing any population, but in the case of the Indian rhino it seems to be the only reliable one. Its main disadvantage is that it takes a long time. In this study it took 2½ years before the rate of registration of new individuals fell to zero. In future studies, it may prove possible to work out a way of estimating the proportion of individuals that has been registered, after a shorter period in the field.

3.9.2 Number of sightings versus number of individuals as a basis for sex and age classification

The group compositions and the sex and age compositions of wild animal populations have frequently been derived from all sightings of groups and individuals, *e.g.* wild goats (Schaller and Laurie, 1974; Schaller, 1977), sloth bears (Laurie and Seidensticker, 1977). An alternative is to identify and classify each individual in the population (*e.g.* Kruuk, 1972; Douglas-Hamilton, 1972). If time is adequate and identification reliable the latter method is obviously superior. The sightings method relies upon the assumption that there is an equal chance of encountering all the sex and age classes and groups within the population. The method of searching has to be such that there is minimal bias towards any particular section of the population.

This study provides an opportunity to check the two methods against each other. The results of sex and age classification by the two methods are presented in Tables 3.10 and 3.12. The differences between them are not statistically significant (Section 3.6.4). The results for Tiger Tops differ more widely than those for Sauraha, as would be expected from the smaller number of sightings at Tiger Tops. This is because repeated sightings of certain individuals, for instance, one that is regularly found in a frequently visited place, inflate the number of sightings proportionately more in a small sample than in a large sample.

Thus, the sightings method appears to be a reliable way of determining sex and age compositions. Assuming that rhinos of each sex and age class form groups of typical sizes and compositions, the method can also be used to study grouping behaviour (discussed further in Section 5.2.1).

3.9.3 Population trend

Forty-two registered cows produced 36 calves in three years, *i.e.* a production of one calf per cow per 3½ years (Section 3.7.1). If this birth-rate is assumed to apply to the whole population, the mean annual number of births to the 73 registered adult females (Table 3.10) would be 73/3.5 = 20.86. Sub-adult females were shown to bear their first calves when, on average, 7.1 years old (Section 3.7.3). As sub-adult females range in age from three years upwards, half of the six to·seven year old individuals (one eighth of the total) would be expected, on average, to give birth in any one year. Thus, from a total of 20 sub-adult females in the registered population (Table 3.10) the estimated mean annual production of calves is 20/8 = 2.50. This figure, added to the figure for adult females, makes a total mean annual production of 23.36 calves (Table 3.17).

Table 3.17. Steps in the estimation of the population trend.

A.	Mean annual number of births to adult females	20.86
B.	Mean annual number of births to sub-adult females	2.50
C.	Total mean annual number of births (A+B)	23.36
D.	Minimum estimated perinatal mortality (5.6%)	1.31
E.	Maximum estimate for mean annual production of calves surviving one month (C-D)	22.05
F.	Minimum estimated subsequent calf mortality (8.5%)	1.87
G.	Maximum estimate for mean annual production of calves surviving to sub-adulthood (E-F)	20.18

All figures refer to the registered population (Table 3.10), and calculations are explained in the text.

Correcting the annual number of births for the minimum estimated perinatal and subsequent calf mortality (Section 3.8.2), the maximum estimate for the mean annual production of calves surviving to sub-adulthood in the registered population is 20.18 (Table 3.17) or 8.9% of the total registered population (Table 3.10). There were 18 registered third-year calves in the population (June, 1975), and as some calves leave their mothers before the age of three years, the estimate seems reasonable. Thus, with a maximum estimate of recruitment from the calf population of 8.9% and a minimum estimate of sub-adult and adult mortality of 2.8% (Section 3.8.2), the rhino population was increasing in June 1975 at a maximum possible rate of 6.1% per year. If, as is unlikely, both calf mortality and subsequent mortality were double the estimated values, the rhino population would still be increasing at a rate of 2.0% per year. I therefore conclude that the population is increasing at between 2.0% and 6.1% per year.

3.10 Summary

1. The considerable variation in appearance between rhinos was used to identify individuals reliably and to classify them according to age and sex.

2. Having individually registered most of the rhinos encountered within the study areas, and having surveyed other areas, the rhino population of Nepal was estimated to be between 270 and 310 individuals.

3. Rhinos were distributed mainly in the flood plain habitats: greatest population densities occurred in the areas of highest habitat diversity, notably near the boundary between the park and the surrounding cultivation. In the Sauraha study area, the crude density was 1.79 rhinos per km^2 and the ecological density 4.85 per km^2.

4. The overall composition of the registered population of the study areas was 32.3% adult females, 19.9% adult males, 21.2% sub-adults and 26.6% calves. The rates of sightings of each sex and age class were approximately the same as their respective frequencies in the population.

5. There were differences both between the study areas and within the Sauraha study area in the distribution of the sex and age classes.

6. Females gave birth to their first calves at a mean age of 7.1 years. The median inter-calving interval was 2.8 years but, allowing for perinatal mortality and the low fertility of the older females, the mean production of calves per female was one per 3.7 years.

7. Causes of death included poaching (now largely controlled), tiger predation (on the calves only), intraspecific fighting (mainly among males) and senility. There was a high annual rate of infant mortality recorded - 5.6% perinatal and 8.5% subsequently - most of it during the first year of life. Among adults and sub-adults an annual mortality rate of 2.8% was recorded. All these rates are likely to be underestimates because it is certain that not all the deaths were detected.

8. Even if the recorded mortality rates are less than half the actual rates, the rhino population in Nepal is still increasing in size - probably by between 2% and 6% per annum.

4. ECOLOGY

Methods

4.1 Analysis of standard information recorded during each observation

General methods of observation and the types of standard information recorded during each encounter with a rhino are described in Section 2.3. A selection of the data was analysed with the help of the IBM 370/165 computer at Cambridge University, using programmes from Genstat and the Statistical Package for the Social Sciences. Each observation of a rhino was numbered and described by 70 numerical variables that were transcribed or calculated from the notebook data onto two 80 column computer coding forms per encounter. The information was then punched onto cards and stored on magnetic tape by the computer.

Those variables of relevance mainly to social behaviour are described in Section 5.1.1: those relevant to ecology are listed, with brief comments, below. They fall into three main categories:- (a) General, (b) Feeding and drinking, (c) Other activities.

(a) General

(i) Date: day, month and year

(ii) Time

(iii) Duration of observation in minutes

(iv) Location: defined by an eight figure grid reference on a 1:23,000 aerial photograph mosaic

(v) Habitat type: classified as in Section 2.1.5

(vi) Sex, age and identification number of the rhino.

(b) Feeding and drinking

(i) Time spent feeding: classified as grazing, browsing or feeding on aquatic plants

   - (ii) Types of food eaten: classified into nine categories
   - (iii) Occurrence of drinking, and whether from a river, lake or wallow.

- (c) Other activities
   - (i) Initial activity
   - (ii) Subsequent activities and time spent on them
   - (iii) The number of changes in activity during the observation.

4.1.1 Seasons

Seasonal changes in weather and vegetation are very rapid in Chitawan, and it is difficult to divide the year into a number of relatively discrete seasons. However, in order to study seasonal changes in diet, activity and movements, I divided the year into three seasons of four months duration:

- (a) the monsoon - June to September
- (b) winter - October to January
- (c) spring - February to May.

I decided on these divisions after considering changes in both vegetation and weather. They are obviously not perfect, because seasonal changes are continuous and also vary slightly from year to year. For example, the temperatures at each end of winter and spring are very different,and the monsoon rains sometimes extended into October (Section 2.1.3). However, the divisions are large enough to include significant numbers of observations in each season, and small enough to have common characteristics of weather and vegetation.

4.2 The study of food selection

4.2.1 Short term food selection

When it seemed likely that I could keep a feeding rhino under observation for 15 minutes or more, I kept detailed records of the food available and the food eaten by the rhino. I recorded all types of food eaten during each minute and all potential food types which had been within reach of the rhino during that minute. I judged what was within reach of the rhino, but trees with no branches below two metres were not considered potential food (although rhinos did occasionally push over such trees - Section 4.3.6). I stopped recording when the rhino was not clearly visible - even for only part of a minute - and restarted when it came back into view. There were no such intervals of longer than about five minutes. When the species or genus of plant could not be determined, I used the classifications of plant types shown in Tables 4.1 and 4.2. Each plant type was scored on the number of minutes during which it had been recorded as (a) within reach of and (b) eaten by the rhino.

I analysed all such feeding records of over five minutes duration: there were 143 observation periods totalling 2,592 minutes, distributed over each month and habitat type and each sex and age class of rhino. Detailed observations were normally made on only one individual at a time, but simultaneous feeding records of a cow and her calf were collected on a few occasions.

I derived two indices for each plant type. The utilization index, a measure of the contribution of the type to the diet,is the number of minutes during which that type was eaten, expressed as a percentage of the total number of minutes of the observation. The preferability index, a measure of preferability, is the number of minutes during which food of a certain type was eaten, expressed as a percentage of the number of minutes it was available (as defined above). This is similar to the preference rating discussed by Petrides (1975), with the exception that the preferability index defined above never exceeds unity or 100%.

There were two main problems associated with this method of studying food selection. Firstly, the method involved recording only the presence or absence of a particular plant species or type within reach of a rhino during each minute. No further measure was made of the abundance of each species or plant type, and it would have been difficult to do so. However, Dinerstein (1975) made a total count of the individual plants of all species occurring in 70 $1m^2$ plots of a one metre wide straight line transect across the Rapti flood plain near Sauraha. Using Dinerstein's data, I found a significant positive correlation ($r_s = +0.819$, $p < 0.001$) between the total numbers of each species and the total numbers of metre squares in which each species occurred. This indicates that the number of $1m^2$ plots in which a species or plant type occurs, can be used as a rough guide to the order of abundance of the species or plant type. It follows that the numbers of minutes during which a plant type is within reach of a rhino can be used as a guide to the availability of that plant type to the rhino.

The second problem is that availability as measured by this method refers to where the rhino chooses to be, and hence there is some inherent bias. The rhino selects its route and chooses how long it stays at any point along its route: thus I was measuring the availability of plants after an initial selection by the rhino. Preferability indices determined by this method should therefore be regarded as measures of short term food preferences. The study of food selection over the long term and over larger areas is considered in Section 4.2.3.

4.2.2 Examination of feeding trails

By following rhinos' fresh tracks, I was able to see from the freshly cut surfaces of grass and browse, which plants had been eaten. Trails were easiest to follow in woodland; on short grass they were clearly visible only when made in the early morning with dew on the ground, or when the ground was very wet. I recorded which plants were eaten by rhinos along these trails,and used the results to add to the list of food plants (Appendix D).

I hoped to be able to quantify the number of food types available and eaten in one metre sections of the feeding trails, but it proved too difficult to record accurately all the food types eaten and to exclude stretches of the trail where no feeding took place. Furthermore, even if it had proved possible, utilization and preferability indices derived from observations relating to space alone would have had less meaning than the same indices derived from timed observations (as described in Section 4.2.1).

4.2.3 Long term food selection

I summarized data collected during all observations of feeding rhinos (Section 4.1) to describe the rhinos' diet in different habitats and seasons. In order to investigate long term or large scale food selection, I measured the availability of rhino food in different habitats at different times of the year. I walked along straight line transects through the study area and recorded the frequency of different plant species and plant types. For each pace (approximately one metre length) of the transect, I considered all plants within reach of my arms but below the level of the top of my head. This is an area on the ground of about $1.6m^2$ and a volume of about $2.9m^3$. Trees with no branches below my head height were not considered as potential food (but see Section 4.3.6).

There were 26 transect lines, distributed over most habitat types (corresponding approximately with the vegetation classes described in Section 2.1.5), and the lines of individual transects were chosen so that each was confined within a particular habitat type. There was enough variation in vegetation in some habitat types to be able to distinguish habitat sub-types (corresponding approximately to the vegetation types described in Section 2.1.5). In these cases, transects were aligned so as to include stretches of each habitat sub-type in approximate proportion to each one's area (determined from aerial photographs and my knowledge of the ground).

In order to study seasonal changes in available plant food, I walked each transect line four times during one year at intervals of approximately three months. In addition, two transects were walked at the same season in subsequent years to measure changes between years resulting from the exclusion of domestic stock. Data were recorded for a total of 40,400 metre sections of transects.

The 26 transect lines described above were confined to uncultivated areas. In cultivated land, I walked transects in the crops at certain times of the year in order to monitor crop-raiding by rhinos. It was possible to record accurately from their footprints and signs of feeding, whether rhinos had fed or not in each one metre section of the transect. I measured utilization by the proportion of metre sections in which there were signs of feeding.

4.2.4 Faecal examination

While walking, I examined by eye a large number of fresh rhino faeces. At the beginning of the study I classified fresh dung according to the abundance of grass and browse. However, grass was much more frequent than browse, and the occurrence of large amounts of browse did little more than indicate the location of the dung. I continued to examine dung but only noted the occurrence of leaves or seeds which could be identified and added to the list of food plants (Appendix D), unusual contents such as molluscs which indicated feeding on aquatic plants,or seeds of agricultural crops which indicated feeding in the fields.

4.2.5 Plant identification

I collected specimens of each plant species which I found in the rhinos' habitats. I used the local Tharu and Nepali names for some species and I assigned numbers to others for easy reference until I could match them with the botanical name. I collected terrestrial plants in presses, and dried them over an open fire, changing the papers several times before the plants were sufficiently dried. Aquatic plants were preserved in alcohol and formalin.

Final identification of the plants was done at the Department of Medicinal Plants, Kathmandu, the Royal Botanic Gardens, Kew, and the British Museum (Natural History), London. Reference collections of all the grass species have been deposited at Kew and Kathmandu. A reference collection of some of the other species has been deposited at the British Museum (Natural History). A full list of all identified species arranged according to families is given in Appendix D.

Results

4.3 Feeding ecology

4.3.1 Diet

Parts of 183 species of plants from 57 different botanical families were found to have been eaten by rhinos during the study period. These species are indicated by asterisks on the full list of collected plant species in Appendix D. I recorded species as eaten by rhinos after one of three types of observation:-

(a) direct observation of rhinos feeding,

(b) observations of vegetation showing signs of feeding by rhinos (Section 4.2.2),

(c) observations of plant remains in rhino dung (Section 4.2.4).

Plant species were classified into six major categories (shown in Table 4.1). The five most frequently recorded food species in each category are listed in Table 4.1 with the numbers of occasions on which each was recorded eaten. I counted a maximum of one feeding record per species for each observation period, feeding trail or defecation. Table 4.1 shows clearly that the majority of feeding observations were on a small percentage of the species of food plants. Apart from the accidental ingestion of small aquatic invertebrates and one reported case of a rhino eating dried fish (J.H. Blower, pers. comm., 1973), there was no evidence that rhinos departed from a plant diet.

There are obviously biases in Table 4.1 towards those plant species

(a) with which I was most familiar,

(b) from habitats which I visited most frequently,

(c) from habitats where the visibility was best,

(d) which showed the most obvious signs of feeding by rhinos,

(e) which were most easily identified in rhino dung.

I overcame the first bias to some extent by classifying food items into a number of types between which I could distinguish with much less bias than between species. I have sub-divided the six categories of Table 4.1, as shown in Table 4.2, to show the frequency with which each type of food item was recorded eaten by rhinos. Here, in order to overcome biases (d) and (e), I have included records only of direct observations of rhinos feeding. The main effect of this is to reduce substantially the numbers of feeding records of trees and saplings. However, they are probably under-represented in Table 4.2 because most trees and saplings are in habitats where the visibility is poor,and are therefore affected by bias (c) (see below, Section 4.3.2).

Table 4.1. The numbers of feeding records for the five most frequently recorded rhino food species in each of six categories.

Category and species		Number of feeding records
(a) Short grasses :	*Cynodon dactylon*	745
	Paspalidium flavidum	110
	Setaria pallide-fusca	104
	Chrysopogon aciculatus	82
	Imperata cylindrica	54
	25 other species	188
(b) Tall grasses and reeds :	*Saccharum spontaneum*	1203
	S. munja	802
	Narenga porphyrocoma	797
	Phragmites karka	85
	Themeda villosa	74
	15 other species	104
(c) Sedges, herbs, small creepers and ferns :	*Cyperus digitatus*	63
	C. pilosus	57
	Polygonum plebujum	38
	Ageratum conyzoides	19
	Erigeron bonariensis	18
	54 other species	238
(d) Shrubs :	*Callicarpa macrophylla*	172
	Artemisia vulgaris	63
	Eupatorium odoratum	29
	Solanum indicum	22
	Colebrookia oppositifolia	17
	17 other species	67
(e) Trees and saplings :	*Trewia nudiflora*	67
	Litsaea monopetala	42
	Premna integrifolia	32
	Murraya koenigii	18
	Ehretia laevis	17
	34 other species	51
(f) Aquatic plants :	*Hydrilla verticillata*	403
	Vallisneria spiralis	403
	Pistia stratiotes	403
	Hygrorhyza aristata	37
	Potamogeton crispum	37
	8 other species	not recorded

Table 4.2. The numbers of direct observations of rhinos feeding on various types of food.

Food type	Number of observations
(a) Short grasses	
(i) *Imperata cylindrica*	54
(ii) Other wild species (mainly *Cynodon dactylon*)	872
(iii) *Oryza sativa* (rice)	36
(iv) *Triticum arvense* (wheat)	17
(b) Tall grasses and reeds	
(i) *Vetiveria* spp., *Cymbopogon* spp.	31
(ii) *Saccharum* spp., *Narenga* (mature)	651
(iii) *Saccharum* spp., *Narenga* (burnt)	210
(iv) *Saccharum* spp., *Narenga* (young)	1101
(v) *Themeda* spp. (mature)	16
(vi) *Themeda* spp. (burnt)	17
(vii) *Themeda* spp. (young)	54
(viii) Reeds (*Arundo, Phragmites, Typha, Thyrsia*)	90
(ix) *Zea mays* (maize)	10
(c) Sedges, herbs, small creepers and ferns	
(i) Sedges	142
(ii) Herbs	190
(iii) Ferns	24
(iv) Creepers	18
(v) Lentils	27
(vi) Mustard	2
(d) Shrubs	292
(e) Trees and saplings	
(i) Saplings	54
(ii) Mature trees (leaves + branches)	23
(iii) Fallen fruits and flowers	77
(iv) Banana (*Musa balbisiana*)	2
(f) Aquatic plants	
(i) Submerged e.g. *Hydrilla*	403
(ii) Floating e.g. *Potamogeton*	37

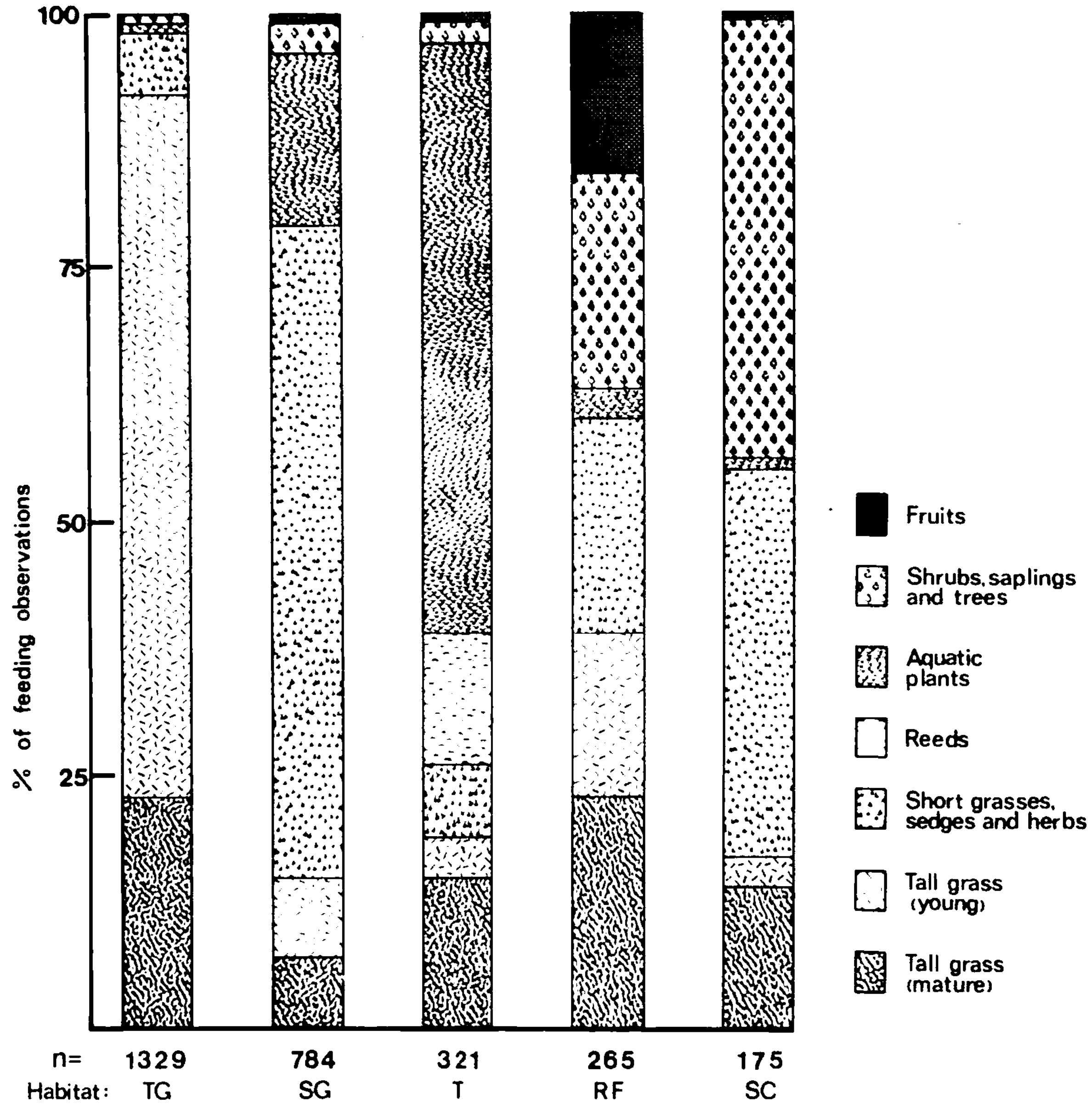
Some species contribute to more than one type of food item in Table 4.2. For instance, both the leaves and fruits of the tree *Trewia nudiflora* and the leaves and fallen flowers of the tree *Bombax ceiba* were eaten. I have included cultivated plants such as rice, wheat and maize under the same categories as used for wild species.

4.3.2 Variation of diet with habitat type and seasons

It can be seen from Table 4.2 that grasses - mainly tall grasses - were the most commonly recorded type of food. However, there was an uneven distribution of the observations over habitats and seasons. I therefore considered five habitats separately and plotted in Fig. 4.1 the proportions of feeding observations on each of various categories of food items. I included only the first food item to be eaten during each observation. This was because visibility varied considerably between habitat types (Section 2.3) and,if I included all feeding observations,there would be a bias towards greater variety in the habitats where the visibility was best.

There are clear differences between the habitats in the proportions of the diet made up by the different categories of food items ($\chi^2 = 317.2$ $p < 0.001$). Furthermore, the composition of the diet in each habitat changed considerably according to the season. Fig. 4.2 shows the same data as Fig. 4.1 divided into the observations made in the three seasons of the year (Section 4.1.1). There are significant seasonal differences in the diet in each habitat type ($p < 0.001$, χ^2 values shown in Fig. 4.2).

The main seasonal change in diet in the tall grassland was in the relative proportion of young and mature *Saccharum* grasses. There were also more observations of grazing on short grass during the monsoon and the winter, and of browsing during the winter. The same trends were prevalent in the short grassland and river-beds, although the relative proportion of young to mature *Saccharum* grasses did not change so much. The other major seasonal changes were in the riverine forest and scrub. Tall



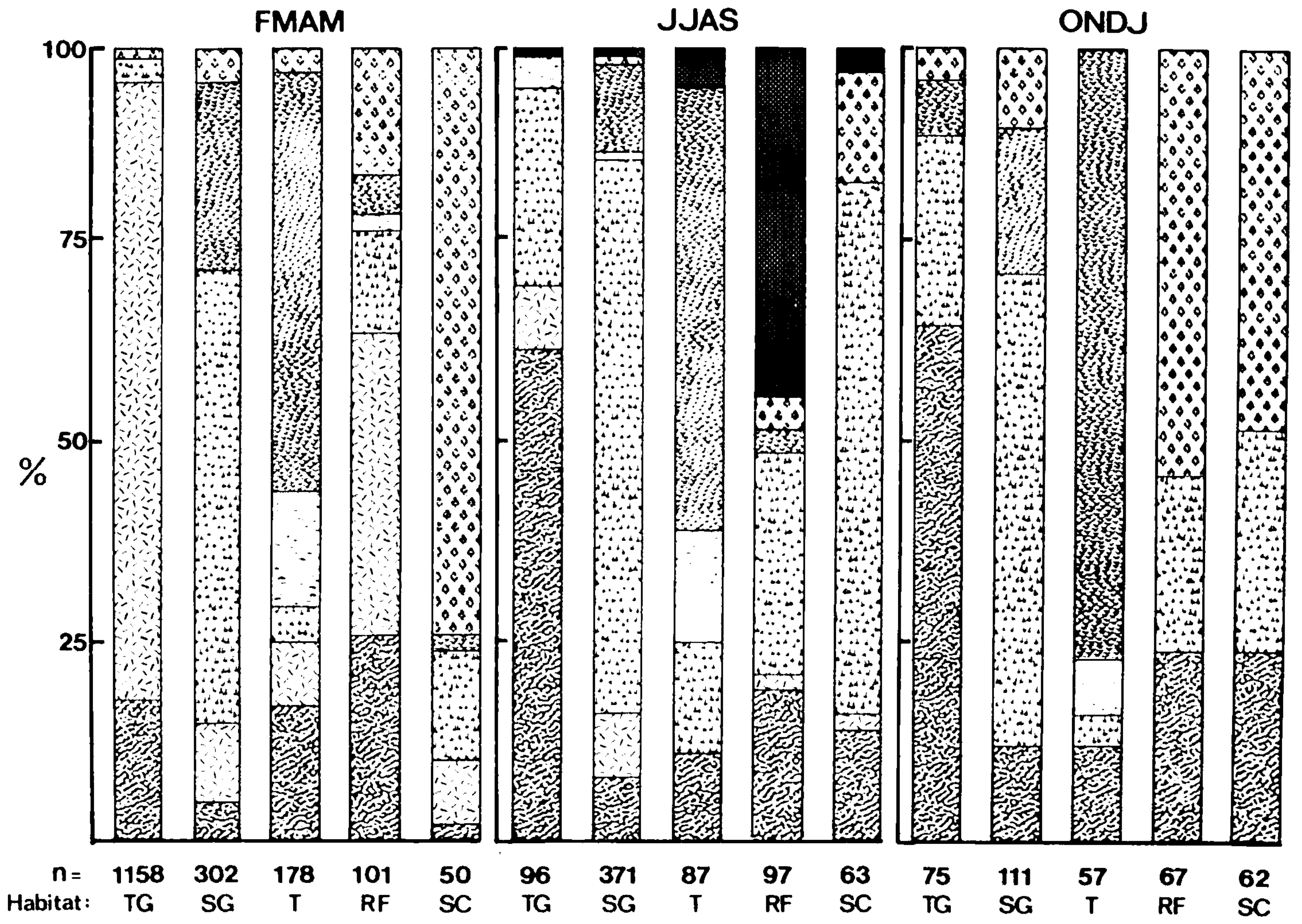
TG = Tall grassland SG = Short grassland T = Tals RF = Riverine forest SC = Scrub

Overall $\chi^2 = 317.2$ $p < 0.001$

Fig. 4.1. The distribution of first feeding observations across seven different food items in five different habitat types.

grasses predominated in the feeding observations in riverine forest in the spring, and short grasses and fruits during the monsoon. Browsing predominated over grazing during the winter.

In scrub, which was usually drier than the short grassland and riverbeds, rhinos browsed predominantly during the spring, but grazed extensively on short grass during the monsoon, and on both tall and short grass during



Key as in Fig. 4.1.

Seasonal differences in each habitat type:

TG: Overall $\chi^2 = 319.2$
$p < 0.001$ df = 6

SG: Overall $\chi^2 = 50.3$
$p < 0.001$ df = 8

T: Overall $\chi^2 = 14.3$
$p < 0.001$ df = 2

RF: Overall $\chi^2 = 242.1$
$p < 0.001$ df = 6

SC: Overall $\chi^2 = 47.3$
$p < 0.001$ df = 4

Fig. 4.2. Seasonal differences in the distribution of first feeding observations across seven different food items in five different habitat types.

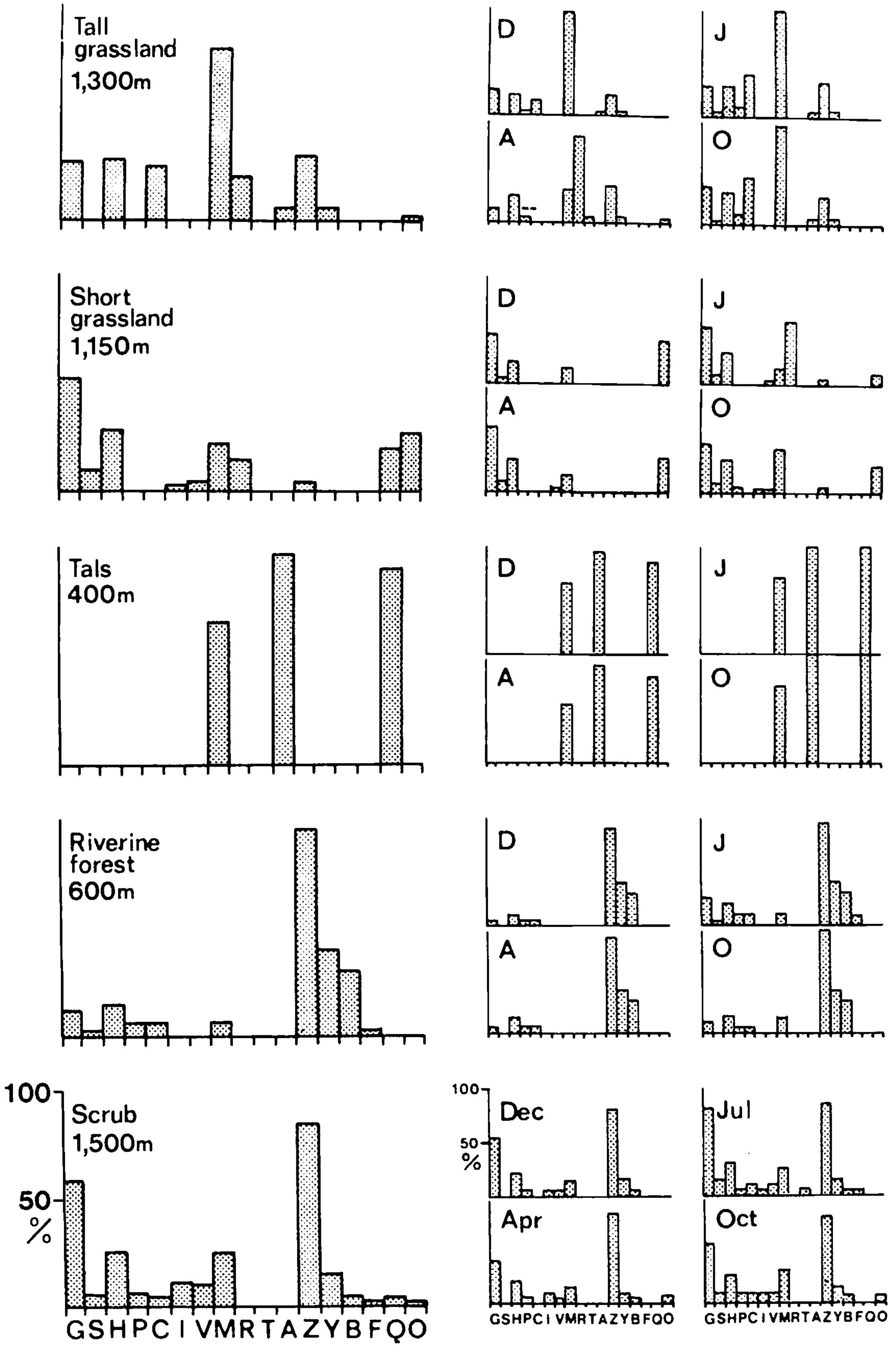
the winter.

4.3.3 Food availability

The data from the vegetation recording transects (Section 4.2.3) are summarized in Fig. 4.3. It can be seen that the quantity and quality of available food varied considerably between habitats, and between seasons within habitats. Furthermore, the various habitat sub-types (Section 4.2.3) for which the data are not shown in Fig. 4.3, differed considerably in vegetation composition. It should be remembered, therefore, that the demonstrated effects of habitat distribution and seasonality on the feeding behaviour and movements of rhinos (Sections 4.3.4 and 4.6.1) are great simplifications. There are many other influences which could be demonstrated using a finer classification of habitat types.

The most marked seasonal changes were in the tall grassland, in the relative proportions of young to mature tall grasses. Burning of the tall grassland during February was followed by lush regrowth of the *Saccharum* type grasses, and this regrowth dominated the burnt tall grassland for three months, before reaching maturity during the monsoon (Section 2.1.5.3). Charred stems of grasses and shrubs also become available after fires in the tall grassland, and were sought after by rhinos (Section 4.3.5). During the monsoon, short grasses, ferns and creepers increased in abundance in open patches.

In the short grassland, river-beds and scrubby areas, there was an increase in available food - mostly short grass or *Saccharum spontaneum* on sandy river-beds - just before, and during the early part of the monsoon (Section 2.1.5.4). Floods often caused a decrease in availability later on, either by permanent inundation, or by extensive deposition of silt. Short grass, herbs, ferns, sedges and creepers increased in abundance in riverine forest during the monsoon, and the fallen fruits of *Trewia nudiflora*



KEY

G	Short grass
S	Sedges
H	Herbs
P	Ferns
C	Creepers
I	*Imperata* sp.
V	*Vetiveria* sp., *Cymbopogon* spp.
M	Mature *Saccharum* spp., *Narenga* spp.
R	Young *Saccharum* spp., *Narenga* spp.
T	*Themeda* spp.
A	*Arundo* sp., *Phragmites* sp.
Z	Shrubs
Y	Saplings
B	Trees
F	Fruits, flowers
Q	Aquatic plants
O	Bare ground

Fig. 4.3. Overall and seasonal results of transects walked in five different habitat types to assess food availability.

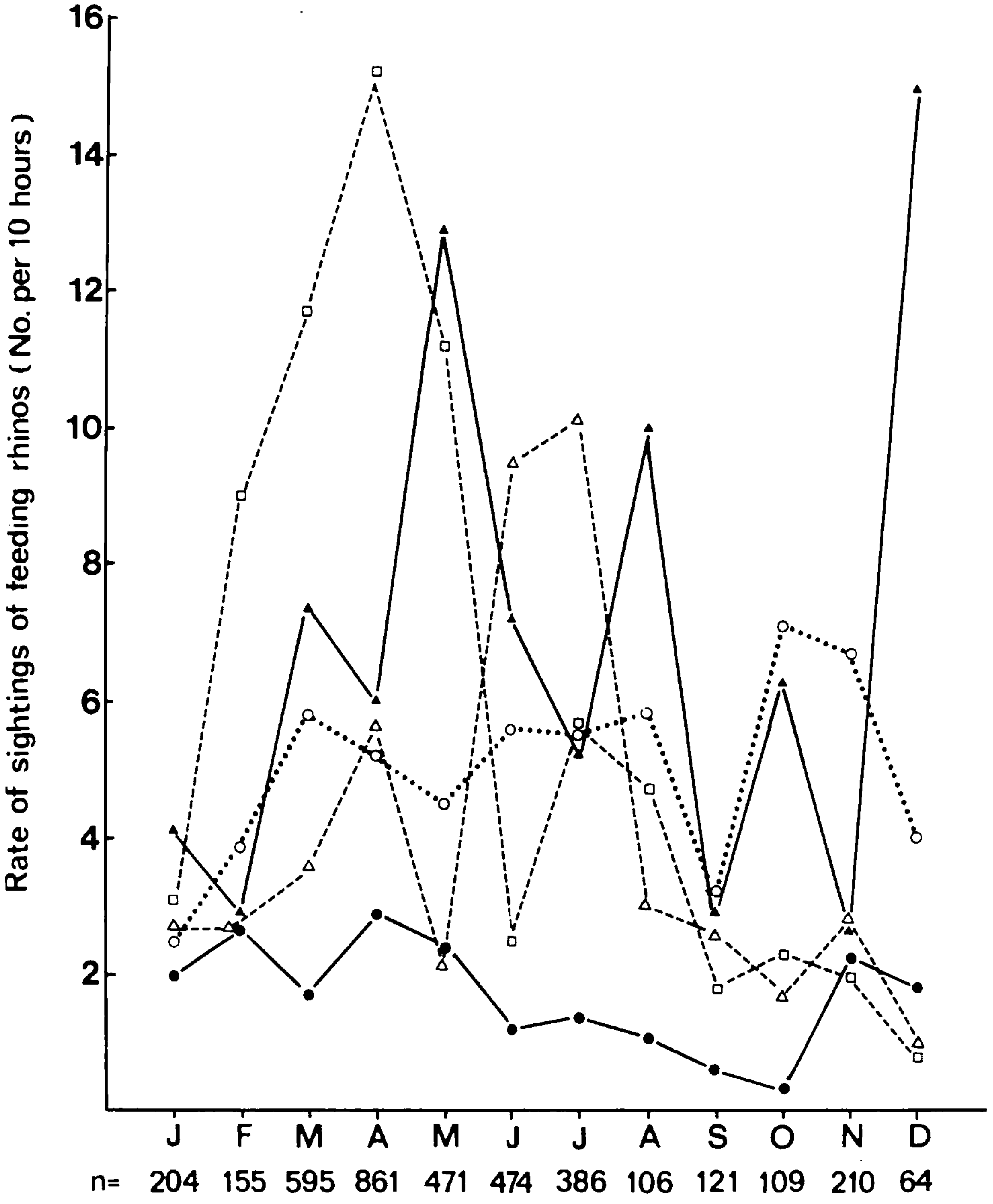
became available there during June and July. In agricultural land, maize plants were available from June to August, rice from August to December and wheat and mustard from December to March (Section 2.1.5.7). In addition, herbs and grasses became more abundant in the fields during the monsoon: rhinos often ate these to a greater extent than the planted crops. Aquatic plants were available in tals the year round, but during the monsoon they were often difficult for rhinos to reach. In the rivers, aquatic plants were often swept away by floods during the monsoon, but were easily reachable during the winter and spring.

Seasonal variations in food availability have been emphasised above, but there were also considerable unpredictable variations both in time and space. Floods washed away areas of forest and the resulting sandbanks became covered in grass in the following year. Fires were also unpredictable in their location and timing, and resulted in widely different distributions of food resources between years. It appeared that some grasslands could only be burnt in alternate years.

4.3.4 Seasonal changes in the use of different habitat types for feeding

Rhinos altered their diets seasonally within each habitat type, and the availability of food varied considerably between habitats, and between seasons within habitats (Sections 4.3.2 and 4.3.3). I examine here the ways in which rhinos changed their diet by seasonal changes in their use of different habitats.

Fig. 4.4 shows the rates of sightings of feeding rhinos in each of the major habitat types for each calendar month. There were slight variations between years. It is clear from Fig. 4.4 that the rates of sightings,



Key: = Tall grassland, Δ = Short grassland, O = Tals,
O = Riverine forest, Δ = Scrub.

Fig. 4.4. The rates of sightings of feeding rhinos in five habitat types in each calendar month.

expressed as the numbers of rhinos seen per 10 hours of searching time, varied considerably over the year. This suggests that rhinos were moving between habitat types, and were feeding predominantly in the tall grassland during February to May and in the short grassland and river-bed habitats in June and July. Recently burned areas of tall grassland were particularly attractive to rhinos. Patches of unburned grass near my machans were often not visited by rhinos for several days but, immediately after they were burned, rhinos started to eat first the ashes and later the young shoots of grass.

Although there is no doubt that rhinos moved into burned areas, there are alternative explanations for some of the other variations in rates of sightings. The most obvious is that the variations are caused by seasonal changes in the visibility of the rhinos. The main differences in visibility were caused by the burning of the grass in the tall grassland in February and March, and the subsequent regrowth of this grass to a height sufficient to hide rhinos by May or June. In addition, grass growth in the river-beds and short grassland reduced visibility in June and July, and flooding reduced visibility periodically in the river-beds throughout the monsoon.

In general, the visibility decreased from June to December and then increased again. Changes in visibility are considered in more detail in Section 4.6 where the actual movements of rhinos are considered. Here it is sufficient to note that although the highest rates of sightings in tall grassland were during the season of best visibility, those in short grassland, river-beds and scrub were during the seasons of poorest visibility. Thus the changes in rates of sightings probably do reflect changes in the rhinos' feeding behaviour and seasonal differences in the amount of feeding done in each type of habitat.

4.3.5 Principal foods and preferred foods

It was shown above that rhinos changed their diets over the year, both within habitat types and also by moving between habitat types. In this section I examine variations in principal foods and short term food preferences with reference to data collected during detailed observations of feeding rhinos (Section 4.2.1).

I lumped all observations in each habitat type and season and counted the number of minutes during which each food type was available and the number of minutes during which it was eaten by rhinos (data in Appendix G). In general, a wide variety of food types were eaten but the bulk of the diet consisted of relatively few types. Eighty-three (64.3%) of the 129 available food types were recorded as eaten by rhinos, whereas only 24 types (18.6%) were eaten for more than 10% of the minutes of observation in any habitat or season.

Table 4.3 shows the numbers of different food types available and the numbers recorded eaten during observation periods in each habitat and season. In habitats other than sal forest and agricultural land, the proportion of available food types that were eaten varied, according to season and habitat, from 30% to 100% ($\overline{x}$ = 62.8 ± 18.0). Those food types eaten during more than 10% of the minutes of observation comprised between 8% and 80% ($\overline{x}$ = 23.2 ± 18.1) of the available types. In the sal forest, *Themeda villosa* was eaten almost exclusively, apart from a few young sal leaves and two other species of grass. In the agricultural land, rice and wheat were similarly preferred. However, the results are less reliable for these two habitats, because there were few observations in the sal forest, and all observations in the fields were made at night.

At least 20 of the common sal forest trees and shrubs were not eaten although they were available during more than 10% of the minutes of observation (Appendix G). In the other habitats, a total of only 20 potential food types were not eaten in certain habitats and seasons although they were available during more than 10% of the minutes of observation (Table 4.4). However, 17 of these were recorded as eaten by rhinos in other habitats or seasons. Thus, only three of the abundant types, *Calotropis*

Table 4.3. The numbers of food types available and eaten during detailed observations of feeding in each habitat and season.

	Number of food types									Number of minutes observed
Season	FMAM			JJAS			ONDJ			
Habitat	Available	Eaten	Eaten during ≥10% of minutes	Available	Eaten	Eaten during ≥10% of minutes	Available	Eaten	Eaten during ≥10% of minutes	
Tall grassland	36	23	4	22	9	8	24	18	4	861
Short grassland	24	12	2	19	14	5	20	15	5	683
Tals	18	13	3	9	8	4	5	5	4	301
Riverine forest	36	20	4	29	12	3	21	11	4	335
Scrub	19	6	2	23	15	3	16	9	3	172
Sal forest	-	-	-	-	-	-	30	5	1	44
Agricultural land	10	3	2	14	2	2	15	7	2	196

Table 4.4. Potential food types not eaten by rhinos although available during more than 10% of the minutes of detailed observation.

	Food types (foliage)		
Season	FMAM	JJAS	ONDJ
Habitat			
Tall grassland	*Bombax ceiba* *Trewia nudiflora*	*Artemisia vulgaris* *Callicarpa macrophylla* *Colebrookia oppositifolia* *Pogostemon bengalensis* *Zizyphus jujuba* *Bauhinia malabaricum* Unidentified creeper	*Calotropis gigantea* *Trewia nudiflora*
Short grassland/ River bed	*C. oppositifolia*	*A. vulgaris*	*C. oppositifolia*
Tal/Reeds	-	*Gonostegia pentandra*	-
Riverine forest	*Clerodendron viscosum* *C. oppositifolia* *T. nudiflora*	*Saccharum munja* *A. vulgaris* *C. oppositifolia* *T. nudiflora*	*Imperata cylindrica* *Chrysopogon aciculatus* *A. vulgaris* *C. oppositifolia* *B. ceiba* *T. nudiflora*
Scrub	*I. cylindrica* *Oxalis corniculata* *C. gigantea* *C. oppositifolia* *Z. jujuba* *Litsaea monopetala* *B. ceiba* *T. nudiflora*	*G. pentandra* *Z. jujuba* *T. nudiflora*	*I. cylindrica* *C. gigantea* *C. oppositifolia* *M. phillipinensis*

gigantea, *Clerodendron viscosum* and the foliage of *Trewia nudiflora* were completely avoided (discussed in Section 4.7.1).

I calculated the utilization and preferability indices (explained in Section 4.2.1) for each habitat and season, of all food types which were

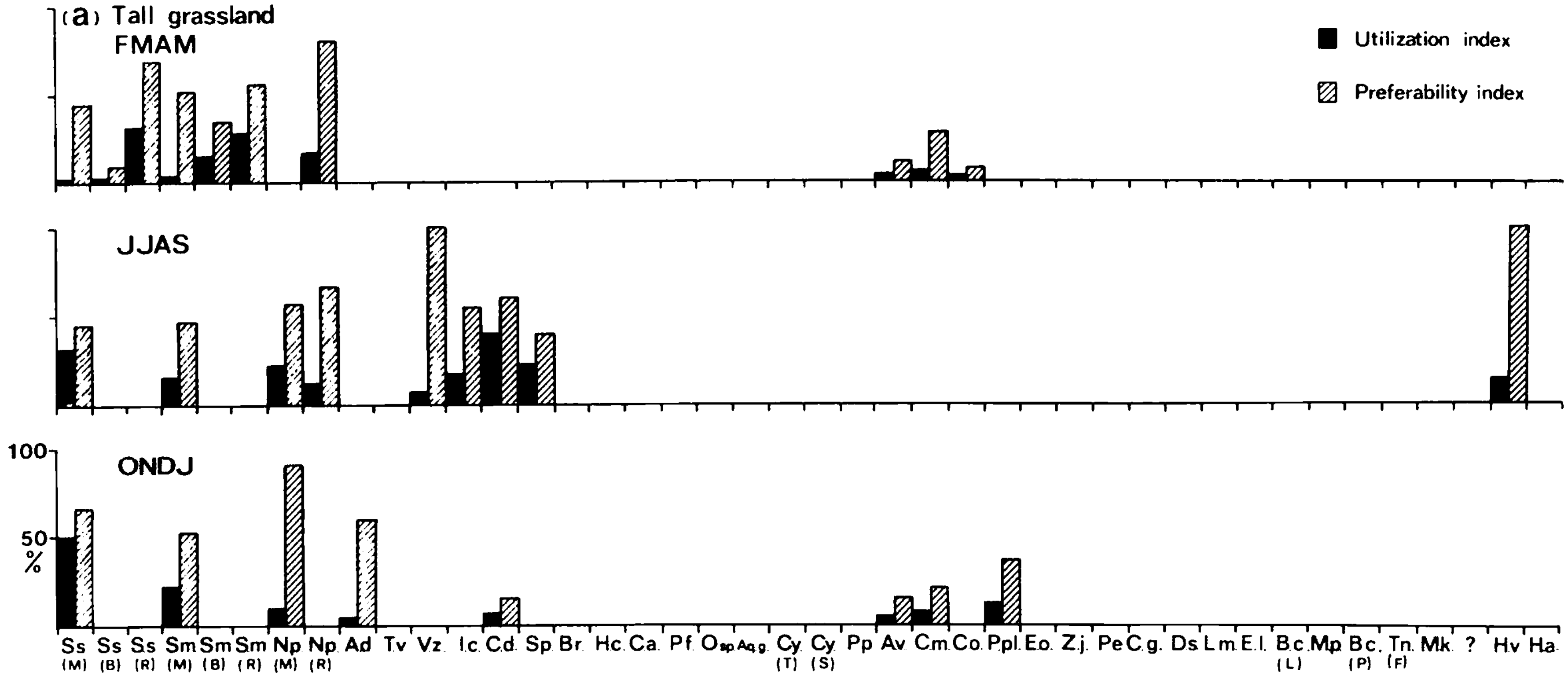


Fig. 4.5. The utilization and preferability indices for all food types eaten during more than two percent of the minutes of detailed feeding observations in each habitat type and season.

Continued/.....

KEY

S.s.	*Saccharum spontaneum*	*P.f.*	*Paspalidium flavidum*	*C.g.*	*Cordia grandis*
S.m.	*S. munja*	*O.*sp.	*Oplismenus* sp.	*D.s.*	*Dalbergia sissoo*
N.p.	*Narenga porphyrocoma*	Aq.g.	Aquatic grasses	*L.m.*	*Litsaea monopetala*
A.d.	*Arundo donax*	*Cy.*	*Cyperus* sp.	*E.l.*	*Ehretia laevis*
T.v.	*Themeda villosa*	*P.p.*	*Polygonum plebujum*	*B.c.*	*Bombax ceiba*
V.z.	*Vetiveria zizanoides*	*A.v.*	*Artemisia vulgaris*	*M.p.*	*Mallotus phillippensis*
I.c.	*Imperata cylindrica*	*C.m.*	*Callicarpa macrophylla*	*T.n.*	*Trewia nudiflora*
C.d.	*Cynodon dactylon*	*C.o.*	*Colebrookia oppositifolia*	*M.k.*	*Murraya koenigii*
S.p.	*Setaria pallide-fusca*	*P.pl.*	*Pogostemon bengalensis*	?	Unidentified shrub
B.r.	*Brachiaria ramosa*	*E.o.*	*Eupatorium odoratum*	*H.v.*	*Hydrilla verticillata* and other aquatic plants
H.c.	*Hemarthria compressa*	*Z.j.*	*Zizyphus jujuba*	*H.a.*	*Hygrorhyza aristata*
C.a.	*Chrysopogon aciculatus*	*P.e.*	*Phyllanthus emblica*		

M = Mature foliage   B = Burnt stems   R = Young regrowth   T = Tall   S = Short

L = Leaves   P = Petals   F = Fruits

Fig. 4.5 (continued)

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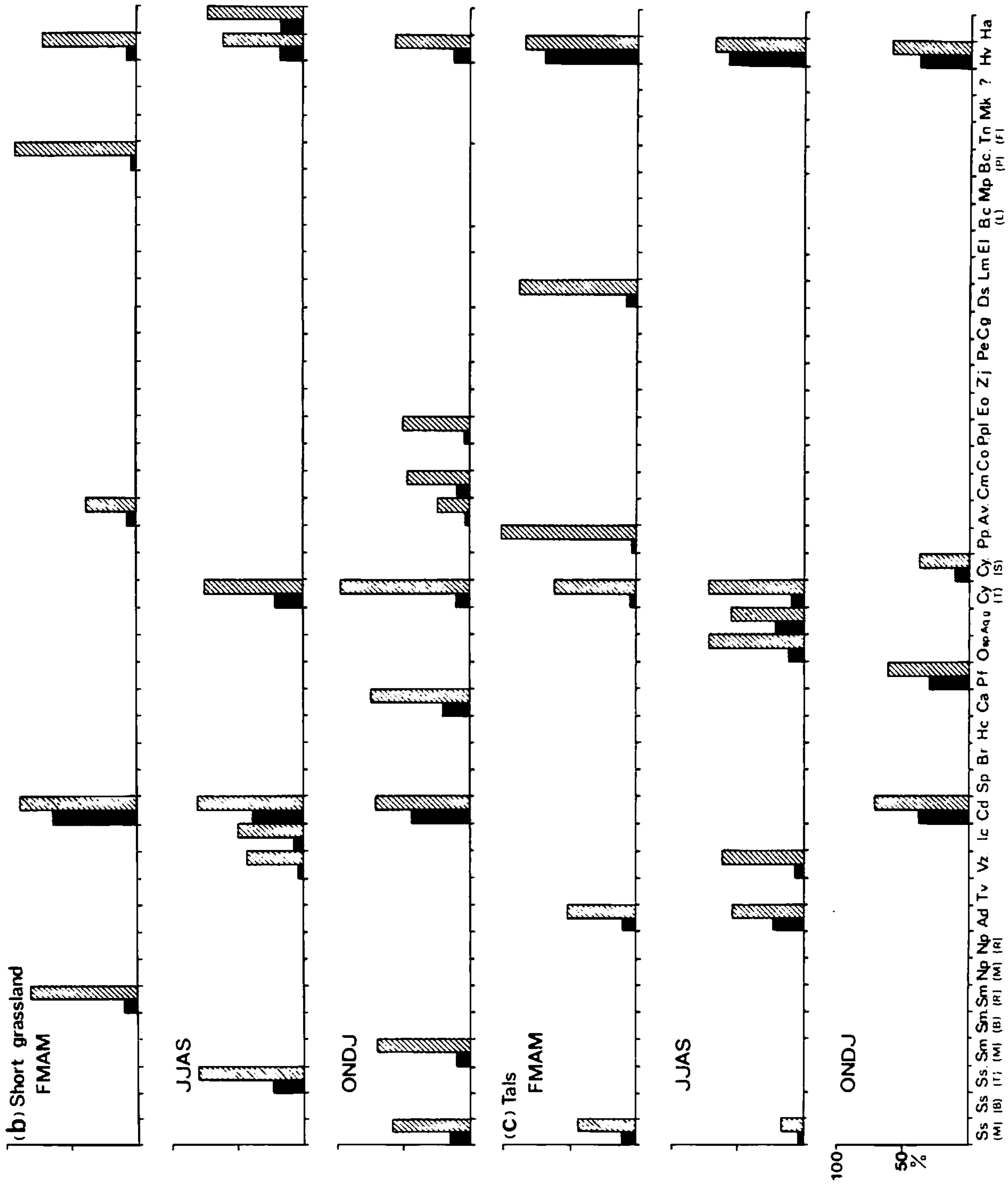

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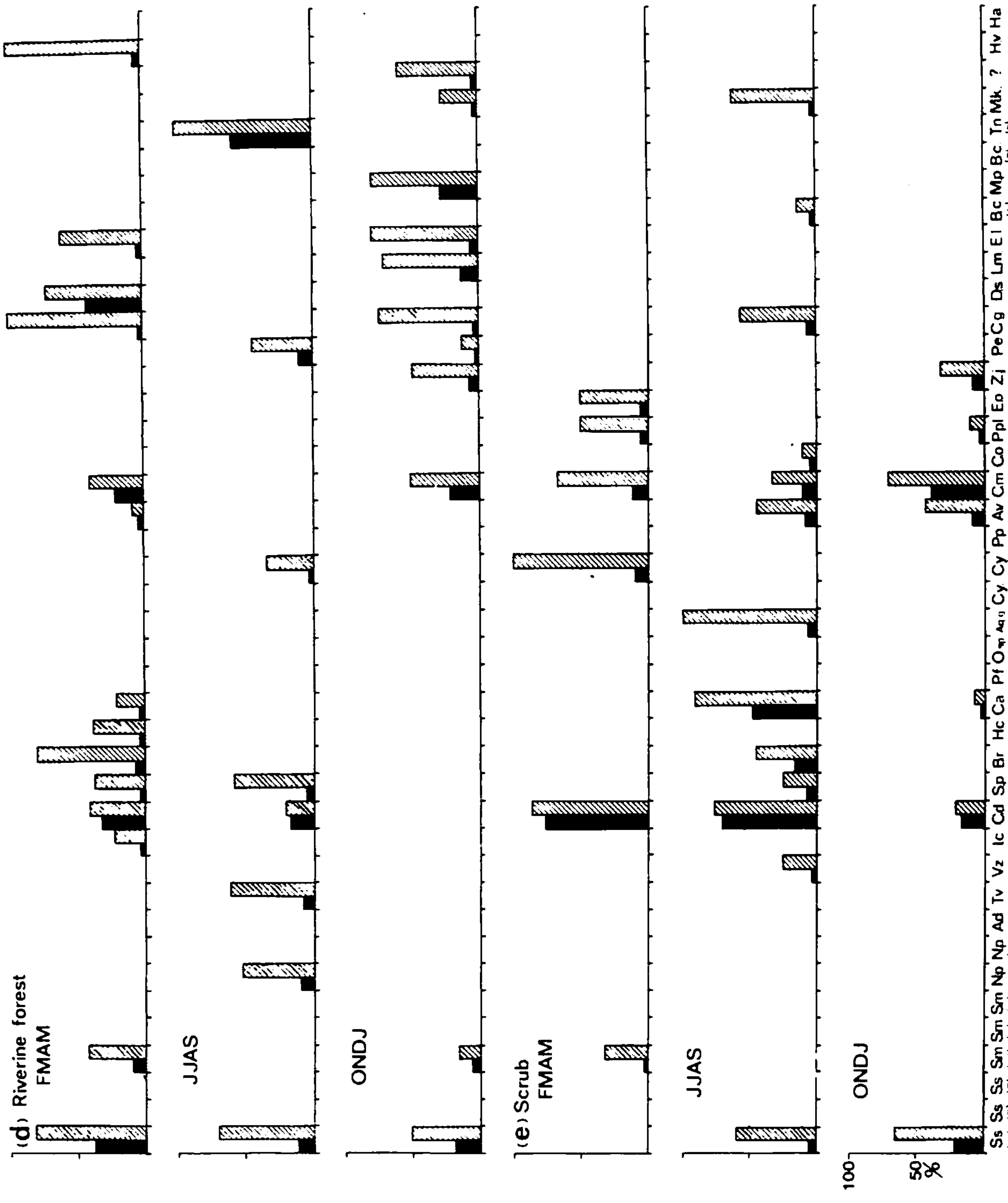


Fig. 4.5 (continued)

eaten during more than 2% of the minutes of observation (plotted in Fig. 4.5). The utilization index is a measure of the importance of the food type in the diet, and the preferability index is a measure of the degree to which the food is sought out or selected. There are very obvious differences between seasons and between habitats in both indices.

Young shoots of the tall grasses made up the bulk of the diet in the tall grassland in spring, and they were also the most preferred items

(Fig. 4.5a). During the monsoon, however, short grasses such as *Cynodon dactylon*, and the tall grass *Saccharum spontaneum* were eaten most, but they were not the most highly preferred food types. Aquatic plants such as *Hydrilla verticillata* and *Ceratophyllum demersum*, the grass *Vetiveria zizanoides*, and the young shoots of *Narenga porphyrocoma* were more highly preferred, although they made up a smaller proportion of the diet. There is a significant positive correlation between the utilization and preferability indices in the tall grassland in spring, and a significant negative correlation in the monsoon (Table 4.5).

Table 4.5. The relationship between the utilization and the preferability of food types according to habitat and season.

Season	Spring (FMAM)			Monsoon (JJAS)			Winter (ONDJ)		
	r_s	N	p	r_s	N	p	r_s	N	p
Habitat									
Tall grassland	+.83	10	<0.01	+.63	9	<0.05	+.57	8	ns
Short grassland	-.10	5	ns	+.96	7	<0.01	+.72	9	<0.05
Tals	-.54	6	ns	+.13	7	ns	+.80	4	ns
Riverine forest	+.42	14	ns	+.29	8	ns	+.55	11	<0.05
Scrub	+.83	6	<0.01	+.44	13	ns	+.82	7	<0.05

r_s = Spearman rank correlation coefficient

N = the number of food types eaten during more than 2% of the minutes of time sampling observations

ns = not significant at the 0.05 level.

Theoretically, a rhino would do best to feed in an area where its most highly preferred food types are most abundant. Preferability indices obviously change according to what is available. Therefore, I have used the correlation coefficients between utilization and preferability indices in each habitat and season (Table 4.5) to indicate which are the optimum habitat types for feeding in each season.

Table 4.5 shows that tall grassland and scrub are the optimum habitats in the spring; short grassland and river-beds during the monsoon; and scrub and tals during the winter. These results are in agreement with the data on seasonal changes in the use of different habitat types for feeding (Section 4.3.4).

The different parts and growth stages of some species were classified as different food types in Section 4.3.1. However, no such distinctions were made for some of the more rarely eaten species. The burnt canes, the young shoots and mature stems of the more abundant tall grasses are distinguished as separate food types, and the high preferability for the young shoots and the burnt canes are readily apparent (Fig. 4.5). Similarly, the fruits of *Trewia nudiflora* are preferred by rhinos to the leaves of the same species (Fig. 4.5). However, in the case of *Colebrookia oppositifolia* and some other shrubs, no such distinction in growth stages or parts were made. *C. oppositifolia* was avoided in most habitats and seasons although it was abundant (Table 4.4). It was eaten only during the spring when burnt stems were taken by rhinos in the tall grassland (discussed in Section 4.7.2)

4.3.6 Feeding methods

Feeding rhinos were observed for a total of 1,501 hours. They exhibited a wide variety of feeding methods. When feeding on tall grass (Plate 22) they used the prehensile upper lip to curl around the grass stems, and then bent the stems over, bit the tops off and chewed them, drawing the tips into the mouth from the side. In very tall grass, rhinos often walked forward with the stems between their legs, pushing the stems down, and then grazing from the tips before walking on. The grass stems either remained bent over or sprang up behind the rhinos. The same method was used when browsing. One cow with a calf was often seen bending saplings over, either by pushing them with her chin or walking over them, and remaining standing over them while she and her calf fed from the foliage brought within their reach. In some areas, notably the Naryani islands, sissoo (*Dalbergia sissoo*) trees were growing at up to 80° from the vertical as a result of repeated bending by rhinos walking over them to feed on the foliage (Plate 23). *Butea frondosa* was similarly affected (discussed in Section 4.7.1).

Short grasses and herbs were grazed close to the ground using the lips. Plants were often uprooted, the foliage bitten off and the roots dropped again. The tip of the prehensile upper lip was curled back into the mouth and short grass and herbs were cropped using the upper surface of the lip opposed against the lower lip (Plate 24).

Aquatic plants were taken by ducking the head beneath the water sometimes to the level of the feet and a metre or more below the water surface. Rhinos kept their heads under water for periods of up to 45 seconds while feeding, but as far as I could tell they ingested food only with their heads above water.

4.3.7 Feeding in cultivated land

Although the actual techniques of eating were the same in the fields as those used in other habitat types, feeding in the fields was hindered by human disturbance. Villagers sat out on platforms in their fields at night and attempted to prevent rhinos from feeding on their crops: they sometimes drove rhinos back to the forest edge, waving lighted torches and even hitting them on the rump. More frequently, however, they simply scared the rhinos off their own crops into fallow land or someone else's crops and woke the neighbouring guard by shouting. Fig. 4.6 shows that frequent detection resulted in the rhino spending very little time actually feeding on crops while in the fields (see below).

Rhinos appeared to be more successful in crop-raiding during misty or cloudy nights and during the dark periods of the month, although I have no

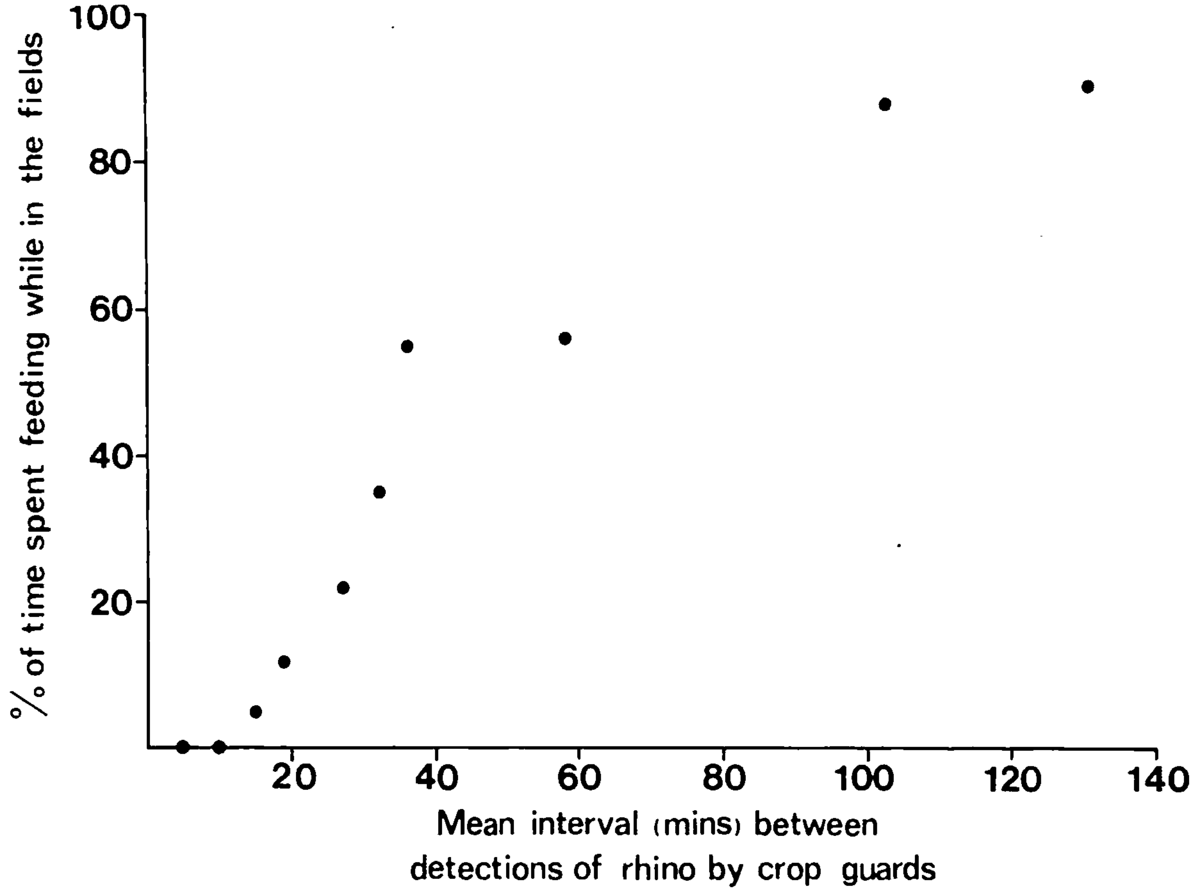


Fig. 4.6. The relationship between the proportion of a rhino's time in the field spent feeding on crops and the mean interval between detections by crop-guards.

conclusive data to show this. However, even during moderately well moonlit nights, rhinos were successful in crop-raiding, particularly during the later part of the night. Typically they were chased from field to field until they found an unguarded field or a sleepy guard. Fig. 4.7 shows the percentage of time spent feeding on crops for rhinos entering the fields at different times throughout the night. The most successful time to enter the fields was between 24.00 and 04.00 h when the crop-guards were often asleep. The earlier in that period the rhinos entered the fields the more food they could eat because there was more time available to feed undisturbed.

On moonlit nights rhinos generally entered the fields at the same time as on other nights but rates of detection by the farmers were higher. Mist reduced rates of detection to very low levels, and even if rhinos were

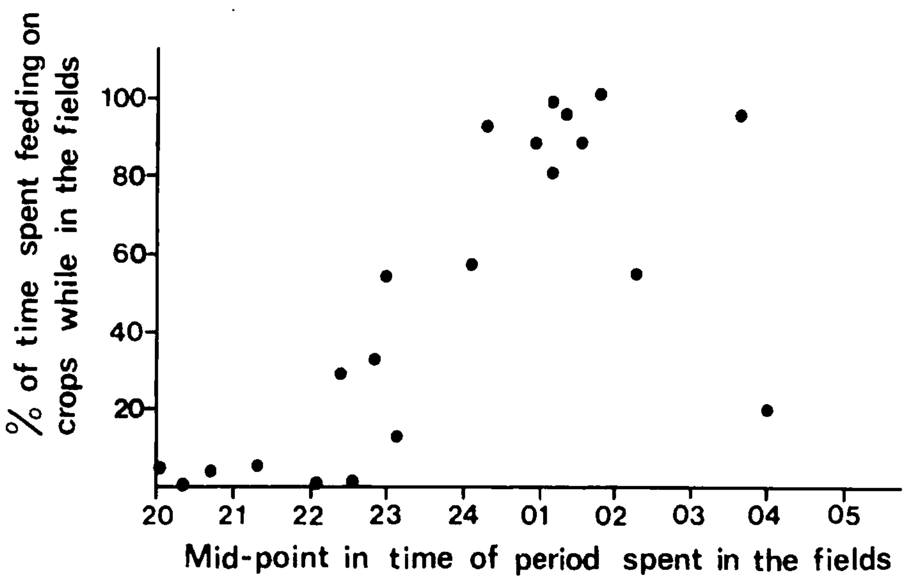


Fig. 4.7. The relationship between the proportion of a rhino's time in the fields spent feeding on crops and the time of the night.

scared off from one field, they only moved off a short distance, waited and returned later. Some individuals, particularly old males, lay down to wait in nearby fields, or fed on weeds in fallow land. Rhinos rarely fed in fields during daylight, but on one occasion an adult male stayed two days and nights in a maize field at Sauraha, despite attempts by the villagers to drive him out.

Rates of detection of rhinos by crop-guards varied greatly according to locality, and the vigilance of the guards contributed greatly to decreased losses of crops in some areas (see Section 4.3.7.1). Undisturbed rhinos caused extensive damage in small areas. One pair fed for 200 minutes within 200m of the forest edge and another pair did the same the next night undetected by four men in machans, although they passed within 10m of them. Both pairs returned immediately to the forest after nearly 3½ hours grazing.

4.3.7.1 Damage to crops

(a) Rice

In order to assess damage to the rice-crop caused by rhinos feeding, 15 one kilometre transects were paced out across growing rice paddies at several places around the park. Each pace was scored for the presence or absence of signs of feeding by rhinos, deer, wild pigs or domestic stock. This was done at two stages of the growing season; roughly six weeks and 12 weeks after sowing. The percentage of paces showing signs of feeding by rhinos varied from nought to 17.0%. Fig. 4.8 shows that most damage occurred within 750m of the edge of forest (or grassland) occupied by rhinos. Anywhere more than 1,500m from the forest-edge was negligibly damaged. Good scaring by crop-guards reduced damage even in areas near the forest-edge.

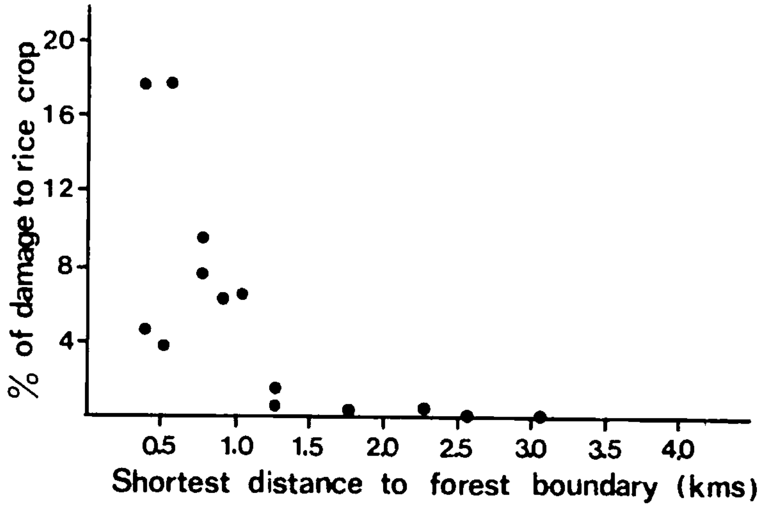


Fig. 4.8. Damage caused by rhinos to the rice crop at various distances from the forest.

Damage to the rice crop was greatest in the Sauraha area - 17.0% north of the river, 16.0% south of the river and 9.5% between Bagmara and Tikoli. Outside the Sauraha area, damage due to rhinos was much lower (Katar, 1.8%; Kasra, 0.1%; north of Tiger Tops, 0.0%; Nawalpur, 0.6%) and machans built for rhino-scaring were much scarcer.

Damage by other mammals was less considerable; in the Sauraha study area, deer had fed in 1.4% of paces, wild pigs in 0.4% and domestic stock in 0.6%. Birds, however, in particular parakeets, were responsible for considerable losses. Flooding also ruined large proportions of the crop - up to 100% in many areas.

(b) Maize

Maize was grazed by rhinos while still in the seedling stage, but the main damage occurred after fruiting. Wild pigs, however, caused considerably more damage to the maize crop than rhinos did. They completely destroyed patches of up to $400m^2$, but there was very little damage further than 400m from the forest edge.

Crop-raiding is discussed in relation to conservation in Section 7.2.1.1.

4.3.8 Drinking

Rhinos drank from streams, rivers, ox-bow lakes, small puddles and wallows. Some of the water in the wallows was (a) very warm and (b) very highly contaminated with rhino urine: it was completely shunned by the domestic elephants. Also, unlike elephants which always face upstream while drinking, rhinos drank from rivers with no apparent preference for facing upstream or downstream and often urinated or defecated at the same time. The drinking of the heavily contaminated water in the small wallows interested me. I analysed some water from one of the wallows and found that it had a high content of potassium, calcium and magnesium (Table 4.6). This is discussed in relation to mineral requirements in Section 4.7.2.

Drinking normally lasted only a minute or two; rhinos drank with lips immersed,and paused at intervals with head lifted. Water was never in short supply, although it was more limited in distribution during the dry

Table 4.6. The quantities of certain mineral ions in samples of soils, rocks and water eaten by rhinos and other ungulates.

Sample	ppm. dry weight				
	Sodium	Potassium	Calcium	Magnesium	Iron
Surung cliff (4 samples)	543 ± 68	35 ± 6	25 ± 12	19 ± 8	28 ± 13
Surung cliff crystalline deposit (1 sample)	70,000	160	3,200	27,000	3
Dumaria (3 samples)	153 ± 40	51 ± 42	13 ± 8	15 ± 11	48 ± 5
Jarneli (2 samples)	85 ± 1	32 ± 1	2 ± 1	2 ± 0	27 ± 23
Bwanipur (3 samples)	12 ± 5	29 ± 6	17 ± 2	15 ± 3	437 ± 304
Wallow water, Sauraha (1 sample)	71	350	1,300	260	9

season. For example, small pools which were full of water during the monsoon were dry between November and April. The distance to the nearest tal, stream or river is never great in Chitawan (Section 2.1.4), but access to water was hindered to some extent by human disturbance on the edge of the park and in outlying areas. During the dry season, rhinos near the edge of the park had to move out of the riverine forest and scrub in which they spent most of the daylight hours to go into the open to drink from the rivers. They drank mainly at night and in the early morning and late afternoon. Rhinos inside the park in the tall grassland usually had water available in permanent lakes and streams which were not exposed: they drank at any time during the day when they were near to a water supply.

4.3.9 Mineral licks

I found four major sites where rhinos or other ungulates had licked or eaten soil or rock material. The site most frequently used by rhinos was a cliff of micaceous sandstone in the Surung Valley near Tiger Tops, and its use was confined almost entirely to the months of November to May. During those months a well trodden rhino path was formed up the valley to the base of the cliff. For the rest of the year the path was almost unused. Rhinos both licked and ate the friable rock material. I observed rhinos raising themselves onto their hind legs in order to reach higher up the cliff and one individual climbed about five metres up the very steep slope and continued to eat the rock. The time spent eating and licking varied in five observations from 10 minutes to 45 minutes. Sambhar also used the lick and my elephant ate large quantities of the rock. In some places there was a crumbly crystalline deposit on the rock surface which was also eaten by both the elephant and rhinos. I collected four samples of the rock from different parts of the cliff and also some of the crystalline deposit. The results of analysis for sodium, potassium, calcium, magnesium and iron are shown in Table 4.6. Both the rock and the crystalline deposit at Surung have very high sodium contents compared with samples from other mineral licks, and the crystalline deposit is considerably richer in potassium, calcium and magnesium than the other samples.

At two sites, Jarneli and Bwanipur, I observed chital licking and eating the soil along an eroded gully in sal forest,and at Dumaria I saw a gaur doing the same. My elephant ate soil at Dumaria also,but was not attracted by that at Jarneli and Bwanipur. Rhino footprints were present at all three sites but there were no well trodden paths like those at Surung.

The soil at these three sites is a yellowish brown silty clay. The results of analysis of samples showed greater variability than the results for Surung, and the iron content was particularly variable. Although I did not analyse local samples as controls, the sodium content of the soil at Dumaria and Jarneli is considerably higher than that at Bwanipur.

Mineral requirements are discussed in Section 4.7.

4.3.10 Feeding competition

The numbers and distribution of wild and domestic ungulates are described briefly in Sections 2.1.6 and 2.1.7. Seidensticker (1976) concluded that rhinos made up over 80% of the biomass of wild ungulates in the riverine forest and tall grassland both inside and outside the park. However, domestic stock in the Sauraha study area had a total biomass density of more than six times that of rhinos outside the park and more than twice that of rhinos within the park. Domestic stock in the middle of the Chitawan Valley, away from forest areas, had a biomass density of only two thirds of that at the edge of the park (Seidensticker, 1976). From these data, domestic stock would be expected to be the main competitors with the rhinos for food.

During the first year of the study, stock-grazing was relatively common in the Sauraha area. Cattle and buffalo grazed grass short, and rhinos sometimes grazed with them on largely the same species. The subsequent exclusion of stock from the park has resulted in a spectacular change in the vegetation in some areas. Previous areas of short grassland have begun to be transformed into tall grassland and are occupied by rhinos in the daytime where previously there was insufficient cover. One 600m transect (Section 4.2.3) walked in June 1973 and June 1975 on the river-bed at Sauraha showed an increase of more than 80% in *Saccharum spontaneum*, although the area had not been altered topographically by floods. Similar effects were noticed in other areas from which domestic stock had been excluded, although detailed measurements were not made. Stock-grazing is discussed in Section 7.2.1.1.

4.4 Resting and wallowing

4.4.1 Resting

Spells of feeding were interrupted by periods of a few minutes to several hours spent resting. Rhinos normally lay down to rest: at other times they rested standing with the head low, almost touching the ground. One form of resting - wallowing - is described below (Section 4.4.2). Resting on dry land took place more frequently during the winter months than during the summer.

Resting rhinos frequently revealed their presence to me by deep sighs or intestinal rumbles. They seemed to spend most of the resting period asleep: the eyes were usually closed and ear movements were less frequent than when alert. Resting rhinos could be approached closely from downwind but a sudden noise or an upwind approach startled them into wakefulness. Resting rhinos shifted position at intervals and often stood up for several minutes before lying down again.

There were no specific resting places; rhinos simply lay down where they happened to be, although they avoided lying in full sunlight during the middle of the day. I noticed no relationship between resting orientation and wind direction as has been reported for black rhinos which nearly always lay facing downwind (Hitchins in Owen-Smith, 1973).

4.4.2 Wallowing

Rhinos frequently wallowed in ox-bow lakes, rivers and temporary pools (Plate 25). Wallowing was observed most frequently during the monsoon and least frequently during the winter (shown in Fig. 4.9). Furthermore, most rhinos encountered during the months May to October had a fresh mud cover or the dry remnants of an old one, whereas rhinos encountered during the cooler months hardly ever had such a cover.

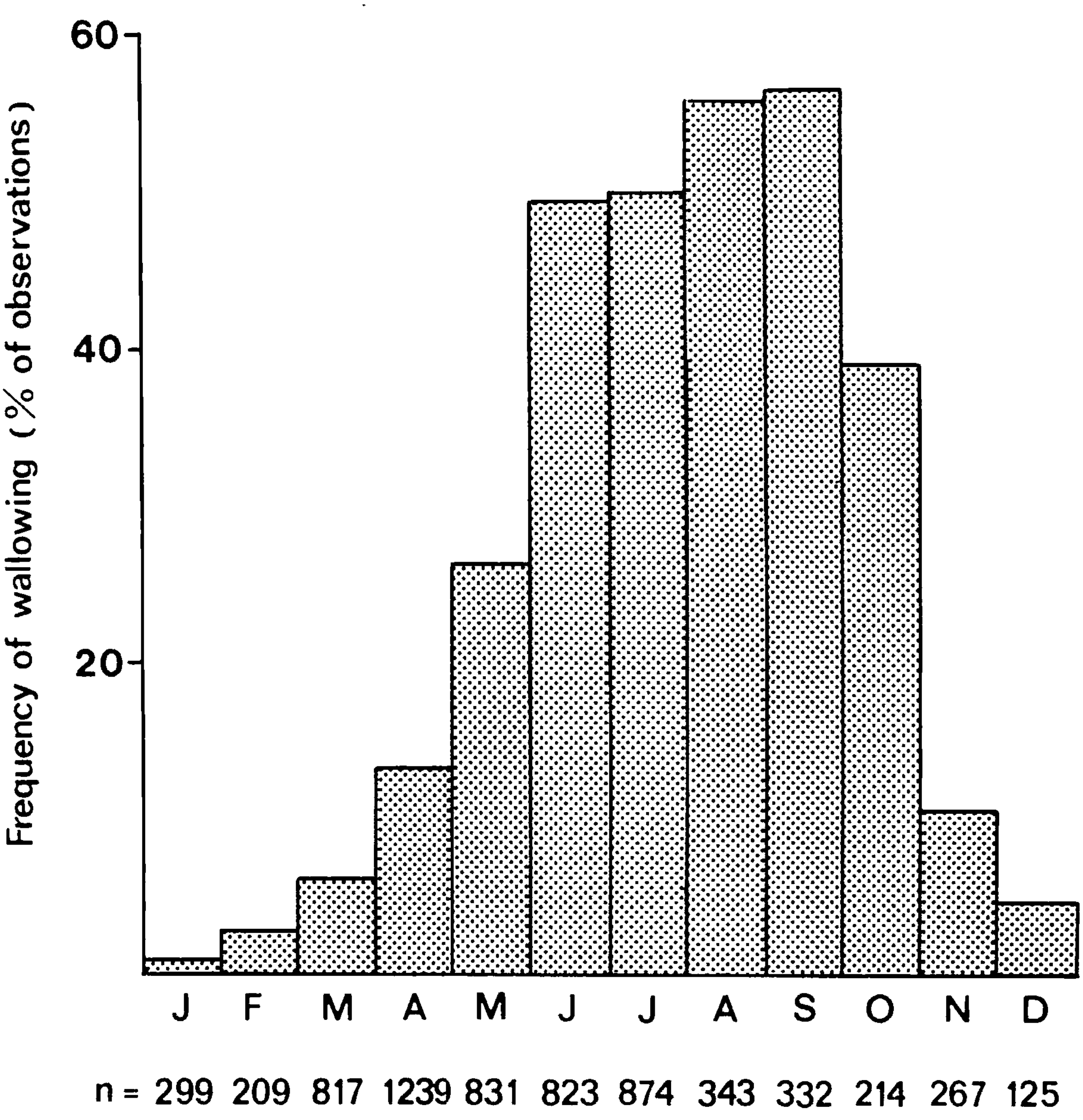


Fig. 4.9. Frequency of wallowing as the initial activity in each calendar month.

While wallowing, rhinos lay with most of the body submerged and let the head drop into the water from time to time. They shifted position fairly regularly and stood up occasionally for a few moments before lying down in a slightly different place or on the other flank. Often at the start or at the end of a session of wallowing, a rhino rolled over onto its back with legs in the air, and, in so doing, coated one flank with mud. Rhinos never rolled completely over: they always stood up and rolled over in the opposite direction to coat the other flank with mud. Vigorous rubbing of the head and horn in the mud, and rubbing of the rump while sitting upright like a dog,were observed frequently.

Rhinos wallowed for periods of between two minutes and seven hours, and they frequently spent up to 20 minutes rubbing various parts of the body against suitably shaped trees or branches after wallowing. Special attention was paid to the head, neck and flanks and the horn was also rubbed. Such periods of rubbing also occurred independently of wallowing, but this was less common. The vegetation along trails leading to and from wallows was typically smeared with mud from the rhinos' skins. At well-used wallows, the smell of rhino urine in the water and on the mud was very strong (discussed in Section 5.7 in relation to scent-marking).

Fig. 4.10 shows the proportion of rhino sightings at different times of the day when the rhinos initial activity was wallowing. Although these data are biased to some extent by my observation methods (explained in Section 4.5), they do demonstrate that rhinos wallowed most in the early morning and least during the night. I noticed that the frequency of wallowing was lower on cool, overcast days during the monsoon and immediately after a long period of rain, but rain itself did not result in an immediate reduction in wallowing.

Heat regulation is probably the main function of wallowing: it is an important requirement for a large dark coloured mammal. However, escape from blood-sucking tabanid flies (*Tabanus* spp.), especially in the tall grassland, may also be important. Thirdly, as wallows are visited by many different rhinos, they are a focal point in the environment and may be important in social communication (discussed in Section 5.7).

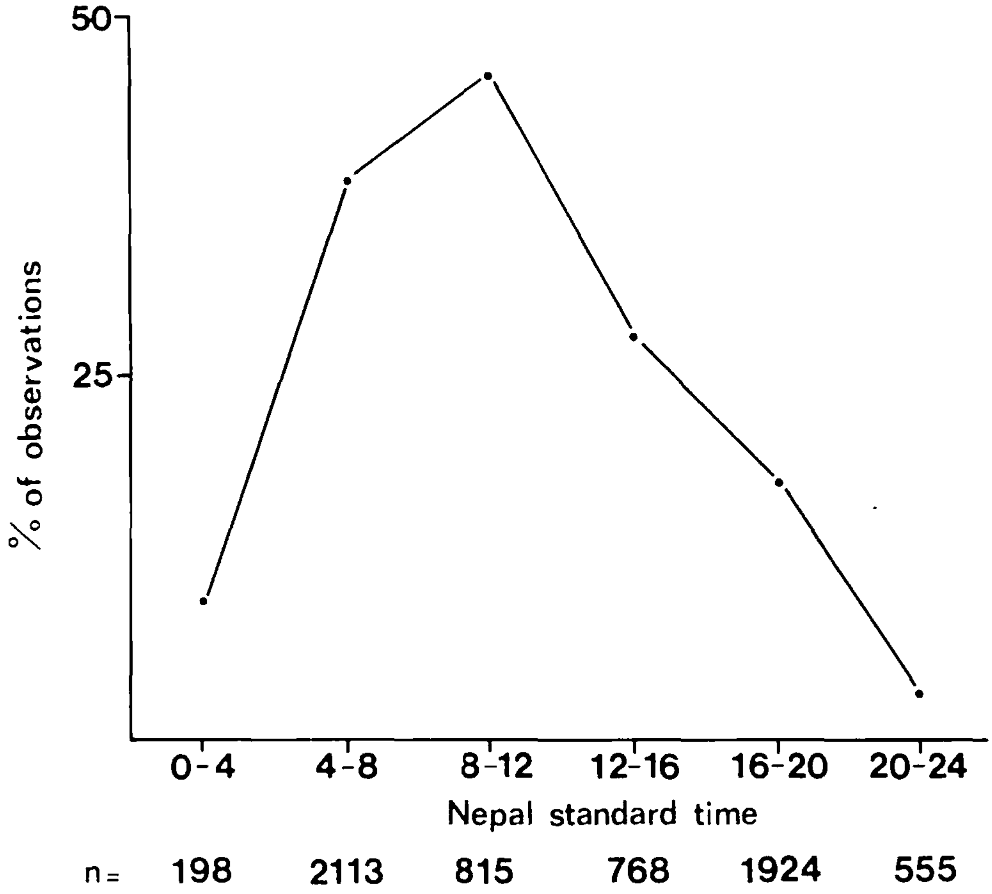
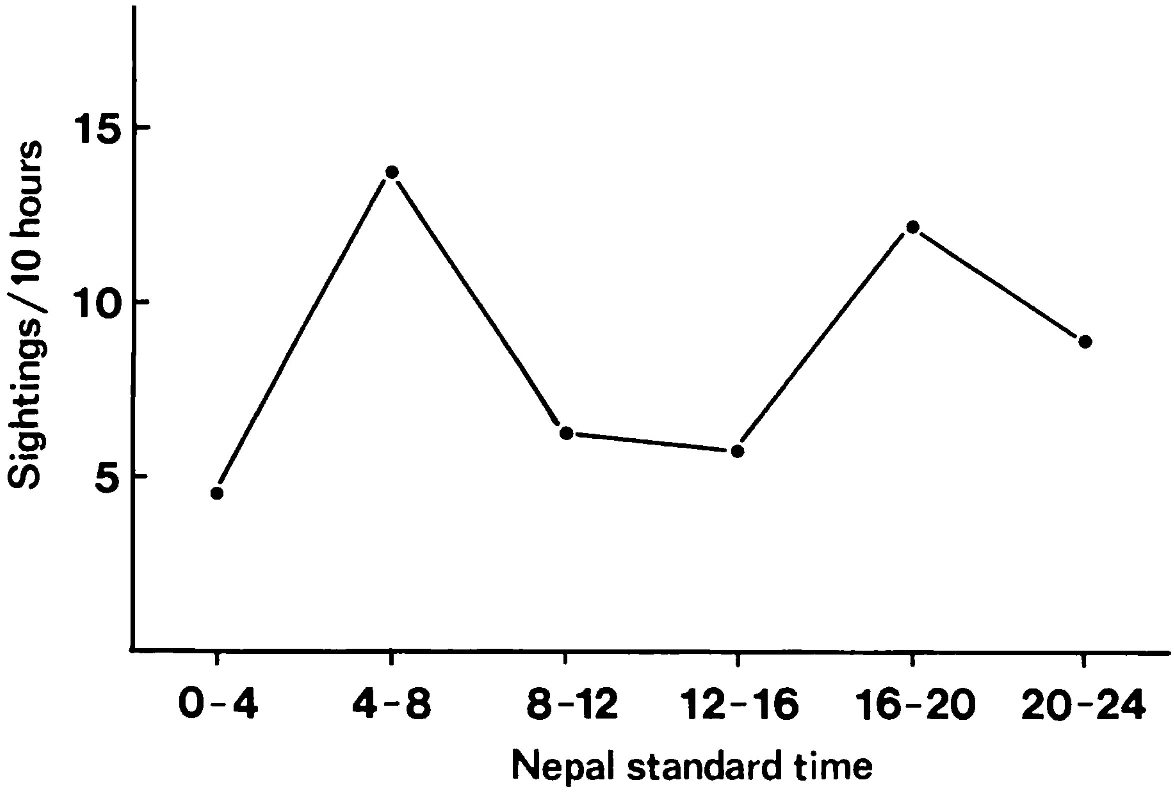


Fig. 4.10. Frequency of wallowing as the initial activity according to the time of day.

4.5 Twenty-four hour activity pattern

Fig. 4.11 shows the rates of rhino sightings (numbers per 10 hours searching time) in each four hour period of the day and night. It demonstrates, as explained briefly in Section 2.3.1, that rhinos were easier to see during the early morning and late afternoon. I consider below whether this is a result of differences in activity of rhinos over the day and night.

I examined the data collected on activity in three different ways. Firstly, in order to make use of as much information as possible, I looked at the times spent in various activities at different times of the 24 hour cycle and lumped all the observations for each month. I found considerable variation between months and, because my observation time was very unequally distributed over the months (Section 2.3.1), I calculated the means of the



Numbers of observations (n) as for Fig. 4.10.

Fig. 4.11. The rates of sightings of rhinos over the 24 hour cycle.

monthly percentages of time spent in various activities in each of six four-hour periods of the day and night. Fig. 4.12 shows the results of this analysis for three general categories of activity: feeding, resting and other activities. It can be seen that, according to this analysis, rhinos spent most time feeding during the night and most time resting between 08.00 and 12.00h. The overall time-budget is also shown (Section 4.5.2), calculated by taking the means of the percentages for each activity in each four-hour period so that no part of the day is over or under represented.

However, it was easier to see rhinos in certain habitat types than in others, and the visibility varied from month to month. It is likely that activity is related to habitat type; some habitats being used relatively more for feeding and others relatively more for resting. Thus

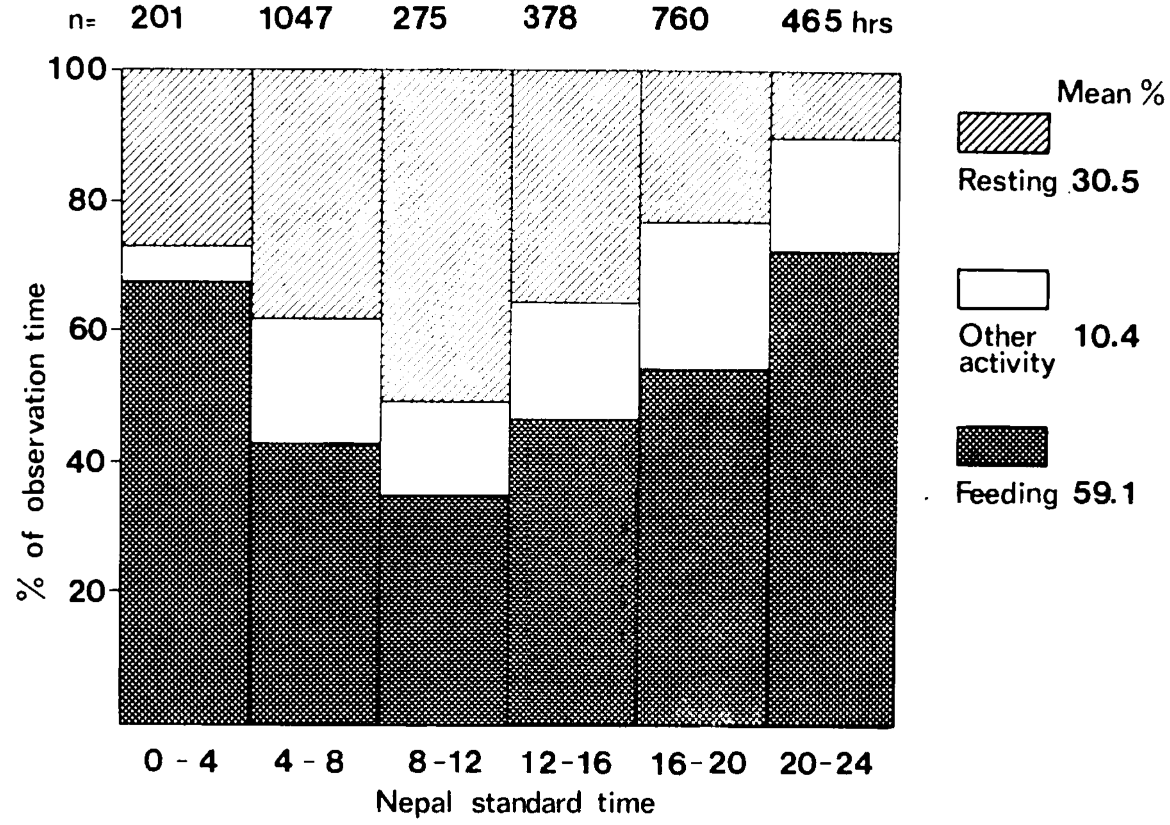
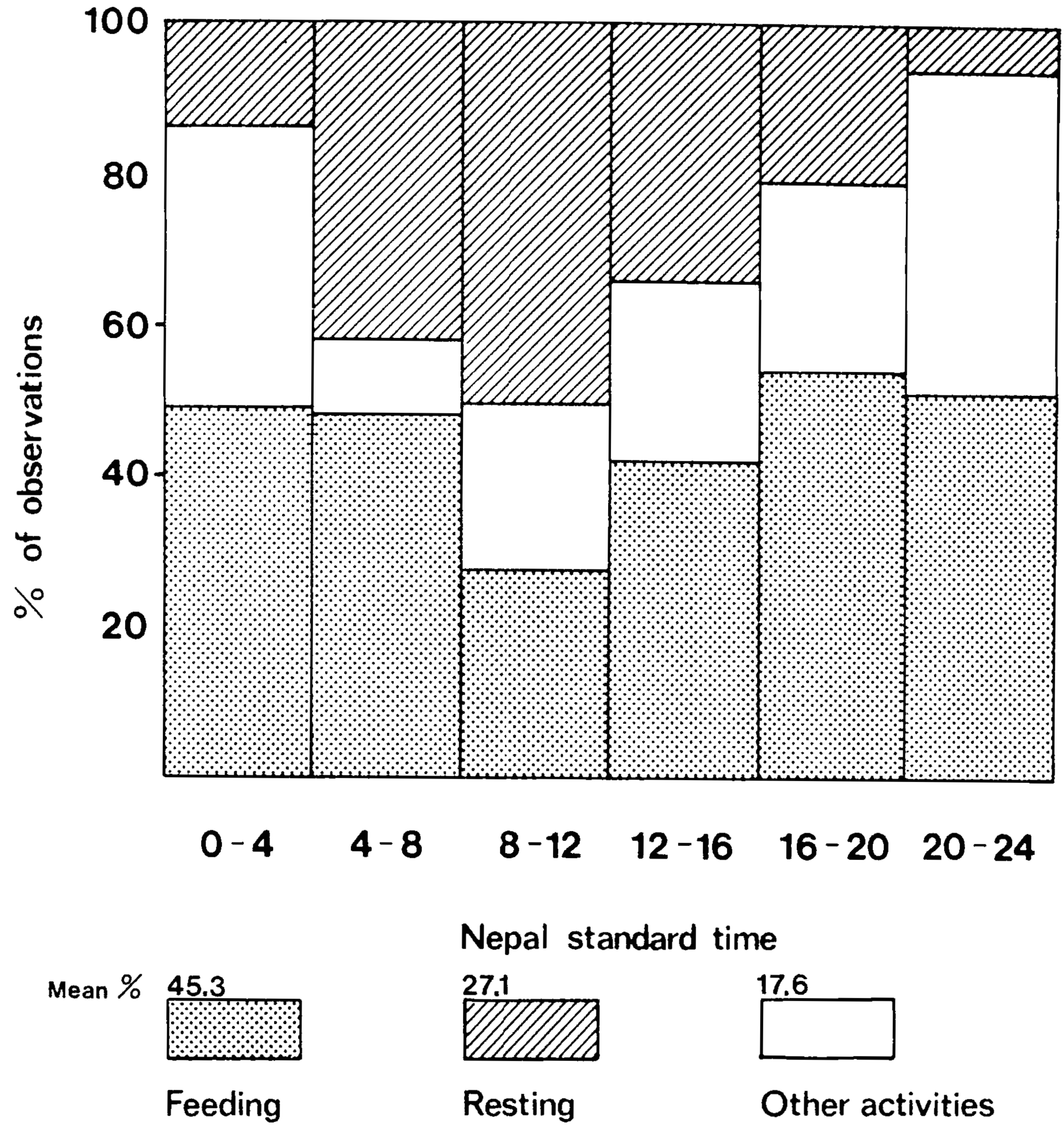


Fig. 4.12. The 24 hour activity pattern as shown by the proportions of total observation time made up by three categories of activity.

the results shown in Fig. 4.12 are biased: better visibility and hence more and longer observations in the open habitats means that data from these habitats are disproportionately represented in the total. I reduced this bias by considering, in a second analysis, only the initial activity of the rhino for each observation.

Fig. 4.13 shows the results of this analysis as the means of the monthly percentages of initial observations of three categories of activity in each four hour period, and the overall time budget calculated as for Fig. 4.12. There is an overall lower proportion of feeding activity indicated in Fig. 4.13 when compared with Fig. 4.12. This is because of the generally higher proportion of 'other activities', including standing, moving, interacting with other rhinos and, in particular, the state of alertness which was often recorded as the initial activity but did not continue for long.



Numbers of observations (n) as for Fig. 4.10.

Fig. 4.13. The 24 hour activity pattern as shown by all observations classified according to initial activity.

There is also a relatively higher proportion of feeding activity shown in the early morning and late afternoon periods in Fig. 4.13. This difference between the two figures is explained by the fact that a high proportion of the observations made during those hours were near wallows which the rhinos approached slowly, feeding on the way, and then spent long periods wallowing in.

It is clear that the uneven distribution of observation time over different habitats, months and times of the day make it difficult to describe accurately the rhinos' activity patterns. In the extreme case, it is obvious that if I sat all day at a rhino wallow it would be very surprising if my observations did not show a high frequency of wallowing compared with other activities. In more general terms, the visibility of rhinos varied according to the activity they were engaged in,and my chance of seeing various activities depended on where I was watching from. Therefore, my third line of analysis was to consider only observations of rhinos which I had followed for relatively long periods.

I considered 14 observations that lasted more than eight consecutive hours, the longest being of 33 hours duration. I calculated the proportion of time spent by rhinos on each category of activity for each four hour period, lumping the data for all 14 observations. Fig. 4.14 shows the results of this analysis. There are obvious differences between these results and those in Figs. 4.12 and 4.13. The proportion of time spent feeding is highest in the early morning and in the early part of the night and the time spent on activities other than feeding and resting appears as a very small fraction of the total time.

The first difference can be explained by the preponderance of winter observations in the data for Fig. 4.14 and of spring and monsoon observations in the data for Figs. 4.12 and 4.13. Only one rhino was followed for more than eight consecutive hours during the monsoon because visibility was so bad that all other attempts failed. Rhinos fed more in the early morning during the winter than during the spring and monsoon (shown in Section 4.5.1). The second difference is explained by the relatively smaller effect of the observer on the rhinos activity patterns in long observations than in short observations.

There are problems associated with all three analyses of the diel

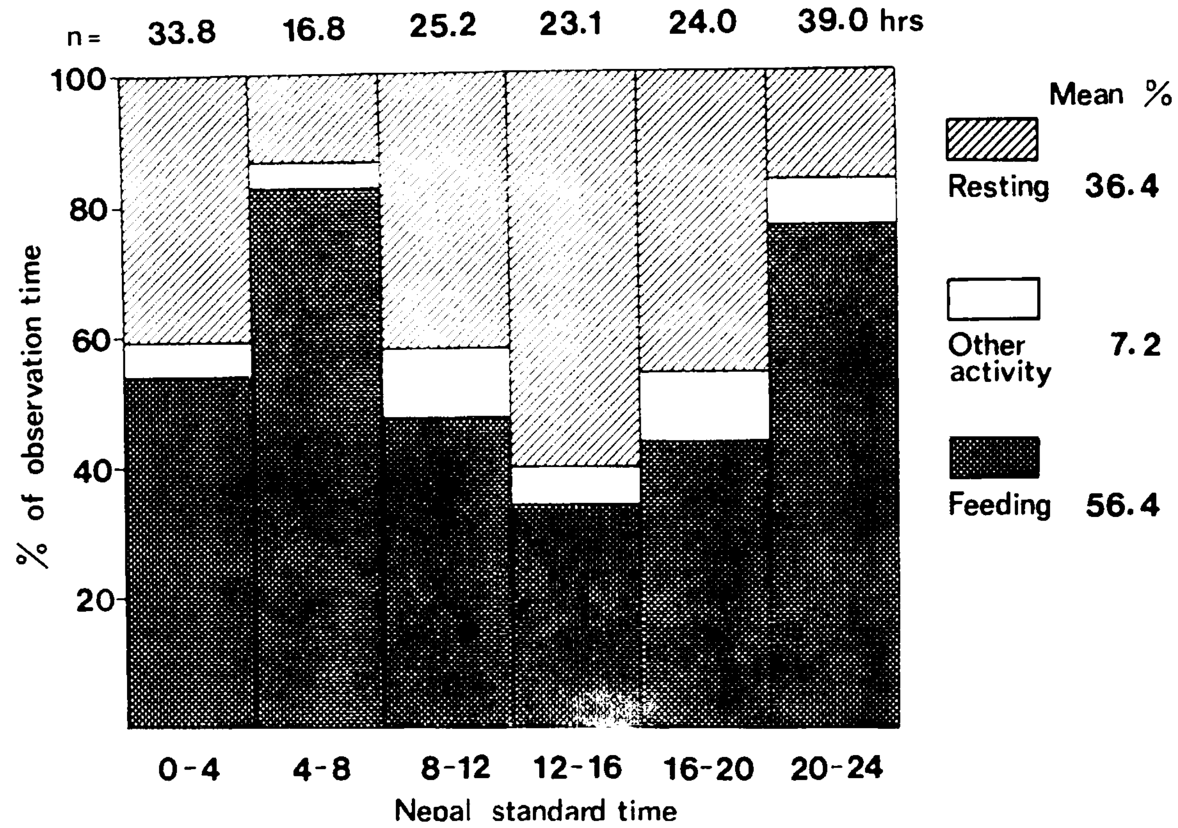


Fig. 4.14. The 24 hour activity pattern as shown by 14 observations of rhinos, each of more than eight hours duration.

activity cycle. To avoid the biases present in these data,it would be necessary to follow rhinos for whole 24 hour periods at various times of the year, possibly using radio-telemetry. However, the present data do show that, in general, rhinos fed most during the night, early morning and late afternoon, and spent the middle of the day predominantly resting. There was also an indication that rhinos rested more during the second half of the night than the first half.

4.5.1 Seasonal variation in the 24 hour cycle of activity

Although the data from individuals watched for long periods were the most unbiased (see above), they were collected almost exclusively during the winter and the spring,and mostly in the winter. It is therefore difficult to deduce seasonal variations from those data. Despite the biases, I consider that the data do reflect real seasonal differences in time-budgets; in particular the greater proportion of time spent feeding during the winter and spring.

I have plotted (in Fig. 4.15) the proportions of total observation time spent feeding and resting over the 24 hour cycle in each season. The most striking seasonal differences shown are in the small amount of time spent feeding in the early morning period during the monsoon. This can be partly explained by the fact that I watched more frequently at wallows during the monsoon and that most of the observations consisted of wallowing. However, I observed individual rhinos wallowing regularly every morning from 04.00 or 05.00h late into the morning, and during the dry season at that time the same rhinos spent more than half their time feeding. Although it is difficult to quantify the difference, rhinos tended to feed more in the early morning during the dry season than in the wet season.

4.5.2 Seasonal differences in time-budgets

Fig. 4.15 shows considerable seasonal differences in the overall time-budget. Only 36.0% of time was spent feeding during the monsoon, compared to 64.8% in the spring and 56.9% in the winter. I did not test these differences statistically because of the inherent biases explained above. However, they do indicate that rhinos were under stress with regard to food supply, during the winter and spring (further discussed in Section 6.1.1).

4.6 Movements

Having shown that there were seasonal changes in the rhinos' use of the wide variety of habitat types within the study area (Section 4.3.4), I consider here the movements of rhinos and how they were related to the

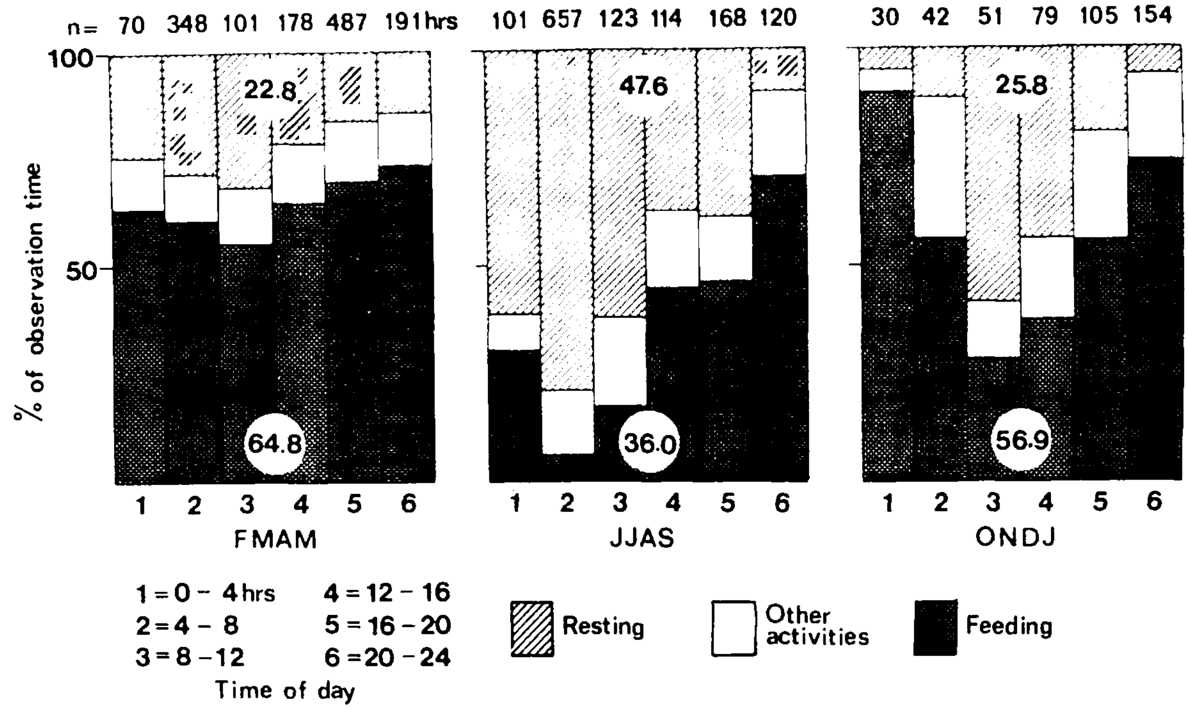


Fig. 4.15. Seasonal differences in the 24 hour activity pattern as shown by the proportions of total observation time spent by rhinos in three categories of activity.

seasons and to the distribution of habitat types. I first consider general seasonal variations in the use of different parts of the study area, and I subsequently examine the movements of individual rhinos.

The locations of all rhino sightings are plotted on a map of the study area in Fig. 4.16. They are clearly concentrated along the Rapti river which flows from east to west through the study area. Ninety-eight percent of all locations lie within a two kilometre wide strip across the study area, and almost all the remaining two percent of locations lie in the Bagmara region north of the Rapti (Block C in Fig. 4.17: see below). It is shown in Section 4.6.2 that movements of rhinos on the north-south axis of the study area were relatively unimportant when considering seasonal and individual differences in the locations of sightings. In order to analyse rhino locations and movements, I divided the study area into seven blocks and 15 sub-blocks labelled A1, A2, B1, B2 etc. from west to east (Fig. 4.17).

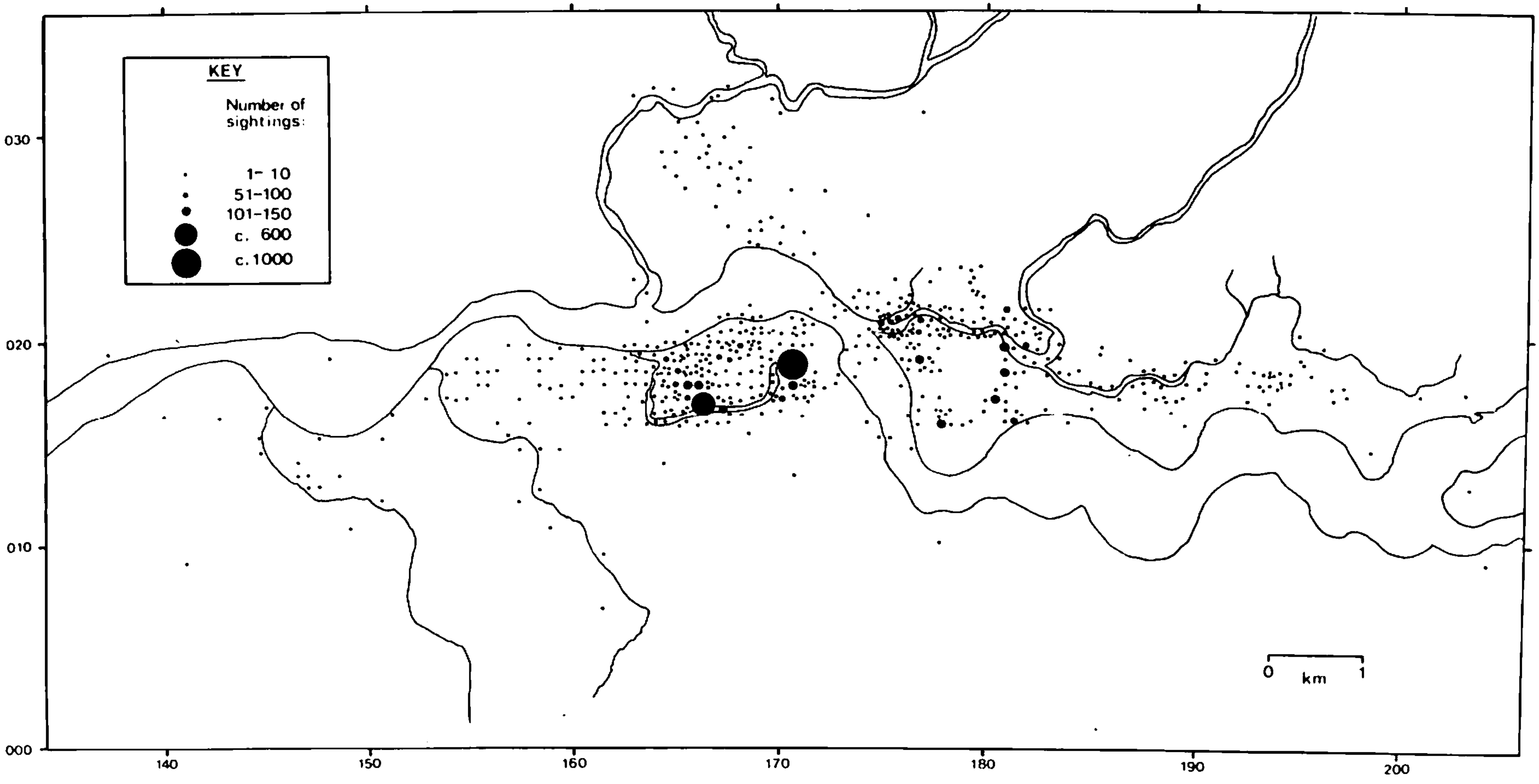


Fig. 4.16. The locations of all rhino sightings in the Sauraha study area.

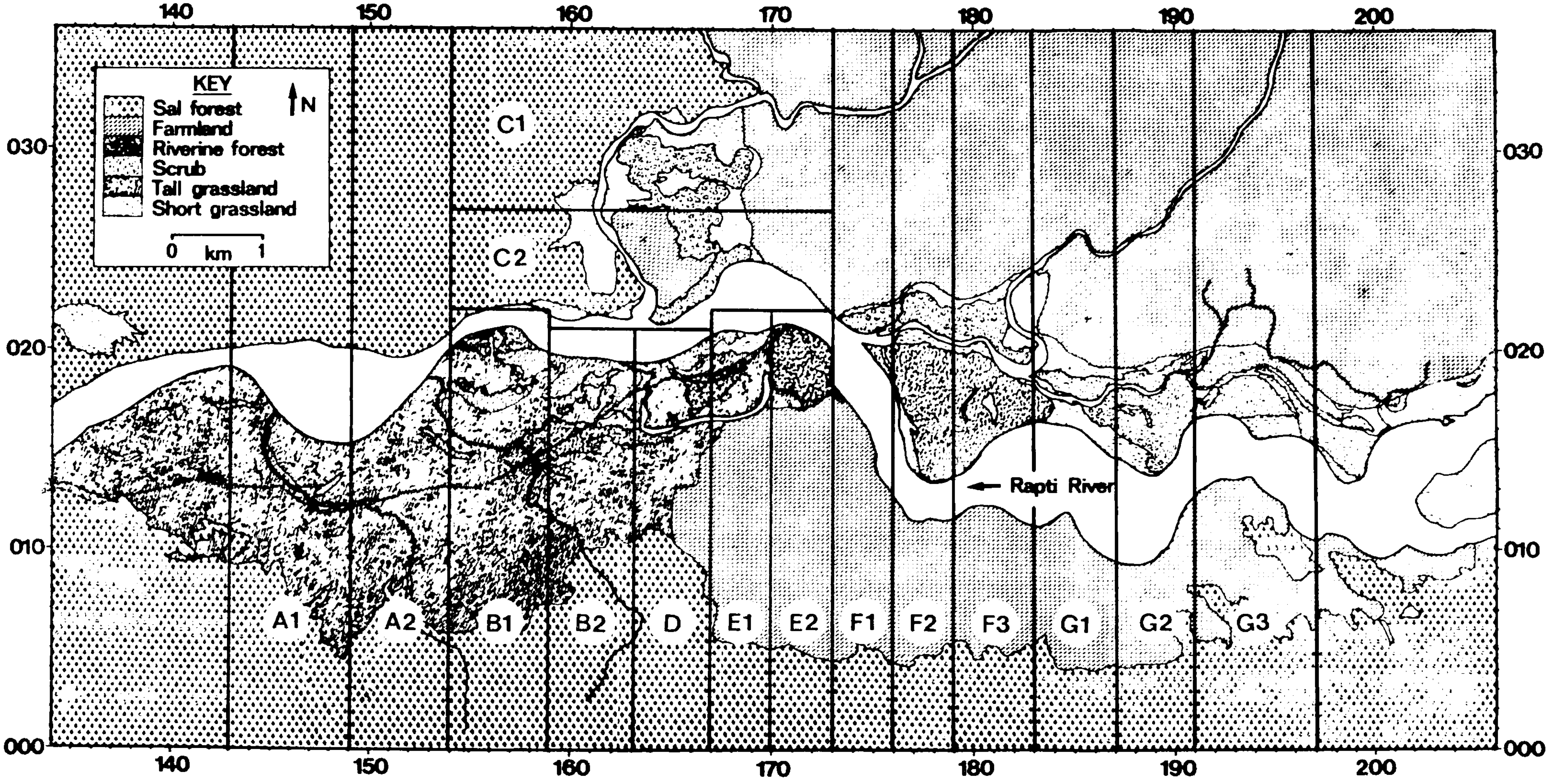


Fig. 4.17. The arrangement of the seven blocks and 15 sub-blocks into which the Sauraha study area was divided.

Most of the boundaries correspond approximately to physical features such as river-beds or woodland borders. The blocks are slightly smaller in areas with a high frequency of rhino sightings. The rationale for this arrangement will become clear. The major blocks are used for general analysis of the distribution of sightings of rhinos (Section 4.6.1): the sub-blocks are used only for the analysis of the locations of individual rhinos (Section 4.6.2).

4.6.1 Seasonal variations in the use of different parts of the study area

The frequency of rhino sightings in each of the major blocks, A to G, varied greatly over the study period. For example, the numbers of sightings per month in blocks D and F are shown in Fig. 4.18. It can be seen that there was considerable variation between blocks and months, but much of this variation resulted from the uneven distribution of searching time over the blocks.

It was easier to make prolonged observations on rhinos in certain blocks at certain times of the year and,in order to collect data for other aspects of the study, I spent longer in those blocks at those times of year. To compensate for the effects of differences in the frequency and duration of my visits to each block, I considered two measures of the rhinos' use of each block:

(a) the number of rhinos sighted per hour in each block

and (b) the number of rhinos sighted per visit to each block.

I naturally had to change my methods of searching according to the blocks and the season. Using some methods, such as visiting well-used wallows, I was able to see up to 15 or more rhinos within a few minutes. On the other hand, by watching from machans or searching an area of thick cover on elephant back, it often took several hours to see the same number

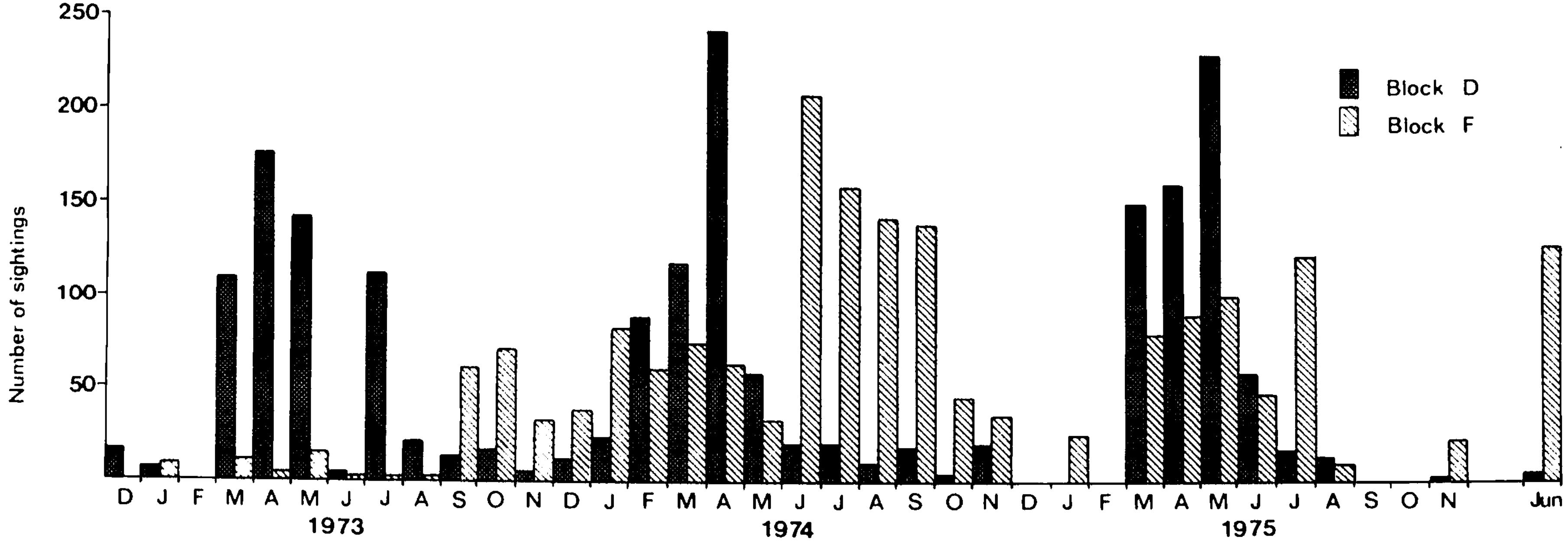


Fig. 4.18. The numbers of rhino sightings per month in blocks D and F.

of rhinos. This difference between methods caused considerable variation in the numbers of rhinos sighted per hour. For this reason, I considered whether the numbers of rhinos sighted per visit to each block might be a more appropriate measure than the numbers sighted per hour in each block. The numbers of rhinos sighted, the numbers of hours searched and the numbers of visits made to each block in each month of the study period are shown in Appendix H. In each block, the numbers of rhinos sighted are significantly correlated with both the numbers of hours of searching time and the numbers of visits to the block ($p < 0.001$) (Table 4.7). The correlation coefficient in each block, between the number of rhinos sighted and the number of hours of searching time is slightly greater than or equal to that between the number of rhinos sighted and the number of visits to the block. Therefore, when practicable, I have used sightings per hour in preference to sightings per visit, as a measure of the rhinos' use of each block. For some purposes however, and for reasons given in Section 4.6.3, I have used sightings per visit.

Table 4.7. The relationship between the numbers of rhinos sighted per month in each block and (a) the numbers of hours of searching time and (b) the numbers of visits to the block.

Spearman Rank correlation coefficients		
Block	(a) Numbers of rhinos with numbers of hours	(b) Numbers of rhinos with numbers of visits
A B	0.60	0.57
C	0.84	0.82
D	0.88	0.86
E	0.78	0.71
F	0.84	0.84
G	0.88	0.70

The data for these correlation coefficients are shown in Appendix G

Despite the significant rank correlation of the numbers of sightings of rhinos with the numbers of hours of searching time, there are significant differences between the monthly rates of sightings in each block. The rates of sightings of rhinos per hour in each of blocks D, E, F and G are plotted in Fig. 4.19 for each month of the study period. The rates of sightings in blocks A, B and C are not shown because there were very few sightings in those blocks. However, the distribution of sightings was significantly different from the distribution of searching time in each of the seven blocks (Kolmogorov-Smirnov one sample test $p < 0.01$, data in Appendix H). This result suggests that rhinos may have used different blocks with varying frequency over the study period. However, there are alternative explanations which could account for some of the variations.

Firstly, movements of rhinos into and out of the whole study area could have caused variation in the frequency of sightings over the study period. However, it is shown in Section 4.6.3 that movements of identified individuals within the study area accounted for much of the variation in the frequency of sightings. Secondly, differences in the visibility of rhinos resulting from vegetational changes or behavioural changes affected the frequency of rhino sightings. The main seasonal changes in visibility are summarized in Section 4.3.4. Visibility in blocks A, B, D, E and F was best in the spring, but the filling of seasonal wallows in all blocks during the monsoon provided good sites for rhino viewing. Rhinos wallowed less frequently in the winter months and, as the grass was also tall in the winter, the rates of sightings were the lowest. However, in short grassland, river-beds and scrub - particularly in blocks E, F and G - visibility was reduced during the monsoon and improved during the winter (Section 4.3.4).

The changes in rates of sightings were not due to inflexibility of my observation methods. By changing my methods of finding rhinos according

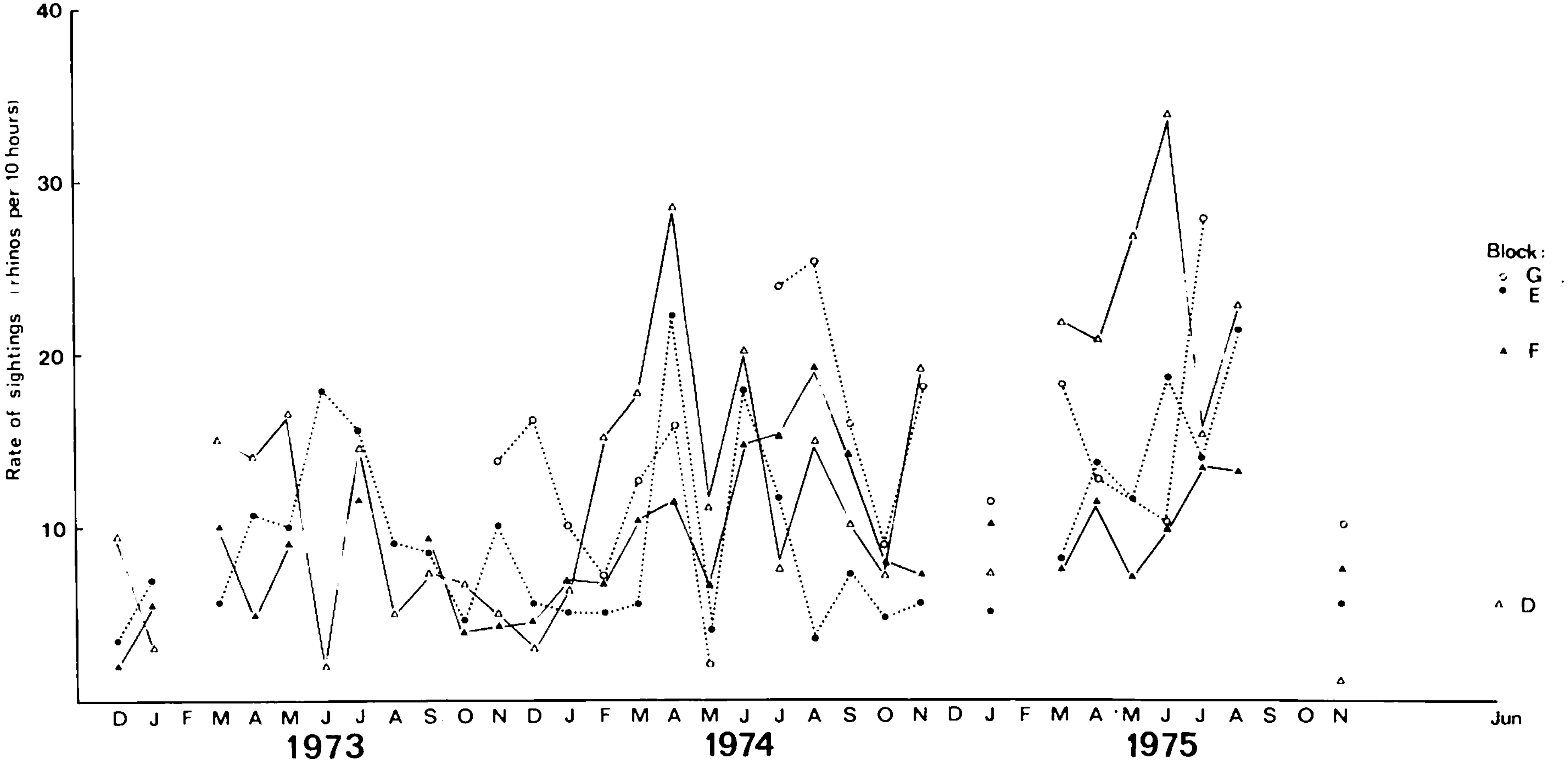


Fig. 4.19. The monthly rates of rhino sightings in blocks D, E, F and G.

to the season and the block I was in, I attempted to maximise the chances of finding rhinos. When the tall grassland was burned,I sat up in tall trees to watch rhinos there: later, when the grass grew higher, I watched from machans at wallows in the same block or watched at night from trees near well used paths that led to open areas such as river-beds or cultivated land. The variety of observation methods used (Section 2.3) normally enabled me to see rhinos if there were indications from fresh tracks or signs that they were present in a particular area. The mean of the monthly rates of rhino sightings in blocks D to G never fell below 0.45 rhinos per hour (shown in Fig. 4.20). Although there were differences between blocks in the timing and degree of changes in visibility during the study period, I took the mean rate of rhino sightings in each month as a general index of visibility. I then corrected the monthly rates in each block for changes in visibility, by dividing each by the mean rate for that particular month.

The corrected rates of sightings showed peaks in block D in February to May, and in November, and in block G in July to August,and November to January. The peaks in blocks E and F were less pronounced, but similar to those in block G. Generally, the peaks in block D did not coincide with those in blocks E, F and G. For example, the corrected rates of sightings in blocks D and F are plotted in Fig. 4.21. There are significant negative correlations between the corrected rates of sightings in block D and those in blocks E, F and G (Table 4.8). Little statistical significance can be attached to these coefficients because a negative correlation is built in to some extent by the correction for visibility. Nevertheless, the results do indicate that there were movements between blocks. Although the peaks were not consistent from year to year, some degree of seasonality was indicated.

Fig. 4.22 shows the corrected rates of sightings expressed as the

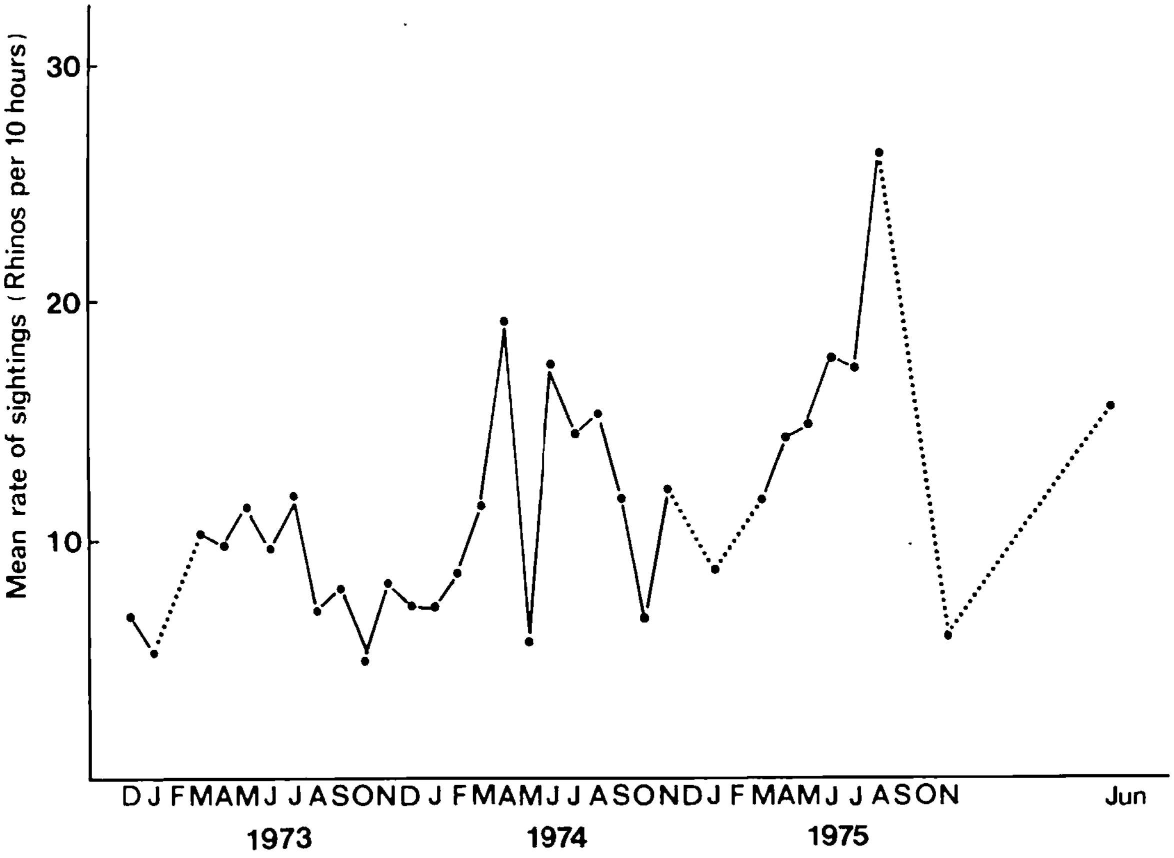


Fig. 4.20. The means of the monthly rates of rhino sightings in blocks D, E, F and G.

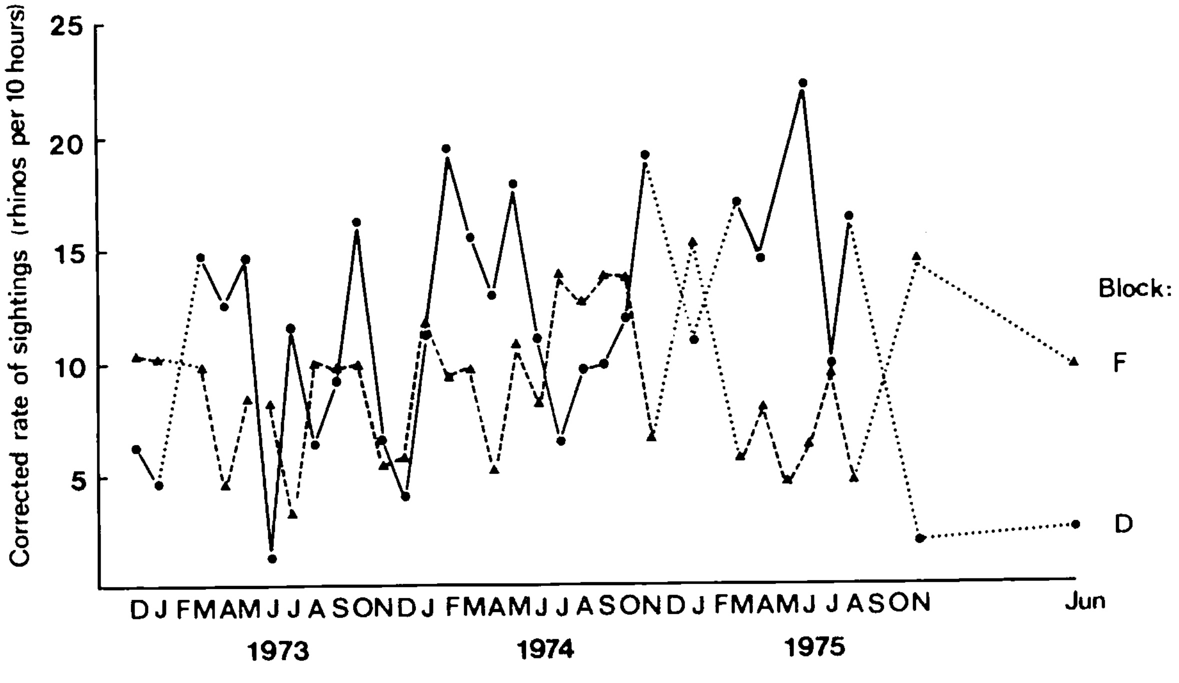


Fig. 4.21. Monthly rates of rhino sightings in blocks D and F corrected for changes in visibility.

Table 4.8. Spearman rank correlation coefficients between blocks, of the monthly rates of rhino sightings corrected for changes in visibility.

Spearman rank correlation coefficients			
BLOCK	D	E	F
BLOCK E	-0.43 (p < 0.01)		
BLOCK F	-0.42 (p < 0.01)	-0.10 (p > 0.10)	
BLOCK G	-0.67 (p < 0.001)	+0.08 (p > 0.10)	+0.28 (p > 0.05)

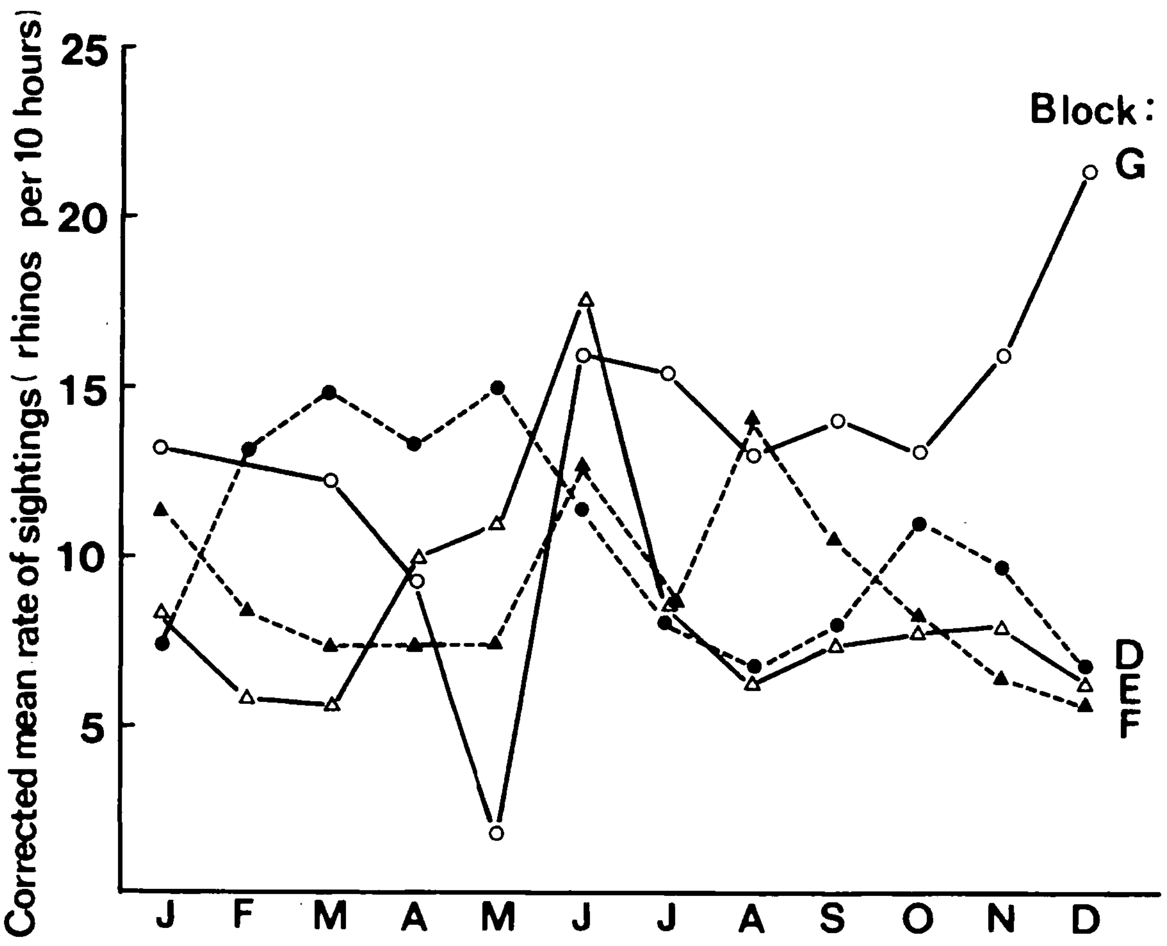


Fig. 4.22. The means for each calendar month of the rates of rhino sightings in blocks D, E, F and G corrected for changes in visibility.

means for each calendar month for the whole study period. There were peaks in block D during February to May and October to November. In blocks E and F there were peaks in January and in June, and in block F there was a further peak in August. In block G, where only a small percentage of the total sightings were made, there was considerable variation in the rate of sightings: it was lowest in May and highest in June, July and December.

To investigate the actual movements which took place and to distinguish those made within the study area from those across is boundaries, sightings of individual rhinos must be considered (Section 4.6.2).

4.6.2 Movements of individuals

It was rarely possible to follow individuals for long periods to plot their movements. Most information on movements of individuals resulted from chance resightings of identified individuals. There was a greater chance of resighting rhinos in the blocks in which I spent most time. Figs. 4.23 and 4.24 show the locations of all sightings of individuals M005 and M045, two of the most frequently observed individuals. Although there are some obvious differences in the distributions of the sightings of the two individuals, all the sightings are concentrated in the centre of the study area. In order to describe the extent and frequency of movements of individuals it is necessary to take into account the very uneven distribution of all rhino sightings over the study area. This unevenness is demonstrated in a map (Fig. 4.16), and in Fig. 4.25 which shows the relative frequencies of sightings in each of the 15 sub-blocks of the study area: an explanation for the clumping is given in Section 2.3.1.

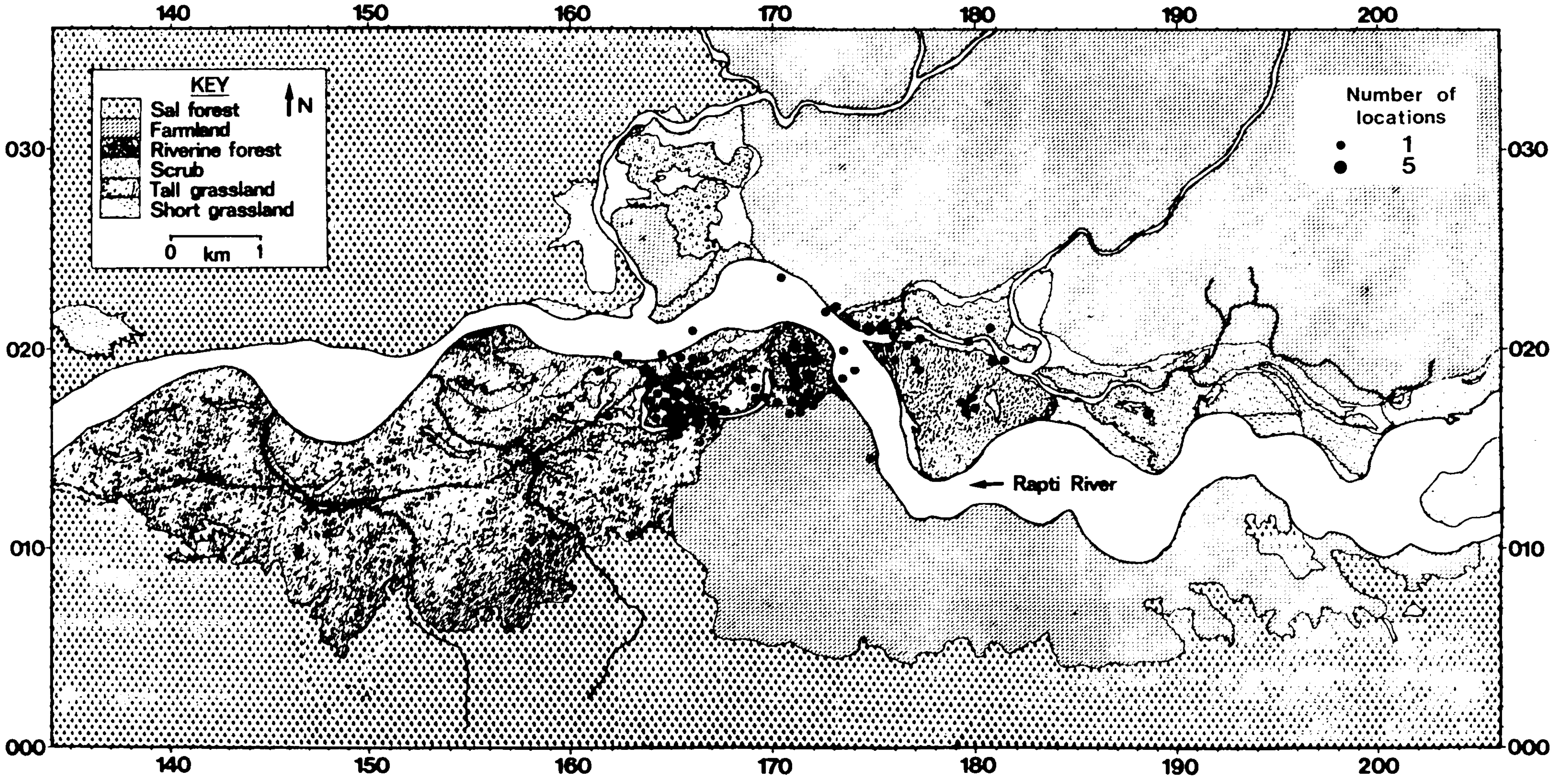


Fig. 4.23. The locations of all sightings of M005.

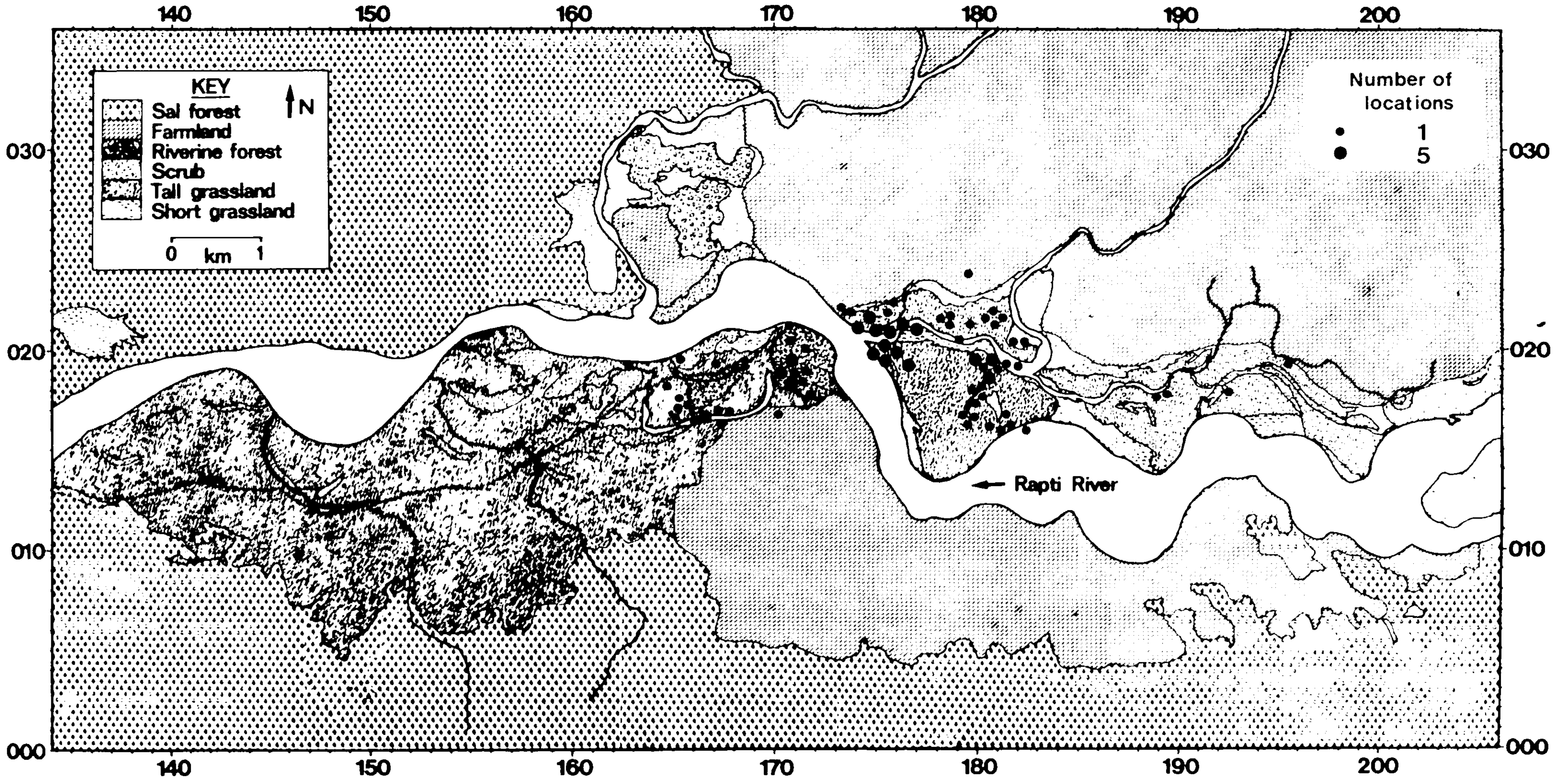


Fig. 4.24. The locations of all sightings of M045.

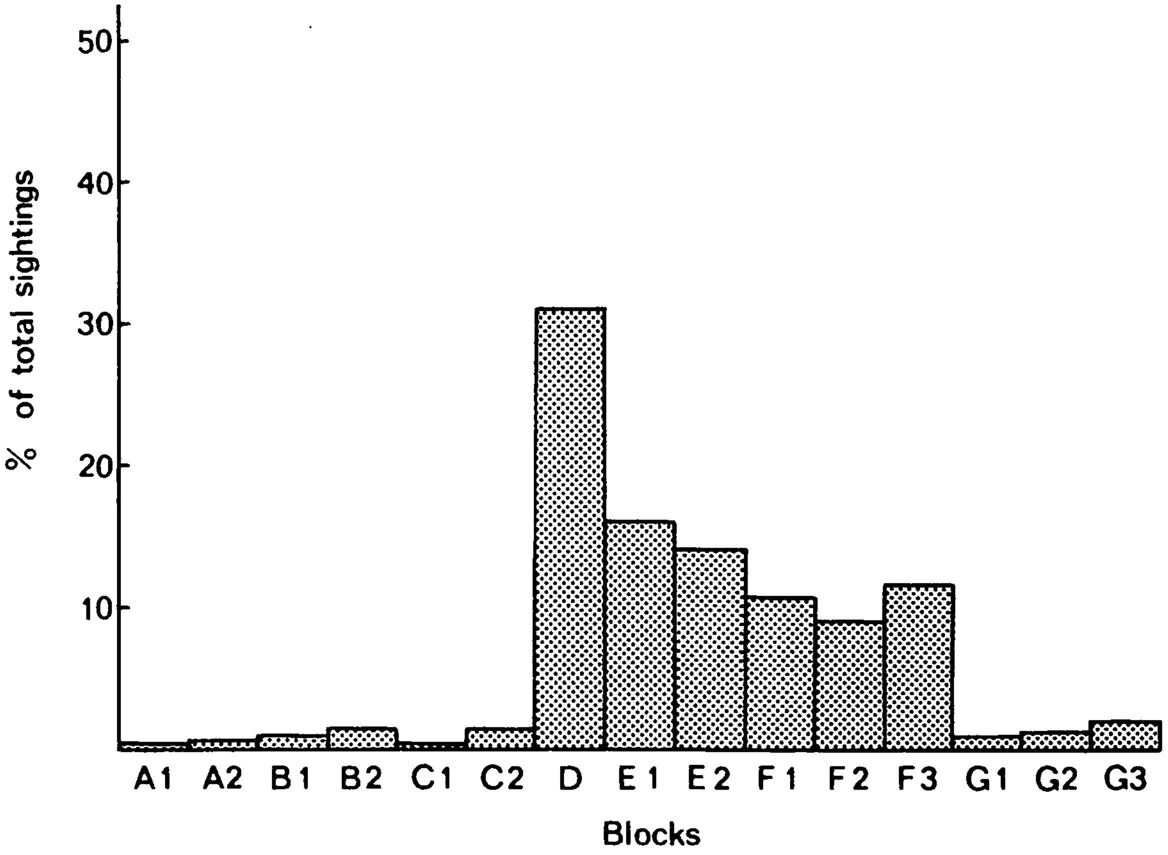


Fig. 4.25. The distribution of rhino sightings (n = 6,038) over the 15 sub-blocks of the Sauraha study area.

4.6.3 Ranges

As the study progressed I noticed that sightings of certain individuals were restricted to relatively small parts of the study area. In order to show that this impression was not due merely to the extremely clumped distribution of sightings over the study area, I compared the distributions of the sightings of 37 individuals with the distribution of all sightings.

These 37 individuals include all those whose locations were recorded on at least 20 different days: except that calves were only included if they were seen on at least 20 different days after leaving their mother. The difference between the distribution of each individual's sightings and the distribution of all sightings was tested by the Kolmogorov-Smirnov one-sample test. As the maximum contribution of any one individual to the total sightings is only three percent, the two distributions in each case were considered to be sufficiently independent not to invalidate the test. Also, any dependence would be conservative, tending to reduce the chance of detecting a significant difference.

Thirty-six of the 37 individuals were found to have distributions of sightings significantly different from the distribution of total sightings shown in Fig. 4.25 (Kolmogorov-Smirnov one-sample test $p < 0.01$, data in Appendix J). However, the statistical test used does not distinguish different degrees of clumping in the sightings of different individuals. For this purpose, I have plotted (in Fig. 4.26) the medians and 90% ranges on the east-west axis; the 90% range includes 90% of all locations, with equal numbers on each side of the median.

I have used the 90% range rather than the total range because it reduces any differences in range size between individuals,caused entirely by different numbers of sightings. For comparison, the median and 90% range of total sightings of rhinos is also shown in Fig. 4.26; it can be seen that 33 of the 36 individuals have more clumped distributions than that of all sightings,and three have less clumped distributions. Thus, 89% of 37 rhinos restricted their movements to smaller ranges than would have been expected by chance, whereas only 8% ranged more widely over the study area than would have been expected from the distribution of all sightings.

Only ranges on the east-west axis were considered in the above analysis (with the exception of the rarely used sub-blocks C1 and C2). To investigate the ranges of individual rhinos on the north-south axis, I looked at the distributions of their sightings over 36 0.23 km wide strips[2] aligned east-west across the study area. Because the rhino

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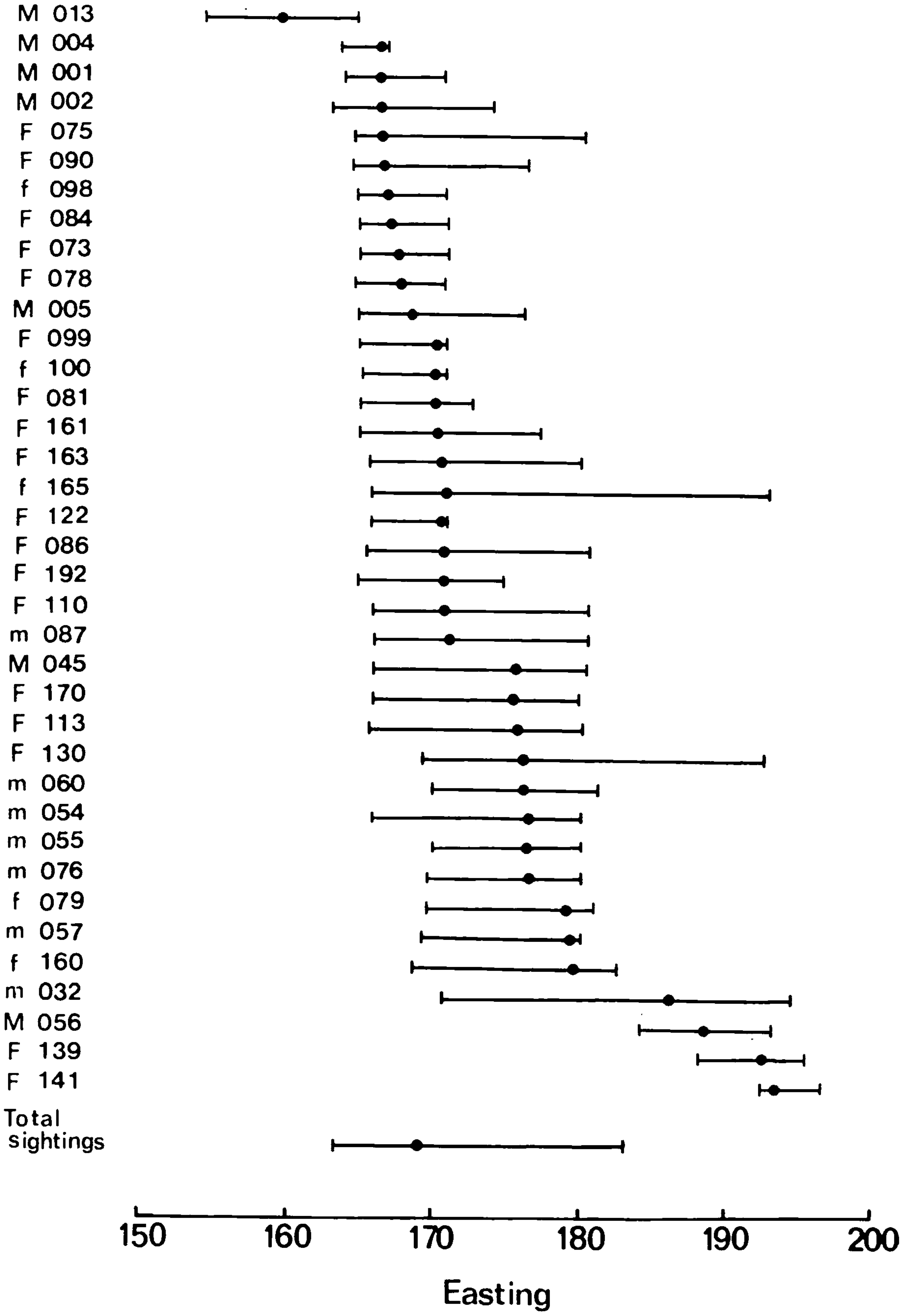
[2] The grid-width shown on the maps of the Sauraha study area (*e.g.* Fig. 4.17) is 0.23 km. I planned to make it 0.25 km but subsequent more accurate measurements led me to change the scale.



Easting refers to maps (*e.g.* Fig. 4.17) of the Sauraha study area.

Fig. 4.26. The medians and 90% ranges on the E-W axis of 37 individuals and of total sightings.

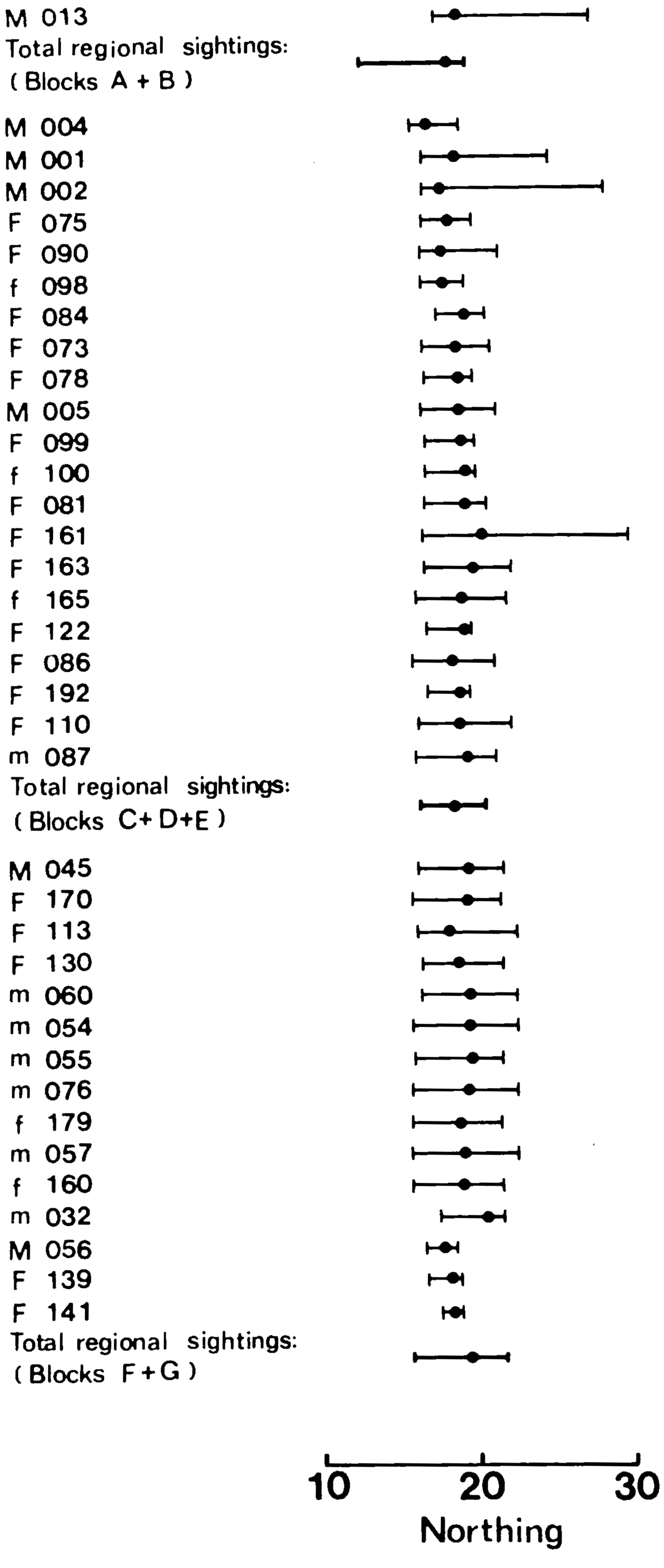
habitat does not lie true east-west, I considered three regions comprising blocks A and B, blocks C, D and E, and blocks F and G, within each of which the rhino habitat does not deviate appreciably from east-west alignment. For each of the same 37 rhinos, I compared the distribution of its sightings on the north-south axis with the distribution of the total regional sightings on the north-south axis for the region in which that individual was seen most frequently. Only nine of the 37 rhinos had distributions of sightings significantly different from the distributions of total regional sightings in their regions (Kolmogorov-Smirnov one-sample test $p < 0.01$).

Fig. 4.27 shows the medians and 90% ranges, on the north-south axis, of all 37 individuals and those of the total regional sightings for the three regions. Of the nine individuals with distributions of sightings significantly different from the regional total, six had smaller 90% ranges and three had larger 90% ranges than the corresponding total regional sightings. There were no significant differences for the other 28 individuals, and their ranges differed only with respect to the east-west axis.

In conclusion, it is clear that these rhinos, when they were in the study area, spent most of their time in a small part of it, which I have termed their range (defined in Section 4.6.3.1). I have avoided using the term home-range because of the many interpretations possible. The study area can be envisaged as divided into a series of overlapping ranges from east to west with relatively few divisions on the north-south axis.

4.6.3.1 Sizes of ranges

I have used the 90% ranges on the east-west and north-south axes to define the limits of each individual's 'range'. I considered using ellipses as the basis of range area calculation, but used rectangles



Northing refers to maps (*e.g.* Fig. 4.17) of the Sauraha study area.

Fig. 4.27. The medians and 90% ranges on the N-S axis of 37 individuals and of total regional sightings for three regions.

instead for two reasons. Firstly, the pattern of rhino movements seemed to be mainly along the east-west axis and then north and south from points along the river, and there was no indication that the north-south movements were shorter near the eastern and western limits of an individual's range. Secondly, the area of an ellipse is a constant proportion ($\pi/4$) of that of a rectangle with the same axes. For comparative purposes, it makes little difference which is used. Thus, I have regarded rhinos' ranges as rectangles and have calculated their areas according to the limits defined above. Range areas varied between 0.44 and 8.86 sq. kms, and are shown for each individual in Fig. 4.28. It is important to remember how the range areas were calculated, when making comparisons between individuals' range sizes and drawing conclusions from them. The defined ranges are only an approximation to the actual areas used by the rhino. Two factors in particular make the defined ranges different from the actual areas used by the rhinos.

Firstly, most sightings of rhinos were in open grassland and wallows which lay in a narrow band along the main river-valley (Figs. 4.16 and 4.17). This was partly because rhinos were easy to see when they were in this band: therefore the distribution of sightings on the north-south axis is probably less representative of the ranges of rhinos on that axis than the distribution of sightings on the east-west axis. The rhinos' use of agricultural land further confounded the calculation of range sizes because it was only possible to discover the use of such areas at night, when observations (particularly individual identifications) were more difficult.

Secondly, the calculated range areas are the ranges of rhinos only while in the study area. Many rhinos were not seen for periods of up to several months. Table 4.9 shows the numbers of sightings of 37 individuals in each of the 13 three month periods of the study. There are gaps in the records for even the most frequently sighted individuals, and it seems

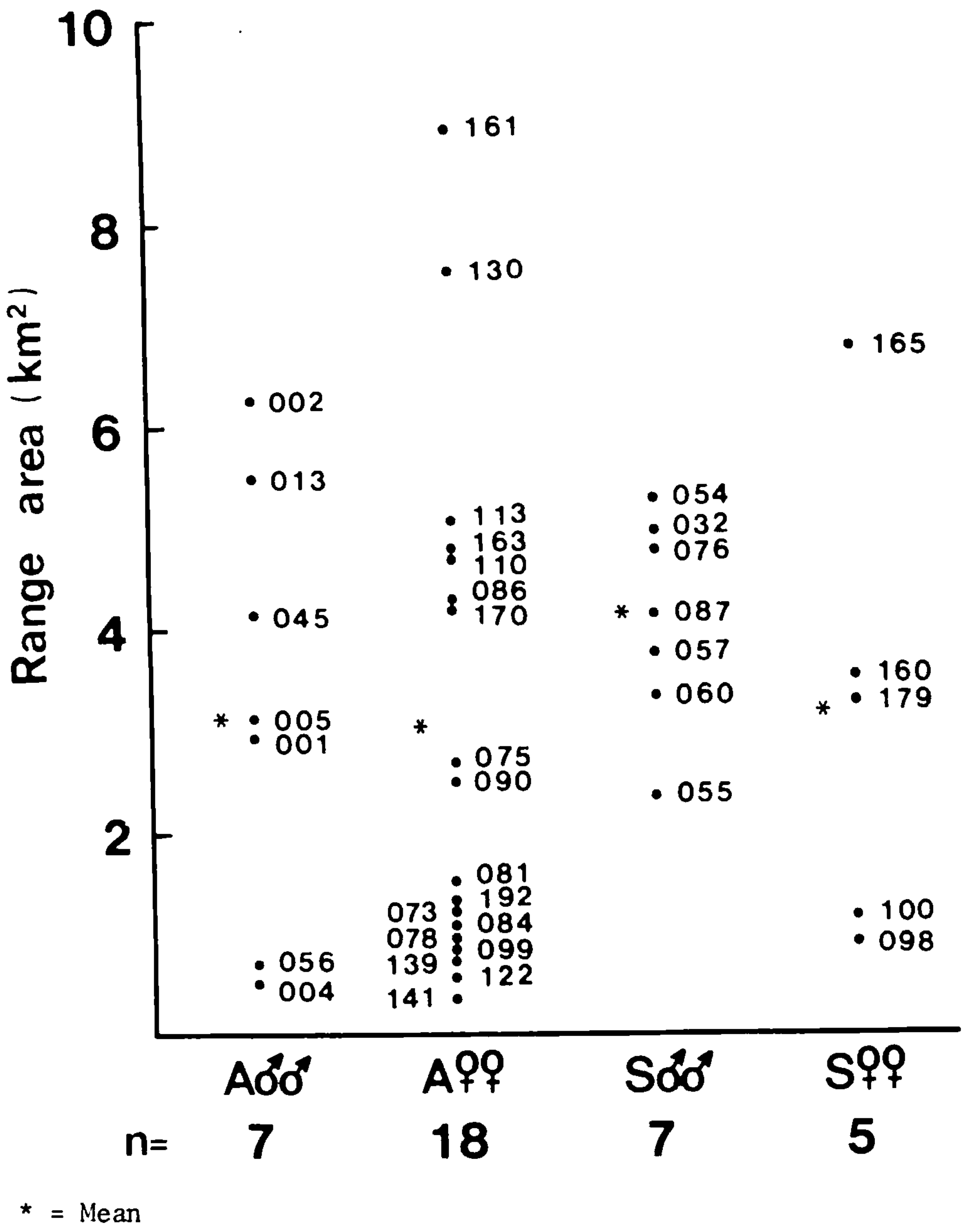


Fig. 4.28. Range areas of individual rhinos classified according to sex and age.

likely that rhinos moved either to the periphery of the study area or completely out of it at some times. There was no significant correlation ($r_s = +0.01$, $p > 0.10$) between the calculated range sizes and the number of three month periods during which each individual was seen at least once. This suggests that the calculated range areas are suitable for comparison of ranges while the rhinos were in the study area, even though some rhinos spent periods outside the study area or in parts of it where observation

Table 4.9. The numbers of observations of 37 individuals in 13 three-month periods.

Individual	1973				1974				1975				1976
	DJ-M	AMJ	JAS	OND	JFM	AMJ	JAS	ON-	J-M	AMJ	JAS	ON-	June
M001	22	17	3	2	6	16	2	4	11	43	5	-	-
M002	8	9	1	-	7	4	2	3	2	1	1	d	d
M004	13	14	1	-	2	2	1	1	3	14	4	1	3
M005	9	24	27	22	30	24	7	-	2	24	8	2	7
M013	-	6	2	-	-	4	-	-	-	8	-	-	2
m032	-	-	-	7	-	8	-	4	3	-	-	-	-
M045	-	-	-	3	8	33	34	8	15	37	11	2	10
m054	-	-	-	-	-	12	22	5	6	7	6	-	6
m055	-	-	-	-	-	17	37	6	5	19	11	2	4
M056	-	-	-	1	2	2	4	2	1	2	2	4	1
m057	-	-	-	-	-	5	9	3	4	4	2	-	-
m060	-	-	-	-	2	5	6	1	1	-	3	-	3
F073	24	37	31	10	25	19	9	3	5	32	7	-	9
F075	10	31	6	5	12	22	16	1	5	19	8	-	5
m076	c	c	-	-	-	8	26	3	6	5	2	-	1
F078	5	5	23	5	13	9	1	4	-	3	2	-	-
F081	11	2	18	3	10	15	11	1	8	22	8	-	13
F084	4	6	21	2	10	14	-	1	d	d	d	d	d
F086	2	15	10	9	8	21	20	2	7	10	6	2	9
m087	c	c	c	c	1	5	20	2	7	4	3	-	3
F090	4	17	28	3	13	15	1	2	8	19	3	2	-
f098	-	13	10	-	5	12	7	1	-	12	6	-	2
F099	-	2	36	-	14	12	3	1	4	11	1	-	1
f100	c	c	c	c	13	13	4	-	7	4	4	-	1
F110	-	-	3	2	5	10	9	2	7	11	4	-	4
F113	-	6	-	1	-	-	14	2	1	-	-	-	-
F122	-	-	34	3	-	-	-	-	-	3	-	-	-
F130	-	-	-	3	4	23	18	2	2	3	4	-	-
F139	-	-	-	4	6	3	2	-	-	1	3	-	2
F141	-	-	-	4	7	4	3	5	-	-	-	-	-
f160	-	-	9	4	10	21	21	5	1	1	2	-	-
F161	-	-	-	-	5	1	1	-	3	24	-	-	2
F163	-	-	2	5	6	6	7	2	6	38	8	-	-
f165	-	-	-	-	4	2	10	-	-	8	2	-	2
F170	-	-	-	2	-	8	16	8	-	11	-	-	1
f179	-	-	-	1	-	6	19	2	5	8	5	-	5
F192	-	-	-	-	-	2	13	3	2	8	9	-	7

c = calf and therefore not recorded separately from its mother
d = dead

was difficult.

Fig. 4.28 shows the range sizes with means for each sex and age class of rhino. There were no significant differences between the range sizes of males and females, although male ranges were more variable in size than female ranges. The ranges of sub-adults ($\bar{a}$ = 3.64 km^2, n = 12) were not significantly larger than the ranges of adults ($\bar{a}$ = 3.08 km^2, n = 25) (Mann Whitney U test $p > 0.10$). This is discussed below in Section 4.6.3.2 where the sizes of home ranges are related to their locations and habitat types.

4.6.3.2 The relationship between range size and location

In Fig. 4.29, the length of the 90% range on the east-west axis is plotted against the length of the 90% range on the north-south axis for each of the 37 most frequently sighted rhinos. There is a positive correlation ($r_s = +0.54$, $p < 0.01$) between the values of the two 90% ranges, which indicates that those individuals with a large range on one axis were also likely to have a large range on the other axis. It was shown above that most individual 90% ranges on the north-south axis were similar to the 90% ranges of total regional sightings. Thus, those rhinos in regions with a large 90% range of total regional sightings on the north-south axis were likely to have larger 90% ranges on the east-west axis than rhinos in other regions.

Table 4.10 shows the mean sizes of the ranges of rhinos according to the positions of their median locations on the east-west axis. There were significant differences in range size between the rhinos with median locations in blocks D, E and F (Kruskal-Wallis test, $p < 0.05$). Range sizes increased from west to east: the distribution of habitat types also differed between blocks D, E and F, becoming more open and less diverse from west to east (discussed in Section 6.1.2).

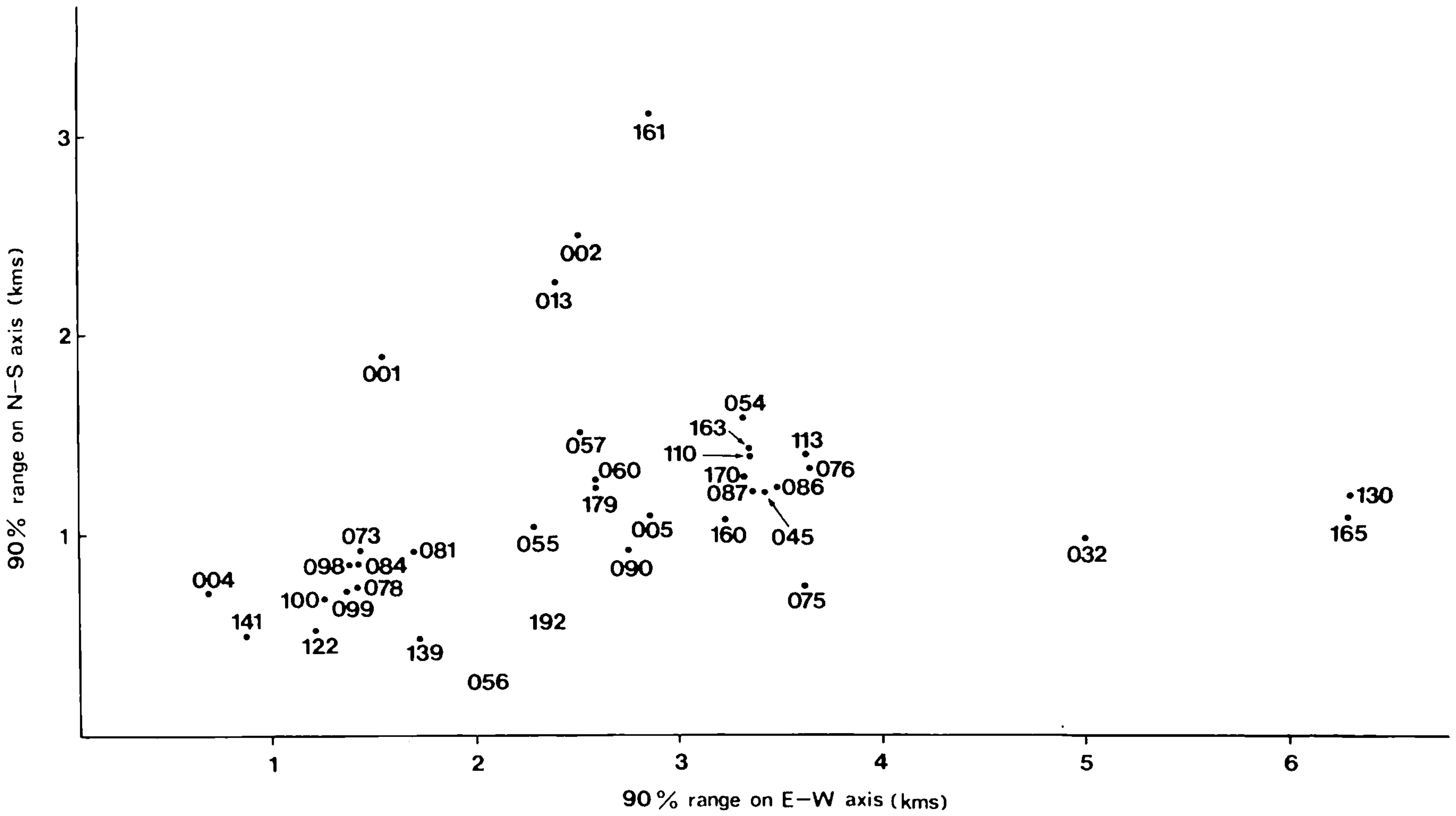


Fig. 4.29. The relationship between the 90% range on the N-S axis and the 90% range on the E-W axis for 37 rhinos.

Table 4.10. Range areas in relation to their locations.

Block	Numbers of rhinos with median easting in the block	Mean range area (km^2)
A,B	1	5.44
D	9	2.15
E	12	3.51
F	11	4.26
G	4	1.70

Kruskal-Wallis one-way analysis of variance (D,E,F): $p < 0.05$
$F > D$, Mann Whitney U test: $p < 0.01$.

The small sized ranges of the individuals in block G are probably not true representations of the movements of those rhinos. It was likely that at least two of these animals moved upriver to the east, and that their ranges within the study area were not representative of their actual ranges.

4.6.3.3 Comparisons of the sizes and locations of individuals' ranges

Rhinos have ranges which differ in size and location between individuals (Section 4.6.3.2). These ranges are by no means exclusive, and indeed it appeared that several rhinos used almost exactly the same ranges as one another. To demonstrate similarities and differences between individuals in their ranging behaviour, I have considered the distributions of sightings over the 15 sub-blocks of the study area, for each of the 37 individuals with more than 20 sightings. I used a principal component analysis on the data for the 37 individuals. This procedure, described by Gower (1966), calculated a correlation matrix of the individuals' values for each of several variables. The variables were the 15 sub-blocks of the study area and the values were the numbers of sightings.

The plot of the second principal component against the first is shown in Fig. 4.30: these two components accounted for 64% of the variance. The plotted points appear to be clumped, and to demonstrate that they are, this plot should be compared with that in Fig. 4.31. The latter plot is the result of principal component analysis of randomized data for the 37 individuals. In two such plots the first two principal components accounted for only 30% of the variance, and the plotted points were widely scattered. By contrast, four distinct groups of points can be distinguished in Fig. 4.30, and these have been circled. Such clumping of points is unlikely to have occurred by chance but it is impracticable to calculate the significance value for it (D. Brown, pers. comm., 1978).

Although most of the variance is accounted for by the first two principal components, finer distinctions can be made by considering the third principal component. The third principal component is plotted against the first in Fig. 4.32; the circled points correspond to the four groups distinguished in Fig. 4.30. It can be seen that the tightest group of points (i) has a span of only 1.0 units on the axis of the third principal component. The groups of points labelled (ii) and (iv) are separated by less than 3.5 units. The scattered uncircled points in Fig. 4.30 are also separated by less than 3.5 units on the vertical scale in Fig. 4.32. Only in group (iii) is there a separation of greater than 3.5 units on the vertical scale; the points corresponding to individuals F192 and F122 are separated by 4.7 units from that of M013.

The principal component analysis indicated correlations between certain individuals in the distributions of their sightings over the study area. I examined the distributions of the sightings of the 37 individuals, bearing in mind the groups into which the principal component analysis had divided them. I considered the uncircled points in Fig. 4.30 and 4.32 as one group

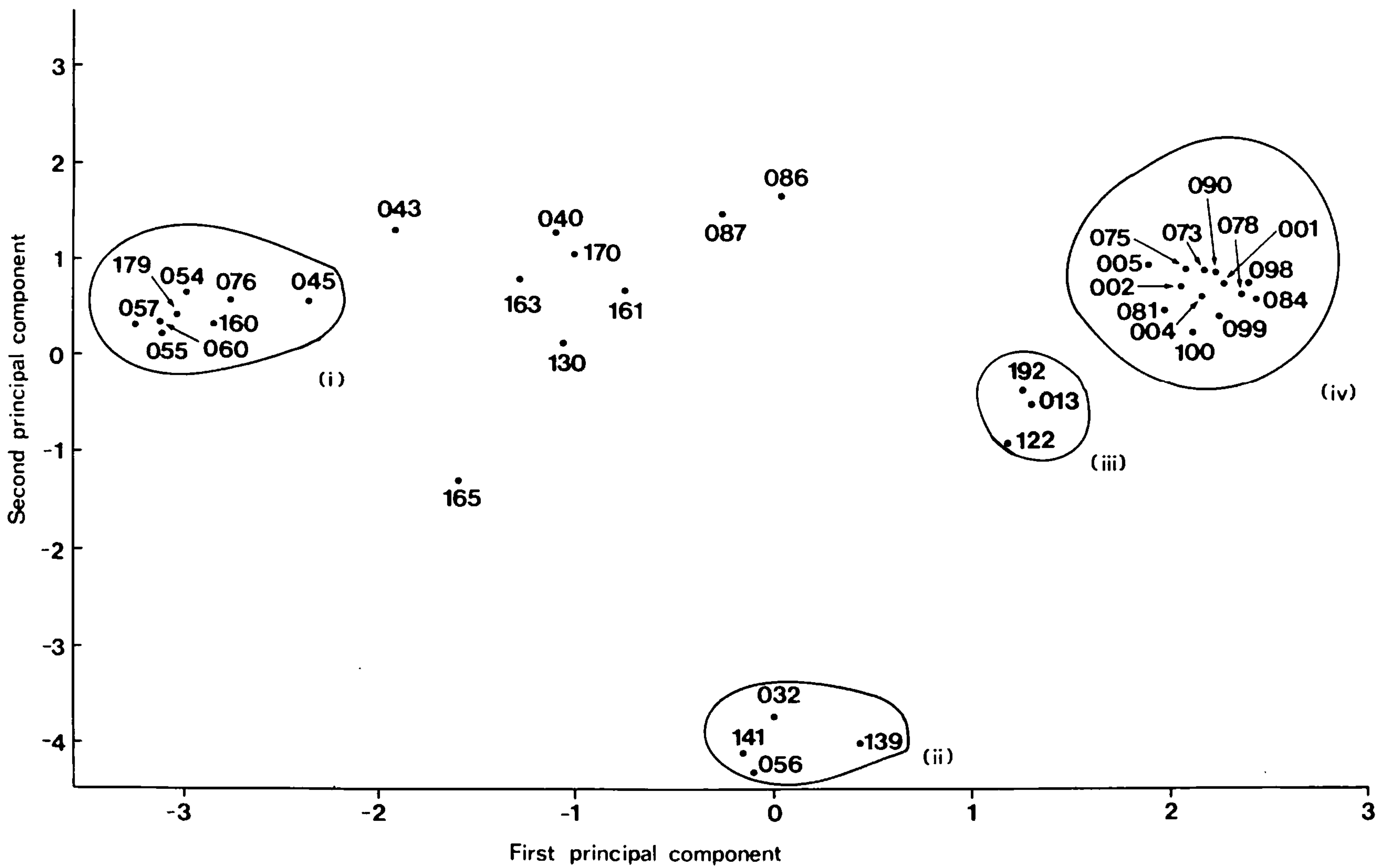


Fig. 4.30. Principal component analysis of the distributions of the sightings of 37 rhinos over 15 sub-blocks: a plot of the second principal component against the first.

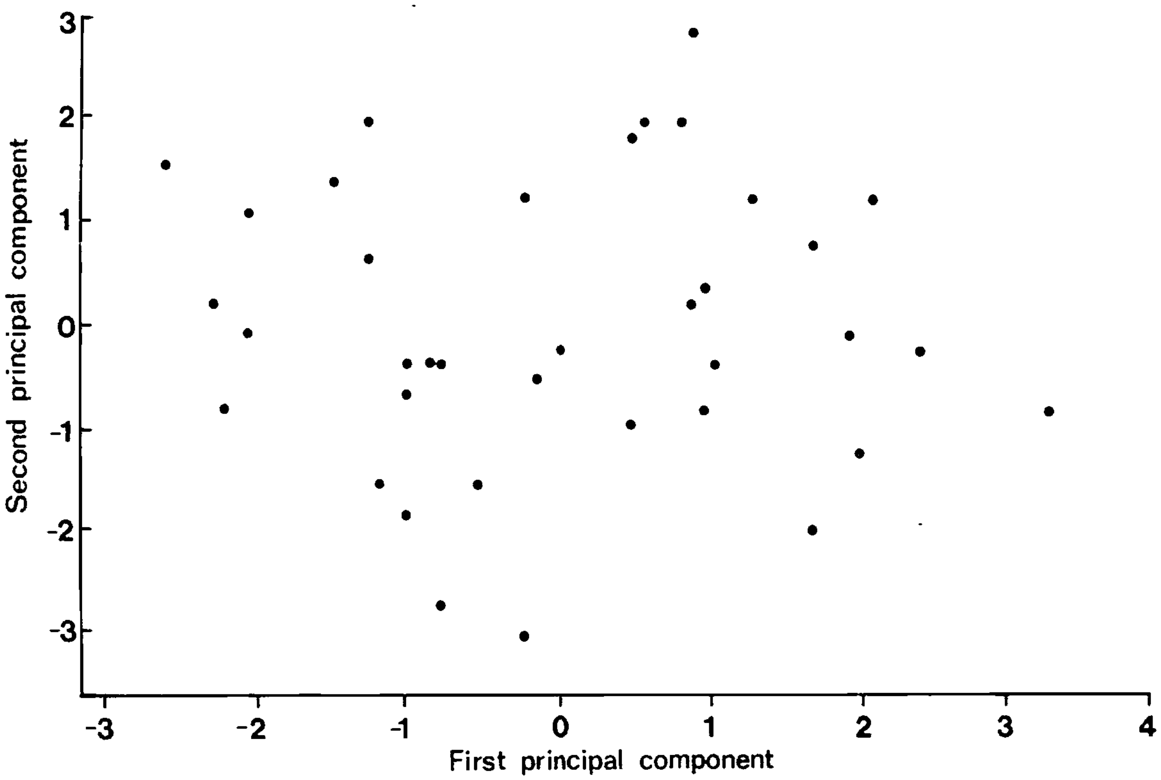


Fig. 4.31. Principal component analysis of randomized distributions of the sightings of 37 individuals over 15 sub-blocks: a plot of the second principal component against the first.

and split group (iii) into two, for the reasons given above. The 37 rhinos were thus divided into five groups of from two to 13 individuals, and one single individual.

The rhinos of each group have certain common characteristics in the positions of their median locations and the sizes of their 90% ranges on the east-west axis. They are listed in their groups in Table 4.11 with the characteristics of their 90% ranges on the east-west axis. A further 21 rhinos, for which there were between 10 and 19 locations apiece, are also listed, classified into groups according to the characteristics used to describe the ranges of the original 37 individuals (Table 4.11). Only one of the 21 individuals - M062 - did not fit into any of the groups (discussed in Section 4.6.4).

The six groups of individuals in Table 4.11 are distinguished by the characteristics of their ranges on the east-west axis only. This is

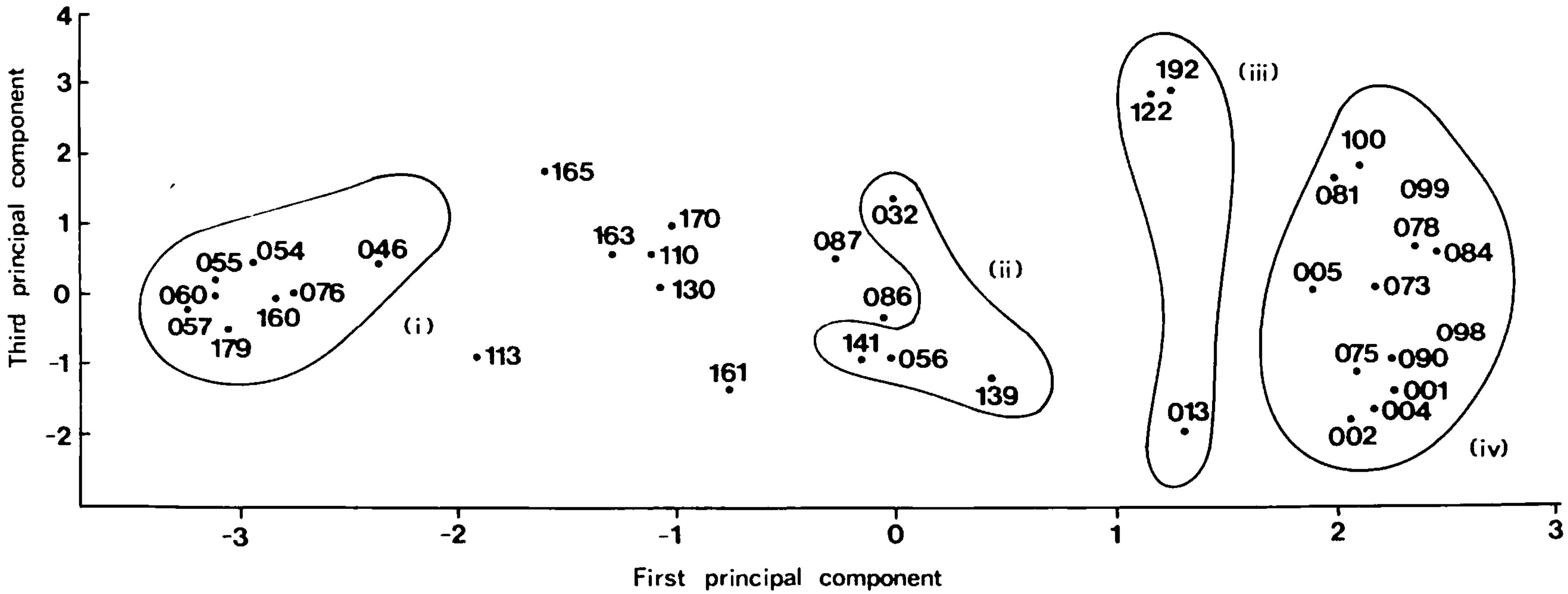


Fig. 4.32. Principal component analysis of the distributions of the sightings of 37 rhinos over 15 sub-blocks: a plot of the third principal component against the first.

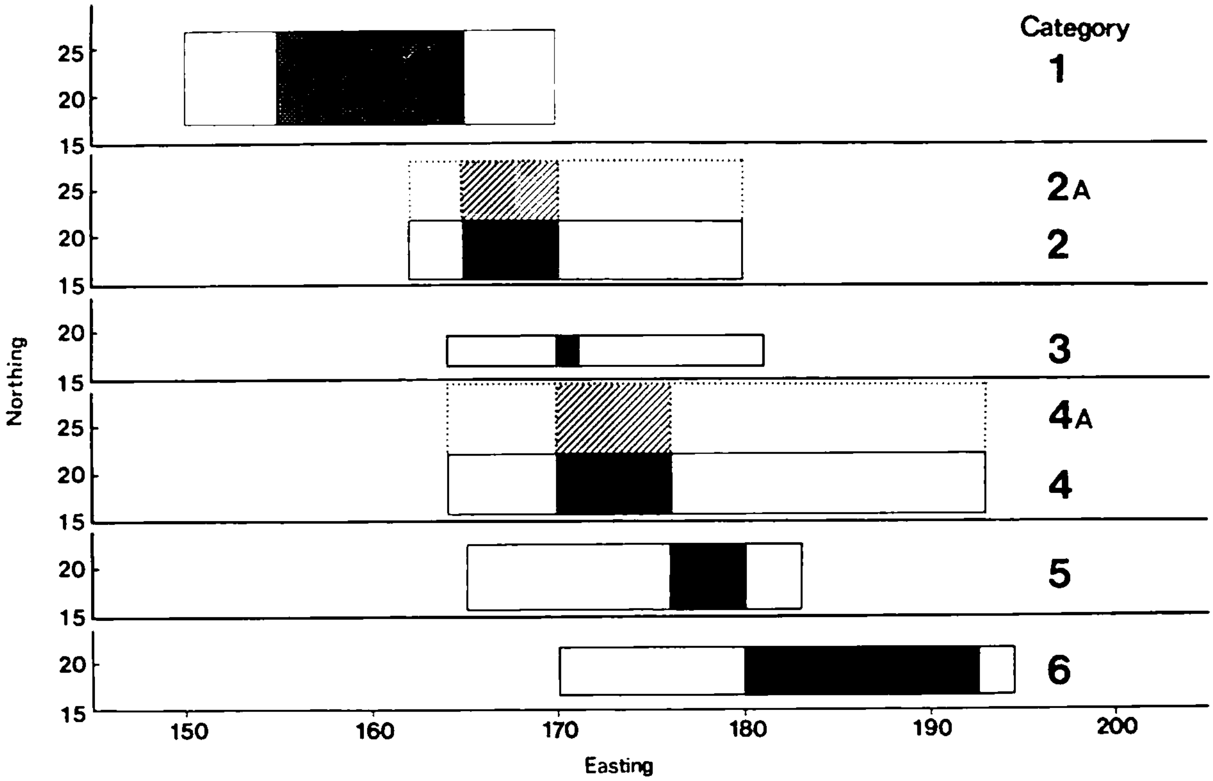
Table 4.11. The characteristics of the eight categories of ranges and the identities of the individuals in each category.

Category No.	(1)	(2)	(3)	(4)	(5)	(6)
Numbers of individuals with ≥20 sightings	1	13	2	9	8	4
Position of median longitude	<165.0	165.0-169.9	170.0-170.9	170.0-175.9	176.0-180.0	>180.0
90% ranges on east-west axis between	150-170	162-180	164-182	164-193	165-183	170-197
Lengths of 90% ranges on east-west axis (kms)	0.9-3.0	0.7-3.6	1.2-2.3	2.9-6.3	2.3-3.6	0.9-4.4
Individuals	M013	M001(A) M002(A) M004 M005 F073 F075 F078 F081 F084 F090 f098 F099 f100	F122 F192	F086 m087 F110 F113 F130 F161(A) F163 f165 F170	M045 m054 m055 m057 m060 m076 f160 f179	m032 M056 F139 F141
Numbers of individuals with 10-19 sightings	3	7	1	4	3	2
Individuals	M003 M034 F194	M053(A) F093 F102(A) f149 F187(A) F188 f196	m061	m048 m064 f172 f221	m049 F138 m253	F152 F180

Postscript (A) denotes individuals in categories 2A or 4A, which have significantly larger 90% ranges on the north-south axis than those in categories 2 and 4 respectively.

justified for most individuals, as it is shown above (Section 4.6.3.2) that 28 of the 37 individuals did not differ significantly from the others of their regions, in the distributions of their sightings on the north-south axis. I also had considerable difficulty in finding rhinos to the north and south of a narrow strip aligned approximately east-west across the study area. Therefore I did not attach much importance to the fact that some individuals had 90% ranges on the north-south axis which were smaller than that of the total regional sightings. However, three of the nine individuals with significantly different 90% ranges on the north-south axis had larger ranges than that of the total regional sightings. Similarly, three of the less frequently sighted individuals had significantly larger 90% ranges on the north-south axis than others in their regions. I have distinguished these six individuals, M001, M002, F161, M054, F102 and F187 in Table 4.11 by the postscript (A).

Thus, with the two subgroups, 2A and 4A, there are eight fairly distinct categories of home range and ranging behaviour to which 57 of the 58 individuals can be assigned. The characteristics of the ranges of each group and subgroup are shown schematically in Fig. 4.33.



Eastings and northings refer to maps (*e.g.* Fig. 4.17) of the Sauraha study area. The rectangles enclose the 90% ranges on both axes of all individuals in the category. The median locations of all individuals in the category lie within the shaded portions of the rectangles.

Fig. 4.33. A schematic representation of the characteristics of the eight categories of ranges defined in Table 4.11.

4.6.3.4 Seasonal movements of individuals

Rhinos moved seasonally either between blocks or into and out from blocks to places outside the study area (Section 4.6.1). Individuals had ranges which they occupied when they were in the study area, and these varied in size and location (Section 4.6.3). Here, the gross seasonal movements demonstrated in Section 4.6.1 are shown to be largely the result of seasonal changes in the patterns of individuals' range use.

There were variations in the distributions of the sightings of individuals over time. For example, Fig. 4.34 shows the numbers of sightings of an adult female, F110, in each of the seven blocks of the study area for each of 11 four-month periods. Twenty-two of the 29 sightings in blocks D and E were between February and May of the two years, whereas 23 of the 28 sightings in blocks F and G were between June and January. However, it is more useful to consider variations in rates of sightings. The number of visits to a block is almost as good a measure of searching effort as the number of hours spent in a block (Section 4.6.1). In order to look at seasonal differences in the rates of sightings in each block, I have used the number of visits rather than the number of hours as a measure of searching effort. Using the number of visits to a block, each visit can be scored as one in which a particular individual was either seen or not seen, and consecutive visits (unlike consecutive hours) can be regarded as independent.

The study area has been divided into two parts along the boundary between blocks E and F, which is the block boundary nearest to the median location of F110 on the east-west axis. For each of the two parts of the study area, the number of visits during which F110 was seen, was compared with the total number of visits, in each season. There were significant overall differences in both parts of the study area ($\chi^2 = 14.18$ and 16.39 $p < 0.001$; Fig. 4.34). In blocks A to E, F110 was seen significantly more frequently during spring (Section 4.1.1) than expected from the relative number of visits made during that season ($\chi^2 = 11.70$, $p < 0.001$). On the other hand, the same individual was seen less frequently than expected

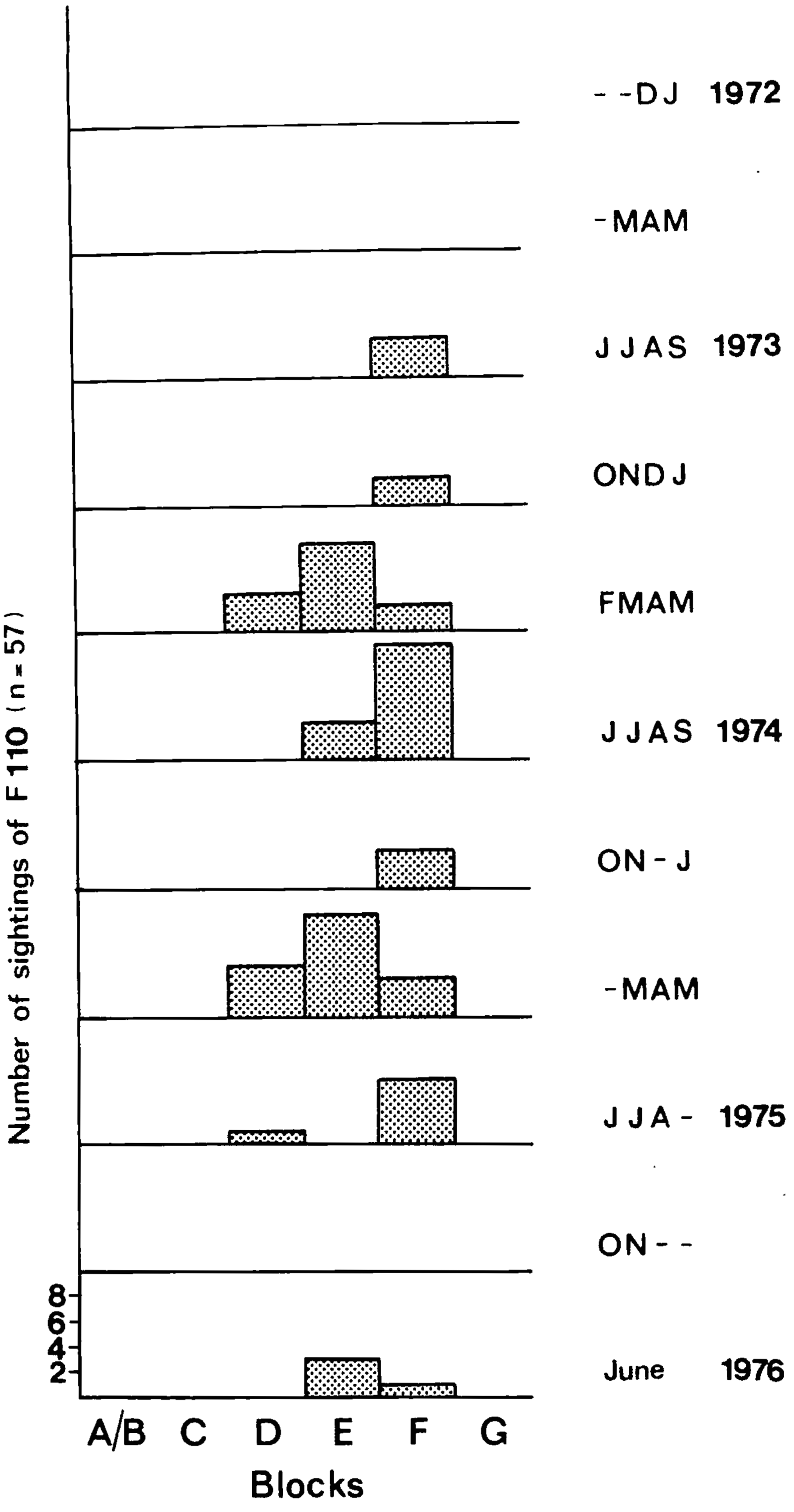


Fig. 4.34. Seasonal variations in the locations of sightings of F110.

Continued/.....

Fig. 4.34 (continued)

	BLOCKS A to E				BLOCKS F to G			
	FMAM	JJAS	ONDJ	TOTAL	FMAM	JJAS	ONDJ	TOTAL
Visits seen	22 (13.0)	7 (9.2)	0 (6.8)	29	5 (10.9)	18 (8.5)	5 (8.6)	28
Visits not seen	207	154	119	480	162	112	127	401
Total visits	229	161	119	509	167	130	132	429

$\chi^2 = 14.8 \quad p < 0.001 \quad df = 2$ $\qquad\qquad$ $\chi^2 = 16.39 \quad p < 0.001 \quad df = 2$

The figures in brackets are the expected numbers of sightings on the null hypothesis that F110 did not show seasonal changes in range use.

in blocks F to G during spring ($\chi^2 = 5.59$, $p < 0.02$). She was seen significantly less frequently than expected in the western part of the study area in winter, and significantly more frequently than expected in the eastern part during the monsoon. The evidence therefore indicates that F110 spent more time in blocks A to E during the spring and more time in blocks F to G during the rest of the year.

Table 4.12 shows the result of the same tests on the distributions of sightings of the 37 most frequently sighted individuals. The study area was divided into two parts either at the boundary between blocks D and E or at that between blocks E and F; whichever was the nearest to the median location of the individual on the east-west axis. The division was between E and F for 21 rhinos and between blocks D and E for the other 16.

There were enough sightings of only 15 rhinos to test for uneven distribution over the seasons in both parts of the study area; there were significant differences in both parts for 14 of these rhinos, and in one part only for one rhino (Table 4.12). Sixteen of the remaining 22 rhinos showed significant differences in the distributions of sightings over three seasons in one part of the study area, four showed no significant differences,

Table 4.12. Seasonal variations in the distributions of the sightings of individual rhinos between two parts of the Sauraha study area.

Individual	Blocks A to D			Blocks E to G		
	FMAM	JJAS	ONDJ	FMAM	JJAS	ONDJ
M013	H	=	L		0	
M004	H	=	L		0	
M001	H	L	L	L	=	=
M002	H	=	L		0	
F075	H	L	L	L	H	L
F090	H	=	L	L	H	=
f098	H	=	L	L	H	L
F084	H	=	L	L	H	=
F073	H	L	L	L	H	=
F078	=	=	=	L	H	=
M005	H	=	L	=	=	H
F099	H	=	L	L	H	L
f100		0		=	=	=
F081	H	=	L	=	H	L
F122		0		L	H	L
F192		0		L	H	L

Individual	Blocks A to E			Blocks F to G		
	FMAM	JJAS	ONDJ	FMAM	JJAS	ONDJ
F161		0		H	=	L
F163	H	L	L	=	H	=
f165		0			0	
F086	H	=	L	L	H	=
F110	H	=	L	L	H	=
m087		0		=	H	L
M045	H	=	L	H	=	=
F170		0		L	=	=
F113		0		L	H	=
m060	H	=	=	L	H	L
m054		0		=	H	=
m055		0		L	H	L
m076		0		L	H	L
f179		0		L	H	L
m057		0		L	H	L
f160		0		L	H	=
m032		0			0	
M056		0		=	=	=
F139		0		=	=	=
F141		0		=	=	=

H - More sightings than expected: χ^2 test $p < 0.05$

L - Fewer sightings than expected: χ^2 test $p < 0.05$

= - Number of sightings not significantly different from expected: χ^2 test $p > 0.05$

0 - Insufficient sightings for significance test.

The data are shown in Appendix J.

and there were too few sightings for the test in both parts of the study area for the remaining two individuals. The data for all 37 individuals is shown in Appendix K.

Table 4.13 summarizes, for each part of the study area and for each season, the numbers of rhinos which were seen significantly more frequently than, or as,expected from the numbers of visits made during each season. Of the 15 rhinos with sufficient sightings to test for significance in both parts of the study area, 14, or 93%, were seen more frequently than expected in the western part during the spring and 11, or 73%, were seen less frequently than expected in the eastern part during the same season.

Table 4.13. The numbers of individuals seen significantly more and less frequently than expected from the number of visits in each season in two parts of the Sauraha study area.

Blocks	A to E or A to D			E to G or F to G		
Seasons	FMAM	JJAS	ONDJ	FMAM	JJAS	ONDJ
Frequency of sightings						
> expected	14 (17)			0 (2)	12 (23)	1 (1)
No significant difference from expected	1 (1)	11 (14)	2 (2)	4 (9)	3 (9)	9 (17)
< expected		4 (4)	13 (16)	11 (21)		5 (14)
Totals	15 (18)	15 (18)	15 (18)	15 (32)	15 (32)	15 (32)

The upper figure in each cell refers to the 15 individuals with sufficient numbers of sightings to test for significance in both parts of the study area. The lower figure refers to the total of all rhinos with sufficient numbers of sightings to test for significance in the part of the study area indicated.

The test used is the χ^2 test referred to in Table 4.12 (data in Appendix J).

There were similar but less striking differences between the two parts of the study area in the other seasons, with most rhinos being seen more frequently than expected in the eastern part during the monsoon and less frequently than expected in the western part during the winter. Among the individuals for which there were insufficient sightings in one part of the study area, most of the few sightings were made during spring in the western part of the study area and during the monsoon in the eastern part.

Thus, the general movements of rhinos which were indicated by the evidence presented in Section 4.6.1 are accounted for, at least in part, by the movements of known resident individuals within the study area. The general trend is for rhinos to move from blocks F and G into blocks D and E during the spring, and out again to blocks F and G during the monsoon. The degree of movement varied between individuals; some came in from considerable distances, and others stayed in the central blocks of the study area the year round.

4.6.3.5 Changes in the pattern of use of the ranges of individuals over the study period

The ranges of all individuals are derived from the locations of those individuals over a period of 3½ years. Seasonally repeated changes in the use of different parts of the ranges are described above (Section 4.6.3.4). In this section, more permanent changes in individuals' use of their home ranges are described. Table 4.9 shows that many individuals were not seen for periods of up to three months, and a few were not seen for up to one year. Little can be deduced about the changes in those individuals' use of their ranges, although it was likely that they had moved away from the study area. Here, I consider changes in individuals' use of ranges within the study area only.

I demonstrated seasonal movements by comparing the rates of sightings of individuals in each of two parts of the study area in each season (Section 4.6.3.4). A simple division of the study area into two parts was effective in demonstrating these movements, but when investigating individual variation in the use of home ranges over the whole study period, I found that finer divisions were necessary to show more permanent changes in the use of home ranges.

Taking individual F073 as an example, Fig. 4.35 shows the rates of sightings of that individual in each block of the study area in three successive twelve-month periods from December 1972 to December 1975. The rates of sightings are expressed as the percentages of my visits to each block during which I saw F073. This female's range appeared to have expanded slightly over the study period, although I saw her most frequently in blocks D and E in all years.

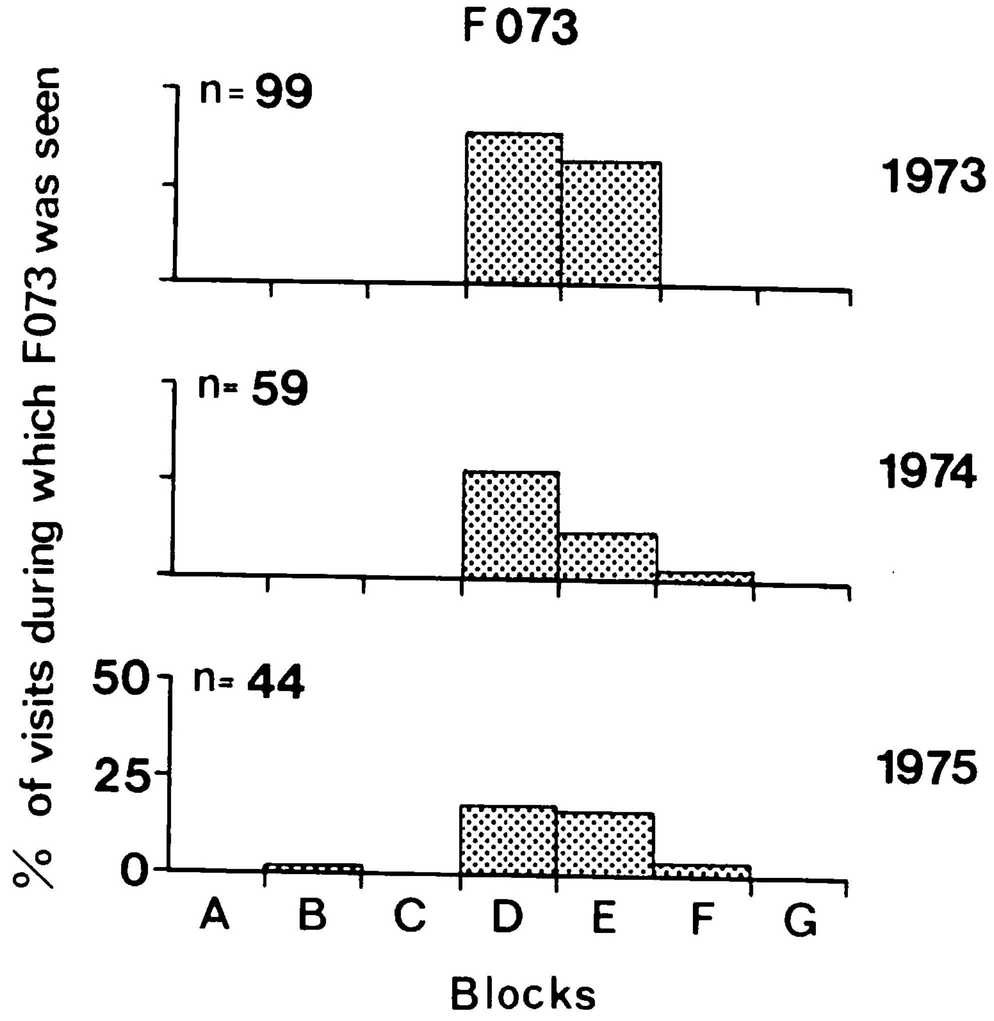


Fig. 4.35. The annual rates of sightings of F073 in each block.

However, as rates of sightings varied seasonally in most blocks (Section 4.6.3.4), annual rates of sightings cannot indicate permanent changes in range use unless the distribution of searching effort over the seasons was approximately the same in each year. This was not so: not only did the distribution of searching effort over the seasons vary as a whole, but it varied in different ways in each of the blocks (Section 2.3). As an example, Table 4.14 shows the numbers and percentages of the visits to blocks E and F in each year, which I made during the months of June to September. In 1973, 45% of the visits made to block E and 14% of those made to block F were during the monsoon, whereas in 1974 these proportions were 23% and 35% respectively. Such changes are likely to influence the rates of sightings calculated for entire years, in such a way that some of the differences between the annual rates of sightings in each block could be attributed to seasonal movements of rhinos rather than to permanent changes in the use of home ranges.

Table 4.14. Seasonal differences in the distribution of visits to two blocks of the Sauraha study area.

Year	Block E		Block F	
	Total visits made	Visits made during June-September	Total visits made	Visits made during June-September
1973	155	70 (45.2%)	86	12 (14.0%)
1974	170	39 (22.9%)	213	74 (34.7%)
1975	139	35 (25.2%)	120	34 (28.3%)

It is impractical to correct the annual rates of sightings of individuals in each block for the effects of the distribution of searching effort over the seasons. However, it is possible to compare the ways in which the annual rates of sightings in each block differed between individuals. I calculated the annual rates of sightings in each block for all 37 individuals with more than 20 sightings. Statistical treatment of the data was difficult because of the low numbers of sightings of some rhinos. Expected frequencies of sightings are too low to discriminate differences between blocks in the same way as seasonal differences were demonstrated between groups of blocks. Furthermore, statistical comparison of rates of sightings is impossible using the nominal data. Ranking of the rates of sightings in each block in each year results in inevitable loss of information but is the only applicable method of objectively demonstrating changes in patterns of range use from year to year.

Therefore, rank correlation coefficients were calculated, for each pair of years, of the rates of sightings of each individual in each block of its range. High positive correlations between years indicated that there were no marked changes in that individual's use of its range while in the study area. For example, the correlation coefficients, r_s, for individual F073 between each pair of years are +0.918, +0.718 and +0.783 respectively.

Six individuals were seen in only one or two blocks during the study period: correlation coefficients are meaningless for these individuals, but the limited distribution of their locations indicated that there were no appreciable changes in their pattern of range use. I used the correlation coefficient for all other individuals as a descriptive statistic to classify the consistency of the distributions of their locations over blocks between years. Table 4.15 shows the correlation coefficients, and summarizes the results. Nineteen individuals showed positive correlations between all pairs of years and,for 17 of those individuals, all correlation coefficients were equal to or greater than +0.500. Twelve

Table 4.15. Spearman rank correlation coefficients of the relationship between the annual rates of sightings of individuals in each block of their ranges.

Individual	1973 with 1974	1974 with 1975	1973 with 1975	Number of Blocks	Number of Locations
† M013			0.000	3	20
M004	+.500	+.500	+1.000	3	56
M001	+.900	-.375	-.175	5	131
M002	-.258	+.013	+.726	5	38
F075	+.091	+.507	+.718	6	135
F090	+.671	0.000	+.447	5	115
f098	+1.000	+1.000	+1.000	3	66
* F084				2	58
F073	+.918	+.718	+.783	4	202
F078	+.500	+1.000	+.500	3	70
M005	+.638	+.758	+.429	6	181
F099	+.500	+.500	+1.000	3	84
f100	+1.000	+.500	+.500	3	83
F081	+.500	+.500	+1.000	3	109
† F161		-.775		4	34
F163	+.350	-.400	+.750	4	80
† f165		0.000		4	26
* F122				2	40
F086	+.800	+.800	+1.000	4	112
† F192		+1.000		3	37
F110	+.875	+1.000	+.875	3	53
m087	+.400	-.200	+.400	4	41
m045	-.775	+.400	-.258	4	151
F170	+.875	+.500	+.875	3	45
F113	-.625	-.125	+.875	3	24
F130	+.500	+.600	+.800	4	59
f160	+.632	+.738	-.056	4	74
† m054		+.875		3	58
† m055		+.875		3	97
* M056				1	20
m032	+.875	+1.000	+.875	3	21
m076	-.625	+.875	+.500	3	93
* f179				2	46
* m057				2	27
* m060				2	21
F139	+1.000	+.775	+.775	3	19
F141	+1.000	+.775	+.775	3	23

* Correlation coefficients were not calculated for individuals which were seen in two or fewer blocks during the study period.

† These individuals were not seen during some years and so there are no correlation coefficients for those years.

individuals showed zero or negative correlations between one or more pair of years.

It should be remembered that the correlation coefficients were calculated for a small number of blocks - three to six, depending on the individual.

The probability of r_s being $\geq$+0.500 under the null hypothesis that the two distributions of sightings are unrelated, varies from 0.500 when n = 3, to 0.149 when n = 6. Thus, no statistical significance can be assigned to the correlation coefficients obtained. However, the correlation coefficients do provide a measure of the degree of relatedness between two distributions of rates of sightings and I have used them as such, rather than as test statistics.

The annual rates of sightings in each block for six individuals are plotted in Fig. 4.36. The distributions of the locations of F078 and F098 did not change appreciably between years. These two individuals and F073 were among the 17 rhinos which showed high positive correlations between all pairs of years and which, together with the six rhinos which were seen in only one or two blocks, I regarded as demonstrating a constant pattern of range use over the three years. The rates of sightings of the two individuals (M005, F075) with low positive correlations between years and of two of the individuals (M045, F163) with negative correlations between at least one pair of years show appreciable changes between years (Fig. 4.36).

The changes in patterns of range use indicated by this analysis are considered at the individual level in Section 5.6.4. I point out here some differences between sex and age classes in use of ranges. Table 4.16 shows the numbers of rhinos of each sex and age class which fell into the three classes of consistency of range use defined in Table 4.15. It can be seen that 71% (five) of the seven males as opposed to 28% (five) of the 18 females showed correlation coefficients of less than +0.500 between at least one pair of years, in the distribution of their sightings over the blocks (Fisher exact probability test p = 0.007). Thus, adult males were more likely to change their ranges than adult females (discussed in Section 5.6.4.2).

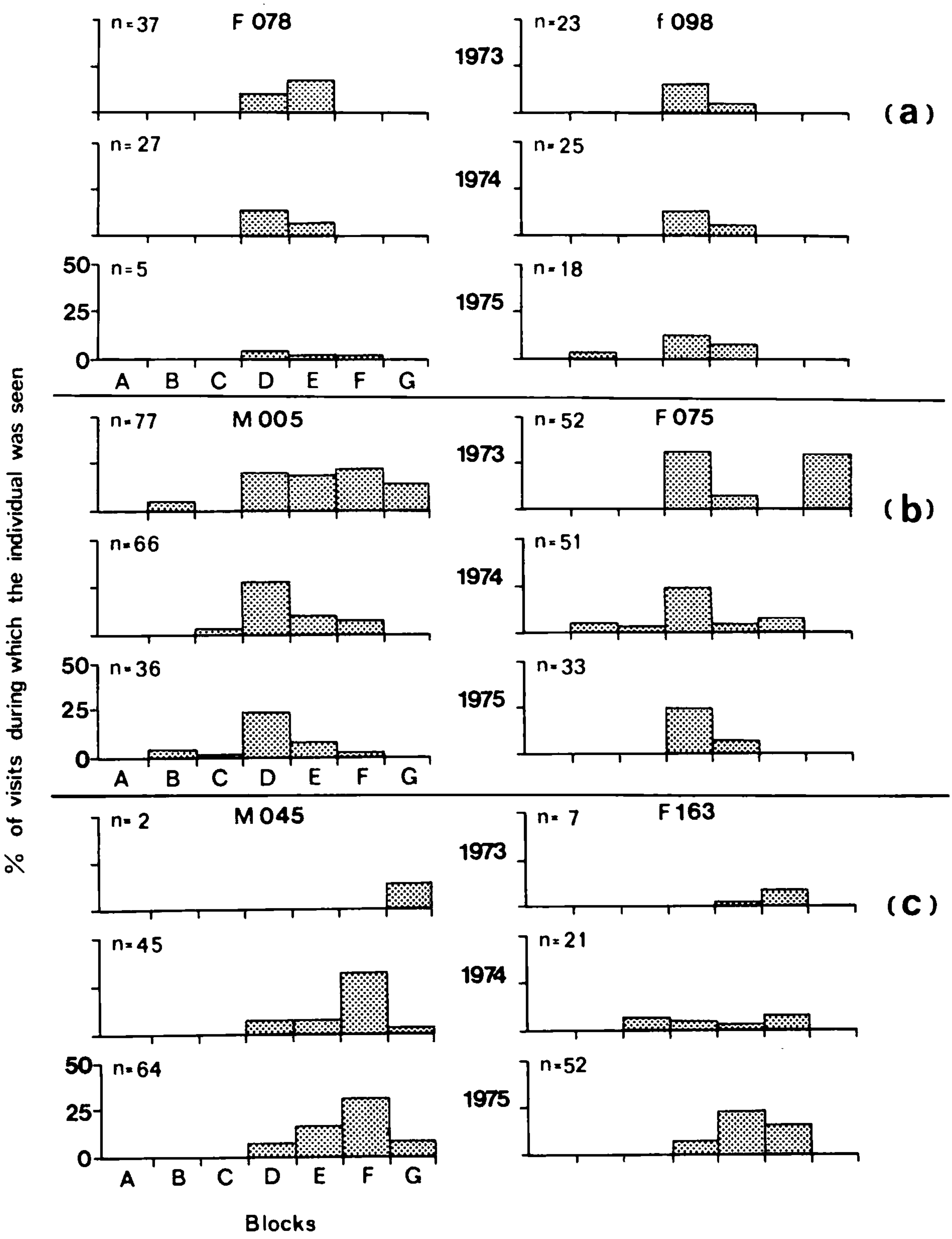


Fig. 4.36. The annual rates of sightings in each block of six rhinos with varying degrees of consistency of range use.

Table 4.16. The consistency of range use among 37 individuals classified according to sex and age.

	A♂	S♂	A♀	S♀	Total
Consistent pattern of range use					
All $r_s \geqslant +0.500$	1	3	11	2	17
Seen in two blocks or fewer	1	2	2	1	6
Inconsistent pattern of range use					
All r_s positive but one or more $r_s < +0.500$	1	0	1	0	2
One or more $r_s \leqslant 0.000$	4	2	4	2	12
Total	7	7	18	5	37

4.6.3.6 Movements of infrequently sighted individuals

I consider here the locations of individuals seen on less than 20 occasions, concentrating on evidence for seasonal or permanent changes in range use. Table 4.17 classifies the registered adults and sub-adults of Sauraha according to frequency of sightings. I first consider the 21 individuals seen on between 10 and 19 occasions, which were classified into eight discrete categories of range use in Table 4.11.

With low numbers of sightings, it is particularly important to correct for the distribution of searching effort (Section 4.6.1), because the median location of an individual could be in an area infrequently visited by the rhino but frequently visited by myself. I therefore consider, in Table 4.18, the overall rates of sightings of each individual in each block, and the mean rates of sightings of the individuals seen in each block. In the central blocks, D, E and F, which were visited most frequently, rates of sightings of most individuals were very low, whereas

Table 4.17. The numbers of sightings per individual among registered adults and sub-adults in the Sauraha study area.

Number of sightings	Number of individuals			
	1-9	10-19	20 or more	Total
Class				
A♂	23 (67%)	4 (12%)	7 (21%)	34
A♀	32 (54%)	9 (15%)	18 (31%)	59
S♂	12 (50%)	5 (21%)	7 (29%)	24
S♀	9 (53%)	3 (18%)	5 (29%)	17
Total	76 (57%)	21 (15%)	37 (28%)	134

high rates of sightings were recorded in the outer blocks.

Low rates of sightings of an individual in a particular block can be the result of the rhino either making infrequent and short visits to that block, or remaining unseen within the block for most of the time. As most of my searching effort was concentrated in the central part of the study area where visibility was good, and where several individuals were seen on more than 100 occasions (Table 4.12), it is unlikely that a rhino resident there throughout the study period would have been seen on fewer than 20 occasions or on less than 2% of my visits to the central blocks. On the other hand, in the infrequently visited outer blocks, where visibility was often bad and where sightings were more a matter of chance, it is likely that individuals which were seen on over 2% of visits to those blocks, were resident there. I regarded long periods without sightings in the central part of the study area as indicating that the individuals were absent from that part. However, long periods without sightings in the outlying parts of the study area cannot be taken as evidence that the individuals were not present there.

Block	Rate of sighting (% of visits during which the individual was seen)							Number of sightings			
	A	B	C	D	E	F	G	1973	1974	1975/6	Total
Individual:											
M062	26.3			1.9				0	4	13	17
M003		3.5	6.1	1.3		0.2		8	4	2	14
M034	5.2	8.8		0.5				3	5	6	14
F194	5.3	7.9						0	0	11	11
M053			20.4					2	6	2	10
F093				1.3	0.8	0.5		8	0	3	11
F102			8.1	0.8	0.8			5	6	0	11
f149				1.6	0.8			0	1	9	10
F187			12.2	0.8	0.8			1	5	7	13
F188				2.4	1.3			0	7	8	15
f196		2.6		2.4		0.5		0	3	11	14
m061				0.5	1.7	0.5		2	1	9	12
m048				1.6	0.4	1.9		0	0	16	16
m064				1.3	0.4	0.9		0	0	11	11
f172		0.9		1.3	0.8	2.1		2	4	13	19
f221						2.3	5.2	0	3	10	13
m049				0.3	0.2	1.9	3.5	0	8	4	12
F138						3.3		4	0	10	14
m253						2.6	1.8	0	0	12	12
F152						0.9	10.5	1	7	2	10
F180						1.9	12.3	0	4	11	15
Number of individuals seen in each block	3	5	4	14	10	13	5				
Mean rate of sighting (± S.D.) of individuals seen in each block	12.3 ± 9.9	4.8 ± 3.1	11.7 ± 5.5	1.3 ± 0.6	0.8 ± 0.4	1.5 ± 0.9	6.7 ± 4.0				

Table 4.18. The rates of sightings in each block, of 21 individuals with between 10 and 19 locations each.

Table 4.18 shows that five individuals were seen in blocks A and B only, C only, or F and G only. A further seven individuals were seen on over 2% of visits to the outlying blocks, A, B, C or G and were also seen in block D, where all sightings were between February and May (apart from two sightings of individual M003 in July). These seven individuals thus showed evidence of seasonal movements into the central blocks during spring.

The remaining nine individuals were seen in the central blocks only, or in outlying blocks on less than 2% of visits. It is unlikely that they remained in the central blocks throughout the study period. Two of these individuals, f149 and F188, were only seen during the spring, and were presumed to have visited the central blocks from outlying blocks or from outside the study area. Similarly, individuals F093 and F138 were seen mainly during the spring although both these individuals were also seen in block F during the monsoon. The other five individuals were seen in all seasons in blocks E and F. Their low rates of sightings were the result of being recorded almost entirely during the last year of the study period. Three young sub-adults, m048, m064 and m253, were not recorded during the first two years, although they may have been seen as calves (further discussed in Section 5.6.3).

Thus, many of these 21 infrequently sighted individuals showed evidence of seasonal movements from the outlying parts of the study area into the central blocks during the spring. These movements are similar to those shown by the 37 most frequently sighted individuals (Section 4.6.3). The rates of sightings shown in Table 4.18 are compatible with the division into categories of ranges in Table 4.11. The only individual which did not fall into any of these categories is M062, an adult male which was seen 10 times in block A over a period of more than one year, and seven times in block D within 10 days in April 1975. The frequent sightings over a short period in block D were the result of my searching daily for that particular individual when he was severely wounded (Section 5.6.4.2), and were therefore not effectively independent of each other. If the rates of sightings of M062 in each block are compared with those of other individuals, they are seen to be most similar to those of individuals in category (1) of Table 4.11.

With such low numbers of sightings, there is no conclusive evidence of permanent changes in the pattern of range use among the 21 individuals. However, in addition to M062, M003 also showed a possible change in the use of its range. It was seen only in block D during the first year of the study, and thereafter it was seen only in blocks B, C or F. Thus, the only two individuals to show any evidence of changes in the use of their ranges between years, were both adult males. These changes are discussed further in Section 5.6.4.2.

Seventy-six individuals were seen on fewer than 10 occasions over the whole study period (Table 4.17), and were obviously not resident over that period in the central blocks. Forty-six of these individuals were seen in block D during the spring, and 26 of these were seen in outlying blocks during other times of the year. Little can be deduced about the ranges of these very infrequently sighted individuals, but there was some evidence for seasonal movements into the central blocks in spring. More adult males than any other sex and age class were seen on fewer than 10 occasions (Table 4.17). This lends further support to the conclusion that adult males change their pattern of range use more than other sex and age classes (see above in this section and Section 4.6.3.2).

4.7 Discussion on diet

4.7.1 The expected diet

Before discussing the observed diet of rhinos, I consider some nutritional factors that may influence it. Ungulates face two general problems when choosing and digesting their food. Firstly, plants are generally low in nutritive value, and contain a high proportion of structural elements that are largely indigestible. Secondly, some plants contain toxic compounds.

The main adaptation by which ungulates cope with the first problem is an enlargement of the alimentary canal containing bacteria that are capable of breaking down cellulose by fermentation (Hungate, 1960). Two main sites of fermentation have evolved: ruminants use the rumen, and perissodactyls and elephants use the caecum. The processes of fermentation are similar in both ruminants and perissodactyls, but there are important differences arising from the difference in the sites of the fermentation chambers. Ruminants are unable to pass food from the rumen into the lower sections of the digestive tract until it has been broken down into particles small enough to pass through the reticulo-omasal orifice. The higher the fibre content of the food, the longer it takes to be broken down; therefore the rate of passage through the gut decreases on a diet with a high fibre content. Caecal fermenters, on the other hand, can increase their rate of food intake and throughput, and maintain a constant rate of nutrient absorption despite a decrease in the quality of the diet. Thus ruminants require a certain quality of food, *i.e.* a minimum protein to fibre ratio ; whereas caecal fermenters are less dependent on high quality food, providing that food is available in sufficient quantity (Bell, 1971).

A further consideration is the large size of a rhino. Since metabolic rates increase only as a function of body weight to the power of 2/3 (Kleiber, 1961), large animals require less energy and protein per unit weight than small animals, and can therefore survive better on low quality food (for discussion of this point see Jarman, 1974; Janis, 1976). It follows that young rhinos, with a lower body weight and an incompletely developed fermentation system, are likely to require higher quality food than adults. It has been shown that young horses and young cattle require high quality protein prior to the time when fermentation begins (Hintz *et al.*, 1969; Hatfield, 1970).

While rhinos can survive on low quality foods, several factors may favour diversity in the diet. By increasing dietary diversity, they will take in a wider variety of amino-acids, which is particularly important for a perissodactyl. Ruminants can maintain their amino-acid requirements on a relatively unvaried diet (Loosli *et al.*, 1949), because their fermentative bacteria break down many amino-acids and reconstitute the recycled nitrogen as bacterial protein. However, in caecal fermenters, all the bacterial fermentation takes place below the small intestine where most amino-acids are absorbed, and the essential amino-acid variety has to come from either coprophagy as in rabbits (Eden, 1940), or from dietary diversity (Janis, 1976). There is evidence that non-ruminant herbivores are dependent to some extent on microbial protein (Robinson and Slade, 1974), but the mechanism of absorption is unknown, and intake of dietary protein is essential.

A second factor favouring a more diverse diet among perissodactyls is that, unlike ruminants, caecal fermenters are unable to benefit from bacterial degradation of plant toxins. In caecal fermenters, most toxins are absorbed in the small intestine before fermentation takes place (Freeland and Janzen, 1974). While other mechanisms of detoxification exist (*e.g.* microsomal degradation), one way of avoiding a toxic dose of any one compound is to select from a wide variety of plants, because species vary greatly in the toxins they contain (Bate-Smith, 1962, 1968; Rhoades and Cates, 1976). Therefore, the presence of toxins in plants reinforces the need for dietary diversity in caecal fermenters.

Many plant secondary substances have been implicated as defensive against herbivores: a natural division occurs between plant toxins which act on metabolic processes within the herbivore, and digestibility-reducing substances which act within the gut to reduce the availability of plant nutrients. Secondary compounds can be expected to affect diet selection because they are not equally distributed among different types of vegetation. They are rare in grasses, bamboos and aquatic plants, but much more common in trees and shrubs (Janzen, 1975). (The lack of secondary compounds in grasses and bamboos is compensated for by a high silica content and tough fibre which protect the plants from animals without suitable dentition.) Commonly involved classes of toxin include alkaloids and pyrethrins; while digestibility-reducing substances include tannins that form complexes with dietary protein (Mangan *et al.*, 1976).

Tannins are metabolically more costly than toxins for plants to produce and store: they tend to form complexes with the plant's own protein. As a result, tannins are found typically in the older tissues of long-lived plants in mature ecosystems and aseasonal habitats. Toxins, on the other hand, are the most frequent form of chemical defense in young tissues of plants which are quick growers and typical of early successional stages in seasonal habitats (Janzen, 1975; Rhoades and Cates, 1976).

Microsomal degradation processes are not effective against tannins although it is possible that some specialist herbivores have developed digestive enzymes that are effective even in the presence of tannins (Rhoades and Cates, 1976; Grant, 1976). Furthermore, some tannins have been found to be capable of detoxifying alkaloids by forming complexes with them (Freeland and Janzen, 1974). However, rhinos are expected generally to include few mature parts of late-successional species in their diet, although their large body size may enable them to take in quantities of secondary compounds which would be unacceptable to smaller animals.

A third factor which reinforces the need for dietary diversity is the mineral and vitamin requirements of the animal, whether a ruminant or a caecal fermenter. Different plants accumulate minerals and vitamins to varying degrees, and a high dietary diversity helps an animal to satisfy its mineral requirements (Ellis *et al.*, 1976).

In conclusion, the Indian rhino, like all herbivores, is expected to select the least fibrous, most nutritious, least toxic plants available, but it is adapted to be able to survive on abundant fibrous non-toxic food supplemented by a wide variety of other plants, especially varied if some of them contain toxins or if essential minerals and amino-acids are lacking. The hypsodont dentition of the Indian rhinos is an adaptation to deal with the abrasive silicates found in grasses (Simpson, 1950), and indicates that the species is primarily a grazer.

4.7.2 The observed diet

In this section, the theoretical predictions of the diet of rhinos are compared with the observations. Seasonal and spatial variations in food availability and the rhinos' diet are discussed in Section 6.1. Fig. 4.2 shows the distributions of first feeding observations across seven food items in five different habitat types according to the season. I weighted these data to take into account differences in the relative importance of each habitat for feeding: the areas of each habitat and the mean rates of sightings of feeding rhinos in each habitat (Fig. 4.4) were considered. Appendix N shows the steps in the calculation of the weighting factors. Table 4.19 shows the overall composition of the rhinos' diet in each season calculated from the data in Fig. 4.2 and Appendix N. Three classes of food are considered: grass, browse and aquatic plants: note that the data do not include observations made in sal forest or cultivated land.

*Table 4.19. Overall composition of the rhinos' diet in each season.**

	FMAM	JJAS	ONDJ
Grass	86.4%	88.7%	70.4%
Browse	8.4%	5.6%	21.6%
Aquatic plants	5.2%	5.7%	8.0%

* Calculated from the data in Fig. 4.2 and Appendix N.

(a) Grass

Grass made up between 70.4% and 88.7% of the diet according to the season (Table 4.19), and the species of grass eaten varied seasonally (Section 4.3). Fifty species of grass were eaten, including some, such as the aromatic *Cymbopogon* spp., which are generally considered as unpalatable to cattle and other ruminants (Field *et al.*, 1973) and were not observed eaten by other ungulates in Chitawan.

Although tall coarse grasses were eaten when young grass was scarce (Section 4.3), the animals selected mainly for young growth stages. After the burning of the long grass areas in the spring, the young shoots of *Saccharum* spp. and *Narenga* spp. were the most preferred: later in the year, the short annual grasses which appeared at the start of the rains were the most preferred (Section 4.3.5). Grass has a low protein to fibre ratio: for most of the time the ratio is lower than for browse, but in young grass it is high, as there is only a small amount of structural material (McKay, 1973; Field, 1971). Grass is also abundant and low in toxins, and therefore fits the description of the expected staple food of the rhinos. The rhinos' tolerance of the aromatic compounds present in such grasses as *Cymbopogon* spp. is probably a result of large body size diluting the effect on the animal. This ability to tolerate small quantities of a number of different types of toxin may also explain the animal's ability to eat from a wide variety of species and thus obtain any rare nutrients or minerals present in some.

Agricultural crops such as rice, wheat and maize are highly nutritious grasses grown in abundant monocultures and hence it is not surprising that rhinos eat these species whenever possible (Section 4.3.7). Maize is eaten in the young stages but not later in the growing season when newly planted rice is available in the same regions. Rice and wheat are eaten during all stages of growth and even after being harvested. The effects of crop-raiding on the distribution of rhinos, their movement patterns and their time budgets are discussed in Section 7.1.2.

(b) Browse and aquatic plants

Although grasses made up the bulk of the rhinos' diet in Chitawan (Table 4.19), 133 species of forbs, ferns, creepers, shrubs, trees and aquatic plants were also eaten (Section 4.3.1), and accounted for between 13.6% and 29.6% of the diet according to the season (Table 4.19). The high diversity of browse and aquatic plants in the rhinos' diet is consistent with the expected diet: it serves to decrease the effects of plant secondary compounds which are frequent in forbs, shrubs and trees, and to provide the necessary variety of minerals.

Aquatic plants provide a particularly high quality food with little structural cellulose or lignin (Boyd, 1974), and essential minerals such as sodium and calcium are generally available in higher concentrations than in grass or browse. In the Isle Royale, Michigan, submerged and floating aquatic plants were found to contain 500 times more sodium than the surrounding terrestrial vegetation (Jordan *et al.*, 1973). Oates (1974) reported that black and white colobus monkeys descend to swamps to eat aquatic plants that are high in sodium.

Trees, shrubs and forbs also have high concentrations of nutrients, especially in the young tissues. In alluvial plains such as those of northern India and Nepal where the water is washed down from young geological formations, the fertility is high (Ooi, 1959), there is less pressure for chemical defence and the plants are high in base ions (Janzen, 1975). The species of browse eaten by rhinos are mainly shrubs typical of newly colonized sandbanks and river-beds and in particular of the areas affected by domestic stock grazing (Section 4.3). These are species which probably contain few secondary compounds, and use alkaloids rather than tannins as defences against herbivores (Section 4.7.1). The dipterocarp, *Shorea robusta*, a large, slow maturing, forest tree is likely to be high in tannins, especially in the older tissues. Robb (1976) found that tannins in *S. robusta* fed to cattle complexed not only with *S. robusta* proteins but with other dietary protein, and resulted in negative digestibility coefficients for protein. The only observations of rhinos feeding on *S. robusta* were on young foliage which is probably lower in tannins than the mature foliage. Similarly, ferns such as *Pteris* spp. that concentrate tannins as they mature (Lawton in Rhoades and Cates, 1976) were eaten by rhinos only when they were young.

Leguminosae comprised the majority of the browse species in the rhinos' diet (Appendix D). This family is known to be a particularly good source of protein and also of phosphorous (Hemingway and Fishwick, 1976). Rhinos also ate 10 species of Euphorbiaceae which are known to be high in toxins and are not eaten by smaller ruminants such as cattle and deer (Laurie, unpubl. data). Perhaps a larger body size and faster throughput of digesta enable the rhino to eat more toxin-containing food than ruminants which, although they have the capacity to detoxify by fermentation, have to retain the digesta for about twice as long (Bell, 1971). The fact that baboons eat *Euphorbia* (Lock, 1972) suggests that faster throughput is more important than larger body size.

(c) Minerals

Rhinos regularly visited at least one mineral lick, in the west of the park, during the winter months. Sodium and magnesium ions were the apparent attractions to the rhinos (Section 4.3.9). Sodium in particular is known to be scarce in terrestrial green plants but it is a major constituent of mammals, comprising about 0.1% of their live body weight (Botkin *et al.*, 1973). Other potential sources of sodium in Chitawan are aquatic plants (Boyd, 1974), the ash from the charred stalks of grasses and shrubs (Kozlowski and Ahlgren, 1974), and the water which the rhinos drink. Rhinos drank from rivers, pools, lakes and even the concentrated urine and dung solution which filled their wallows during the monsoon (Section 4.3.8). Drinking the wallow water, may be a way of recycling the sodium excreted in urine and dung (Section 4.3.8). Domestic elephants provided with a daily salt ration did not drink from such water. Weir (1969) pointed out that the sites of salt lick pans in Rhodesia were originally areas with a high concentration of various soluble soil chemicals which attracted ungulates to dig them out and to wallow in them during wet periods. It is possible that the temporary wallows at Chitawan developed in the same way although, unlike Weir (1969), I did not find wallows associated with termite mounds.

(d) Differences between diets of calves and adults

When calves first started to eat solid food at the age of about two months, they appeared to select more browse than their mothers, especially creepers and fern shoots, while the mothers ate short grass (Laurie, unpubl. data). Such food was less abundant and of higher quality than grass, and therefore the calves' diet is consistent with their expected diet (Section 4.7.1).

4.8 Summary

1. Parts of 183 species of plants from 57 different botanical families were found to have been eaten by rhinos during the study period. Grass (50 spp.) made up 70% - 89% of the diet according to the season. Other foods included fruits, leaves and branches of shrubs and trees, submerged and floating aquatic plants and agricultural crops.

2. There was considerable seasonal variation in food availability and hence in the rhinos' diet. This, combined with variation in food availability between habitat types, resulted in seasonal changes in the use of different habitat types.

3. As a result of seasonal change in diet and the habitat type frequented, there were seasonal changes in time budgets and in the 24 hour cycle of activity. Rhinos spent more time feeding during winter than in the summer.

4. After taking into account the uneven distribution of searching effort

and seasonal changes in visibility in the study area, I showed that there were seasonal variations in the rhinos' use of different parts of the study area.

5. During the spring the highest rate of sightings were in the tall grass areas; during the monsoon the highest rates were on the borders of the agricultural land.

6. By comparing the distribution of the sightings of individuals with the distribution of total rhino sightings, it was shown that each individual used certain parts of the study area more than other parts.

7. Each individual's range was defined as the area enclosed by a rectangle with sides corresponding to the 90% ranges of its sightings on the east-west axis and the north-south axis. These ranges are smaller than the total area covered by the rhinos. Most individual's ranges differed from each other only with respect to the east-west axis which corresponds to the bed of the Rapti River. Sizes varied from 0.44 km^2 to 8.86 km^2 with a mean of 3.08 km^2 for adults and 3.64 km^2 for sub-adults.

8. The ranges of 57 of the 58 most frequently sighted individuals were divided into eight fairly discrete categories of size, location and pattern of use. In general, the ranges were smaller in areas of greater habitat diversity.

9. Most individuals maintained the same annual pattern of use of their ranges but adult males were more likely than adult females to change their ranging behaviour between years.

10. The rhinos' diet conformed to certain predictions about the diet of a large perissodactyl. The rhino is adapted to feed on abundant fibrous non-toxic food supplemented by a wide variety of other plants.