for experimental purposes, it is suggested that several radii be selected at the same height above the ground on each tree so that the average diameter growth and an estimate of its error can be calculated. An alternative would be to take only one measurement per tree, but to measure a large sample of trees so that the average growth with its error of estimate can be calculated.

It is recommended that the word "precision" should not be applied to the dial gauge dendrometer since it is misleading and tends to give misplaced confidence in an instrument whose precision is limited as adapted for forestry purposes.

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TERRITORIAL AND SEXUAL BEHAVIOR IN THE GREAT INDIAN RHINOCEROS, A SPECULATION

The amount of information which is available about the life history, behavior and social organization of any one of the species of living rhinoceros is so scanty that no detailed or authoritative study is possible. This is a potential tragedy, as more than one of the five living species is threatened with extinction. *Rhinoceros sondaicus* Demarest, the Lesser One-horned Rhinoceros, apparently lingers in very small numbers only in west Java. *Rhinoceros sumatrensis* G. Fischer, the smallest of living species, is estimated (Ansell 1947) to number between 21 and 45 individuals in Burma with perhaps a scattering in Malaya, Sumatra, Indochina and Borneo. These species are particularly secretive forest dwellers, relatively inaccessible to an ecologist.

The Great Indian Rhinoceros, *R. unicornis*, on the other hand, lives in the open, in large park-like areas of swamp along the banks of the northern feeders of the Gangetic River systems in central Nepal, northern Bengal and Cooch Behar, and in Assam on either bank of the Brahmaputra River. A proper ecological study could and should be made of this species, of which Mr. Salim Ali and I estimated that there were just under 300 individuals left in 1949. Mr. Ali published an abstracted report on our findings for the International Technical Conference on the Protection of Nature (1950), in which he made a plea that a proper census and ecological study of this vanishing species be performed as part of the groundwork for any attempt at conserving these extraordinarily interesting animals. No action so far has been taken on this report by the Indian Government or other interested agencies, although the need remains great. Undoubtedly funds could be found for such a work provided an interested biologist would come forward to undertake such a study. The following tentative notes based on observations made in 1947, 1949 and 1950 are intended only as a suggestion and a potential line of thought about this fascinating problem.

The reason for the decline of all the Asian Rhinoceros species is the prevailing mythological belief, particularly among the Chinese, in the curative and aphrodisiac powers of rhinoceros horn, either powdered and taken internally, or rubbed against an affected part of the body, or indeed as a sort of talisman, used as a cup in votive ceremonies. In the latter form it would seem to be linked with the mediaeval European belief in the poison-sterilizing properties of a rhino horn cup for drinking. Other products such as blood and urine are sold as well, and the Calcutta Zoo finds a ready market for small bottles of urine from their captive *unicornis* at 14 annas (17 cents) each. Poaching of the three species of rhinoceros still goes on, although presumably the very decline in numbers of the species will make it increasingly unrewarding as an occupation. However, the political disturbances in Malaya, Java, Indochina and Burma with well-armed gangs using inaccessible trails in the jungles of those countries will undoubtedly be a continuing menace to the small *sumatrensis*.

Breeding

Scant data is available on the longevity or on the age at which breeding commences in the Great Indian Rhinoceros. A pair has been known to live 45 years in captivity. An age of 50–60 would seem a reliable guess, a comparable age to that of the elephant. As with the elephant, it could be presumed that a rhinoceros is adult by 12–15 years of age, although it may continue to grow after that. The gestation period is approximately 19 months (Ali 1927), and young at birth may weigh from 75–120 pounds.

From the above it will be seen that the female rhino cannot breed annually. Assuming a minimum lactation period of six months, a gestation period of nineteen months means that at the most a female in the prime of life could not mate more than every twenty-five months. Actually a cow rhino seems to keep her calf with her for far longer than six months. Perhaps three to three and a half years would be the shortest average time between breeding.

At present there is an adult pair in a roomy enclosure in the Calcutta Zoological Gardens. This pair has never bred because, as has been observed by the administering officials (personal communication), the female *or* the male may come into breeding condition, but so far their periods have not coincided. At one particular time the female may be in heat and receptive to the male, and at another time the male apparently comes into "rut," only to be refused by the female. From observations in captivity an unmated female will come into heat about once a year, and similarly a bull rhino will have an annual breeding or "rut" cycle. The length of this breeding cycle is uncertain but in captive animals it is only of a few days duration.

I cannot find any exact data on the time of breeding during a year. A pair that did breed in the Calcutta Zoo bred in March. The adult female at the Chicago Zoo has shown sexual excitement only once, in September, 1949, (personal communication). At the Kaziranga Sanctuary in Assam, the largest (164 sq. mi.) reserve for these animals in India, and the one with the estimated largest population (anything up to a figure of one per square mile of sanctuary area = maximum of 164), there are no accurate records of the breeding season. Young animals have been seen running behind their mothers in March at an estimated age of perhaps two months. This would mean a conception in June. Other young have been seen in January of a size to indicate a March mating. Mr. E. P. Gee reports (*in litt.*) matings in

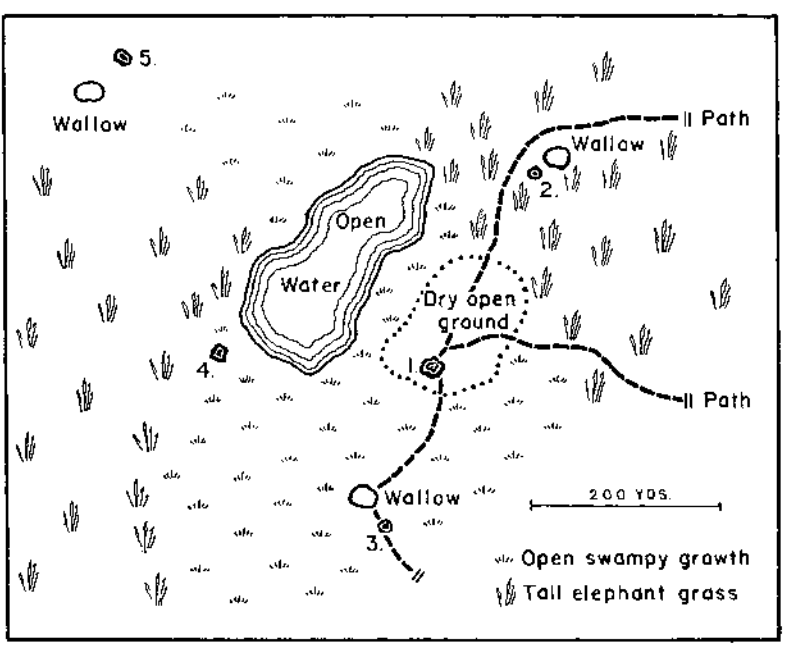

Fig. 1. Schematic diagram of a Great Indian Rhinoceros territory, showing central hard-trodden area, radiating paths, wallows, and central (No. 1), and outlying (Nos. 2, 3, 4) dung heaps. No. 5 dungheap and the wallow across the open water presumably belong to another animal.

February and April, and has seen newly born calves in November. All stages of slightly larger young have been seen in autumn, winter and spring, so that one can only presume that there is an extended and irregular breeding season with the spring months more generally favored.

Territory

The Great Indian Rhinoceros is noted for its habit of choosing a particular spot for the deposition of dung. These piles or mounds are usually in the center of a cleared area, and may be several feet high, perhaps three in the center, spreading outwards to a radius of four or five feet. Other smaller piles may be found on trails, in small clearings along trails or near wallows. The consensus of local opinion is that these piles are created by individual animals of either sex. The rhino is distinctly an unsociable animal. Two adults are never seen together except during a fight or when mating. The implication then is that these dunghills are territorial markers and that during part of the year each individual male or female rhino is king or queen of his or her own dung heap. The dung is deposited in balls about the size of a duckpin bowling ball, and the hill is created by the rhino's habit of slowly backing up to the mound in order to defecate.

The actual size of a territory seems to be a variable one. At Kaziranga there is one particularly favorable area along the bank of the Mora Diphlu stream where 14 or 15 animals may be seen in a morning's elephant ride. Elephants are used to get into rhino country here because of the great height of the grasses (up to 20 feet), the deep swampy streams and morasses, and the uncertain temper of the rhinos themselves. An average territory here would consist of perhaps 20–50 acres, usually near one of the *bhils* or swampy ponds, the shores of which are turfed with shorter grasses, on which, along with water plants, the rhinos graze. During the spring burning season, rhinos also graze on the tender young shoots of the heavy elephant grass, cane, and wild ginger, which form such a dense and enormously high growth most of the rest of the year. A typical territory then might appear somewhat like Figure 1.

Two rhinos may divide a *bhil* between them, apparently sharing opposite banks. Each rhino will have one or more wallows, on which it is dependent for a daily lubrication of the hide with liquid mud. In other parts of the Kaziranga Sanctuary, the size of the "territories" seems much larger. Rhinoceros may be one to a pond, or one to every other pond, or lacking altogether for a square mile or two for no readily observable reason.

Wandering

At certain times of the year the rhinoceros appears to wander far away from its haunts. During March, 1949, when Mr. Ali and I were studying the rhinos at Kaziranga, we continually visited old territories with old dung heaps dating back to the previous summer. The rhinoceros occupying each of these former territories had apparently moved somewhere else. At the same time we were told of an individual rhino which had recently swum across the Brahmaputra River to the north bank and had arrived in the Orang Sanctuary in Darrang District. All local observers were certain that the rhinos do move about periodically, although they had no specific data about the season. But it seemed significant to me that many of the animals were away from their habitual grounds during March in the middle of the supposed spring breeding season.

At this spring season, or at any rate when in mating condition, rhinos are said by the local inhabitants to emit a different call. Their ordinary notes are occasional grunts or low bellows of alarm or anger. The so-called mating call is a sweet high whistle, very penetrating and presumably capable of being heard for a long distance by another rhino. I have heard this sound only once, in March 1949, and was told by the mahout that it was a rhino. In addition, rhinos project their urine with great force backwards and may discharge it over quite an area of grass or trees. It seems safe to assume that it is an important recognition signal to these animals whose power of scent is well developed. By analogy with other mammals the urine during oestrus would doubtless be recognizable to the male.

Significance of Wandering

From the above scanty evidence, a supposition might be made that the Great Indian Rhinoceros tends to hold a territory during part of the year, but that at the onset of the rather indefinite breeding cycle, an individual may leave its territory and embark on a wandering migration, a *Wanderung*. Recognition apparatus is provided by the urine "sign," plus the high-pitched call. Since both sexes must be in an equivalent condition which persists only for a short time and is not adequately synchronized by the environmental cycle of the seasons, then males and females may have to wander very considerable distances in order to meet a physiologically-attuned member of the opposite sex. This is reminiscent of the condition in some of the *Mustelidae* (Marshall 1939). The very long gestation period, lasting well over a year, may be involved also in producing the irregularity of response to season changes. This wandering form of migration to secure a mating

would also tend to explain the occasional long-distance trips known to be performed by these otherwise territorial animals. From time to time, an animal will appear in an area in Assam where the species has not been recorded for many years. The small *R. sumatrensis* is also a great wanderer (Thom 1944). The only way in which such a speculation as the above could be proved or disproved would be of course by some method of banding or marking individuals. Meanwhile comments or added data would be greatly welcomed.

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INSECT REMOVAL OF NITROGEN AND PHOSPHORUS COMPOUNDS FROM LAKES

The general features of the limnological cycle of nitrogen are known from the work of Mortimer (1938), and those of the phosphorus cycle from Einsele (1941), Hutchinson (1941) and Hutchinson and Bowen (1950). However an attempt has apparently never been made to include the role of aquatic insects in the conceptual framework of either cycle. This group has the peculiarity among lake organisms of spending the adult stage of the life cycle outside the hydrosphere. It is likely that many of the adult insects which emerge from lakes never live to return there, as Borutsky (1939a, 1939b) has shown for three species of Diptera from Lake Beloie. Since the adult mass is almost entirely derived from the lake bottom, a depletion of the chemical energy of the lake basin must result. It therefore becomes of interest to know the quantities of chemicals removed by adult insects, and the relations that these bear to the corresponding amounts sedimented. The present study was limited to analyses of total nitrogen and total phosphorus in freshly emerged adult insects from Lake Opinicon, Ontario. The author is indebted to Dr. H. W. Curran for permission to carry out the investigation at Queen's Biological Station.

Needham (1908) first devised a method of trapping adult insects as they emerged from a water surface. He named the pyramidal structure a tent trap. Modifications used by later workers have been given the names of Auffange-Netz or collecting net (Grandilewskaja-Decksbach 1935), emergence cage (Ide 1940) and Fangtrichter or funnel-trap (Brundin 1949). The general name of emergence trap is suggested for all devices designed to sample the emerging adults of aquatic insects, with a subdivision into floating and submerged types. The utility of the method has been discussed by Ide (1940) and requires no further comment here except to note that Macan (1949) found floating traps to act selectively in the collection of some dragonflies. Adults of *Pyrrhosoma nymphula* were never collected in Three Dubs Tarn by floating traps although the naiads were abundant in the bottom and adults did emerge elsewhere.

During the summer of 1951 a latin square experiment was designed and executed to test the hypothesis that floating emergence traps of different size and shape collect the same number and kind of aquatic insects per unit area of surface covered. A series of five traps was used in the experiment. The traps were arranged in the form of a circle in a shallow bay of Lake Opinicon, Ontario, at the location 24.4–12.6 on the bathymetric map of Lake Opinicon published by Curran, Bardach, Bowman and Lawler (1947). The results of that experiment will be reported at a later date. Interspaced among the five traps of unequal size and shape were five others, all cubical, each covering 0.25 m.^{2} of water surface. The collections from the latter were used for chemical analysis. The wooden framework of each trap was enclosed on the four sides and on half of the roof by a translucent plastic-coated screening. The other half of the roof was covered with a double layer of cheesecloth to permit air exchange. The traps were supported by 4 by 4 in. wooden floats in such a way that the bottom of each trap was 15 cm. below the surface of the water. Each float was tied to two poles which had been