Omelene 100: commercial horse chow, manufactured by Ralston Purina Company.
Pet Milk: manufactured by Pet Industries, an IC Industries, 400 South Fourth Street, St Louis, Missouri USA.
Mixed cereal: manufactured by Gerber Products, 10825 Watson Road, POB 22068, St Louis, MO 63127, USA.

Nasco calf nipple: rubber nipple with cross-cut opening (no. C1561N), manufactured by Nasco, 901 Janesville Avenue, Fort Atkinson, WI 53538, USA.

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Activity cycles of the Southern white rhinoceros *Ceratotherium s. simum* in captivity: implications for management

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The first fully documented case of a rhinoceros in captivity was in 1834 with the arrival of an Indian rhinoceros *Rhinoceros unicornis* at The Zoological Society of London (Crandall, 1964). It is recognised that members of the Rhinocerotidae were held in captivity long before this although exactly which species were kept is uncertain. The Southern white rhinoceros *Ceratotherium s. simum*, however, was virtually unknown in zoos until 1946 when an orphaned ♀ calf was successfully reared in Pretoria, South Africa (Bigalke, 1947; Bigalke *et al.*, 1950; Bigalke, 1960). The endangered northern subspecies *C. s. cottoni* is still rare in captivity.

Since the success at Pretoria the number of White rhinoceroses, particularly the southern subspecies, has progressively increased. The captive population numbered 351 on 31 January 1977 (Klös & Frese, 1978), growing to 558 by 31 December 1980 (Klös & Frese, 1981). The increase has been due not only to translocations from the wild but also to successful breeding in a number of zoological collections. These collections owe their success mainly to the careful consideration they have given to exhibiting the animals in groups of optimum size and sex ratio. The two largest groups are at San Diego Wild Animal Park in the USA and Whipsnade Park in Great Britain. Data obtained for the *Yearbook* census of rare animals in captivity show that on 1 January 1982 San Diego held 20 individuals and Whipsnade held 15, although numbers do fluctuate over the year.

A study of the behavioural ecology of 14 Southern white rhinoceroses at Whipsnade was carried out from May to August 1982. One of the aims of the study was to see how the activity cycles of the animals at Whipsnade compared with data on the species in the wild in order to determine whether any obvious changes in management could be suggested so as to encourage more natural behaviour. Observations were made only during the summer months because it is at this time that the animals are likely to exhibit the most natural activity patterns since there are few disturbances caused by management procedures such as restricted feeding times. The group of 14 rhinoceroses consisted of two adult ♂♂, eight adult ♀♀,

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two subadult ♀♀ and two ♀ calves. The group is kept in a 12·14 ha grass-covered paddock bounded partly by strong fencing and partly by a dry moat.

During the three-month study period data were collected in five-hour blocks of time, usually two in 24 hours, for a total of 80 blocks (400 hours). The majority of the observations were made by day using 7×50 or 9×25 binoculars, although some night-time viewing (seven five-hour periods (35 hours)) was possible with the aid of an image intensifier. Observations were made on consecutive days for a minimum of three and a maximum of ten days, the number of days elapsing between observations ranging from five to 14. Watch periods normally began at 0500, 1000 or 1500 hours and the data were unevenly distributed throughout the day. Observation methods included point sampling, where one individual was chosen each day as a study animal and its location and activity were noted at five-minute intervals (as close to the minute as possible). Individuals were easily identified through horn shape, body size, folds and scars; some animals also had coloured numbered tags in one ear pinna. Location was determined using landmark proximity and compass readings and was recorded on a map which was later used to obtain an indication of the daily range of the animal. Activities were noted on data sheets. Any hours missed on one day were made up for on a subsequent day so that full records for each animal were obtained. To determine group composition and social interactions scan sampling of all the animals in view was done every half hour during the same period as the point sampling. The distance of each individual from its nearest neighbour was estimated on the basis of the number of body lengths (*c.* 5 m) they were apart (Owen-Smith, 1973), and a group was defined as a set of animals located within 20 m of one another that moved as a unit. Although social behaviour was recorded, it is not considered in this paper.

As in the wild (Owen-Smith, 1973) captive White rhinoceroses are active during the day and at night, alternating between sleeping and grazing. The percentages of time devoted to different activities are represented in Fig. 1. Over 24 hours the rhinoceros group spent 48·8% of its time feeding, 43·5% resting and 7·7% involved in other behaviours including vocalisation, defecation, urination, sexual behaviour, walking without feeding, running, drinking, fighting, standing and suckling. Resting was categorised as animals lying down but occasionally they dozed while standing and this was recorded as resting also.

DAILY ACTIVITY CYCLE

Three peaks of activity are evident from Fig. 1 although the early morning peak might not be as marked as it appears because the data from 2200–0400 hours are few. A curvilinear regression analysis of only daytime data confirmed that there is significant variation in the percentage of time devoted to feeding and resting from 0500–2200 hours (O'Connor, 1982). In another analysis the 24-hour cycle was subdivided into six four-hour units, in an attempt to reduce the effects of the small number of night-time samples, and was tested for variability (Fig. 2). The decrease in feeding activity at night proved significant (Kruskal-Wallis test $\chi^2 = 11{\cdot}45$, DF = 5, $p < 0{\cdot}05$) although this particular test did not reveal any daytime variation possibly because of the arbitrarily chosen time units.

Grazing more or less continuously over a 24-hour period is a feeding strategy found in animals with very large body sizes and non-ruminant-type digestion. African and Indian elephants *Loxodonta africana* and *Elephas maximus* are examples of other species that have adopted this routine although they spend significantly more time feeding than resting (McKay, 1973; Wyatt & Eltringham, 1974; Vancuylenberg, 1977). The food of large mammals such as elephants and rhinoceroses passes through the gut quickly and they must therefore continue to feed throughout much of the day in order to obtain sufficient bulk (Field, 1968; Owen-Smith, 1973; Geist, 1974).

VARIABILITY

There did not appear to be much day-to-day variation in activity patterns although on very hot days rest periods were often longer. On

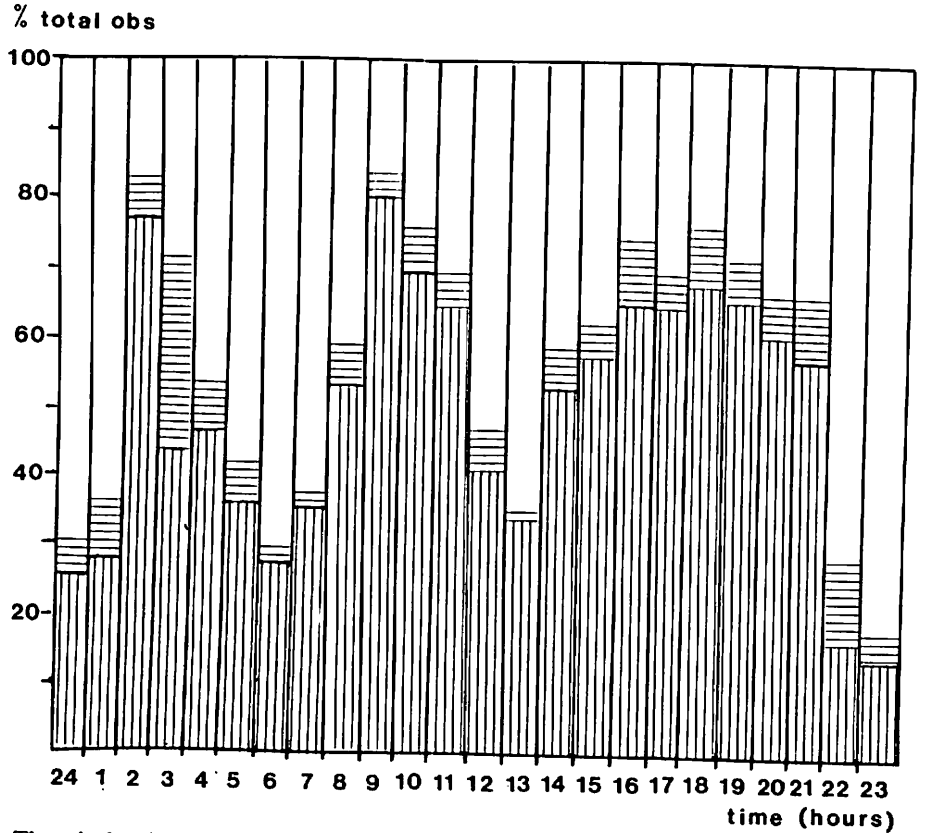

Fig. 1. The calculated percentage of time spent over 24 hours on three categories of activity by representative individuals from each age-sex class in the group of Southern white rhinoceroses *Ceratotherium s. simum* at Whipsnade Park. The pattern has been determined on the basis of a total of 700 half-hour scans and 4800 point samples taken during twice-daily five-hour periods between May and August 1982. The percentages shown are of the total of all these observations. Resting is represented by unshaded columns, feeding by vertical hatching and other activities by horizontal hatching.

average feeding bouts were longer than rest periods (Fig. 3), the longest continuous rest periods occurring at midday and just before dawn. The length of these rests and the places chosen for them are probably related to wind velocity and the availability of shady places as well as to the proximity of other individuals and of the public.

A typical day for the rhinoceroses during the summer usually progressed as follows: One or two hours after dawn (*c.* 0500 hours) the animals woke and stood up, after which a feeding bout lasting several hours began almost immediately. The calves stood near their mothers during the early morning and ate only a little grass since they spent most of their time suckling. While grazing the rhinoceroses moved in a slow but progressive manner which allowed them to pluck the grass firmly with their lips as they moved their heads from side to side across the ground. In this way the animals were exploiting a uniformly distributed food source. Grass cut from other zoo paddocks was sometimes offered during the late morning. The food was distributed using a tractor which most of the rhinoceroses approached and followed for a short distance. The animals seldom fed on the cut grass for more than 20 minutes in total and usually some remained uneaten. At midday a rest period of one to two hours was common, followed by another

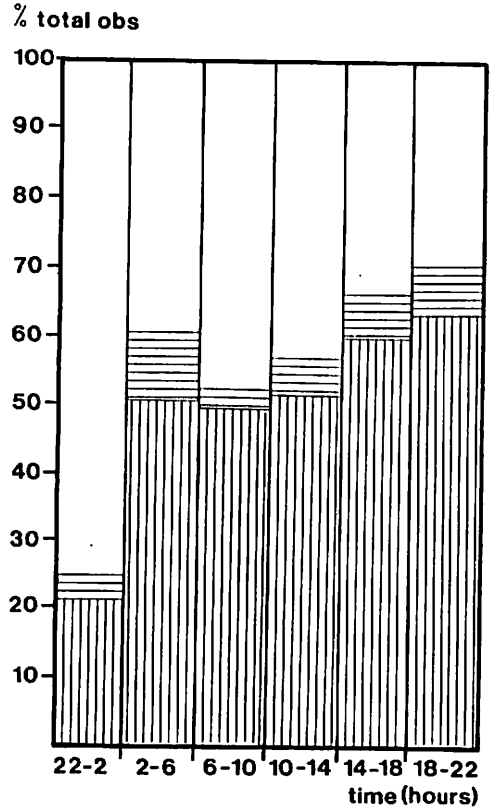

Fig. 2. The 24-hour activity pattern shown in Fig. 1 divided into six four-hour units in order to reduce the level of inaccuracy caused by the small number of night-time observations. Resting is represented by unshaded columns, feeding by vertical hatching and other activities by horizontal hatching.

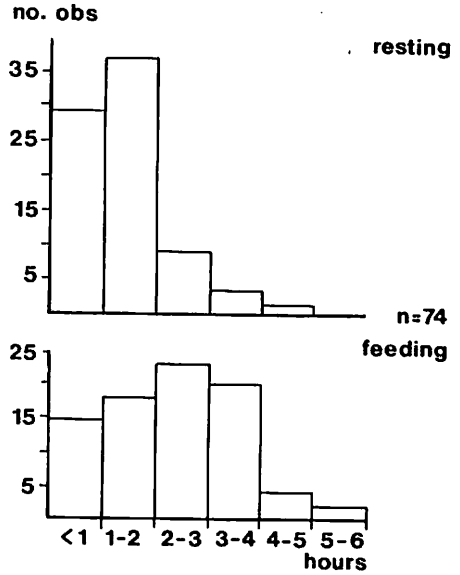

Fig. 3. The various lengths of resting and feeding bouts of a group of Southern white rhinoceroses, based on a total of 148 point samples (74 on resting and 74 on feeding) of representative individuals from each age–sex class.

feeding session in the late afternoon. They continued feeding until dark although short rest periods often alternated with feeding bouts during the rest of the day. It is likely that day-to-day variation is more extreme at other times of the year. The weather, particularly winter storms, day length and management restrictions would all be important factors during other seasons.

AGE-SEX CLASS DIFFERENCES

No differences were found between the proportion of time given to various activities by different age-sex classes except, as one would expect, for calves (Table 1). The age-sex classes which were represented were adult ♂ (aged 14 and *c.* 18 years), adult ♀ (8–27 years), subadult ♀ (4 and 6 years) and ♀ calf (nine and ten months old). Calves spent less time feeding on grass and more time lying and standing than did other individuals. The obvious reason is that these young animals were still dependent on their mothers and were nursed several times a day. The calves were also more inquisitive, regularly investigating other animals as well as objects. There were noticeable individual differences in the times of day that bouts of feeding or resting began, but the total amount of time over 24 hours was very similar. It is interesting that the ♀♀ representing all phases of the reproductive cycle did not feed for appreciably longer periods (Table 1).

The adult ♂♂, particularly the subordinate (18-year-old previously dominant) one, devoted more time to miscellaneous behaviour such as walking and standing than either adult or subadult ♀♀. Owen-Smith (1973) also recorded more participation in these types of activities by adult ♂♂ in the wild than by any other age-sex class. Presumably,

AGE-SEX CLASS	NO. OBS	% TOTAL OBSERVATIONS			
		GRAZING	LYING	STANDING	WALKING
Calf*	325	23	49	13	15
Adult ♂ (dominant)	696	57	29	8	6
Adult ♀	298	59	33	6	1
Subadult ♀	456	57	30	8	5
Pregnant ♀	561	61	27	9	3
Adult ♀ with calf	384	51	35	12	2

*Suckling by the calf is not included in the figures given.

Table 1. Results of an analysis to determine the proportion of time spent on four activities by one representative from each of the age-sex classes in the group of Southern white rhinoceroses *Ceratotherium s. simum* at Whipsnade Park; the same information is shown for a pregnant ♀ and a ♀ with calf. The figures are based on point samples taken every five minutes during twice-daily five-hour periods.

standing and walking are investigative activities that enable a dominant ♂ to determine who is within his territory, and a subordinate ♂ to observe the location of the dominant ♂.

WEATHER

The relation between activity and weather conditions was not analysed in detail but a number of researchers have shown that many species of rhinoceros become inactive during the hottest part of the day (Goddard, 1967 and Schenkel & Schenkel-Hulliger, 1969 for the Black rhinoceros *Diceros bicornis;* Owen-Smith, 1973 for the White rhinoceros; Laurie, 1982 for the Indian rhinoceros *Rhinoceros unicornis*). On hot days at Whipsnade the midday rest period was often extended, probably because the mechanism for heat loss in very large animals is not particularly efficient. Therefore, unless the animal has special morphological adaptations for heat dissipation (such as the large ears of the African elephant) it becomes fairly inactive or rests in a shady area.

Data on the temperatures around the Whipsnade area were available and a preliminary analysis using a Spearman rank correlation test was conducted between these and the time spent feeding; the results were not significant ($rho = -0{\cdot}129$, $N = 20$, n.s.). On the other hand Owen-Smith (1973) found an association between lower temperatures and increased midday activity, although cloud cover was seen to have more influence on activity levels than temperature. Furthermore, peaks in daily activity were found to be influenced by ambient temperatures and amount of exposure to the sun's rays. The cooler temperatures at Whipsnade in the early morning may lead to the rhinoceroses rising later but having longer feeding sessions once they have begun grazing.

DISCUSSION

A number of important factors must be considered if natural activity cycles are to be induced in a captive environment. Natural behaviour is most likely to be exhibited by graminivores because they can become to some extent independent of the restrictions imposed by captivity. The size of the paddock is the foremost consideration. Sufficient grazing to accommodate captive animals precludes the need for providing them with other food. Naturally 'sufficient grazing' depends on the number of animals, the availability of grass, its productivity and its nutritional content. The close cropping action of the White rhinoceros stimulates rapid growth on grassland and increases its level of productivity. Minimal supplemental feeds, particularly during the summer in temperate regions, decrease the number of keeper disturbances and interruptions of the activity cycle. From the point of view of management, paddock

animals require little attention during the summer; this is particularly true of rhinoceroses since they defecate in communal dung piles.

Other management considerations include adequate wallows, rubbing posts and shady resting places. Again, the number of interruptions decreases if these facilities are available because veterinary care and indoor lock-up can be kept to the minimum. During the study at Whipsnade the rhinoceroses rarely needed extra care except, occasionally, for the treatment of injuries created by Magpies *Pica pica*. These birds would open up the skin and eat the flesh until a sizeable wound had developed; none of the variety of treatments given so far has been successful in deterring the birds.

It is likely that the activity cycles of captive animals are affected by certain weather conditions; these would be most noticeable in temperate areas. The most obvious are temperature, wind velocity and sunshine, since variations in these factors lead to the animals adjusting the beginning of feeding and resting bouts and their duration. Victor Manton (pers. comm.) has noticed that the Southern white rhinoceroses at Whipsnade are slower to become active on cold and misty days. Day length might also be important since the rhinoceroses feed more during the daylight hours which are more variable in England than in the tropics. Weather is not only important from the point of view of activity. Rawlins (1979) suggests that it is an indirect cause of the differences in total number of offspring born at Whipsnade and San Diego Wild Animal Park. The composition of these two groups was very similar when they arrived at the zoos in 1970 and 1971, respectively, and their breeding rates should have followed a similar pattern; the group at San Diego, however, has produced almost twice as many calves. The discrepancy is probably due to necessary differences in management; ♀♀ which calve in winter at Whipsnade are sometimes shut indoors, occasionally for several months, to protect the newborn from cold weather whereas the milder climate at San Diego requires no such action. This is the likely reason for the different mean interbirth intervals of 19·5 months at San Diego and 29·5 months at Whipsnade (Lindemann, 1982).

The proximity of the public may also be a consideration if natural activity cycles are a goal. Nevertheless, at Whipsnade it was rare to find that the rhinoceroses moved away from the paddock barrier because they were made nervous by members of the public. Visitors have even been observed tapping on rhinoceroses' horns without any apparent effect. A miniature train which traverses the paddock appears not to alter the animals' activity either.

It is evident from the data obtained on the Southern white rhinoceroses at Whipsnade that it is possible to keep animals, particularly ungulate grazers, under captive conditions in which they will display natural activity cycles. In turn, natural behaviour (although social behaviour has not been considered in this paper) improves breeding success and provides educational opportunities for zoo visitors.

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Analysis of reproductive data on the Addax *Addax nasomaculatus* in captivity

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The Addax *Addax nasomaculatus* is an increasingly rare North African desert antelope, designated as Vulnerable in the IUCN *Red data book.* The present report is part of a study currently under way on the species' reproductive biology in captivity and on possibilities for the use of artificial insemination as a means of increasing the captive population.

Records provided directly by 25 zoos (listed in the Acknowledgements at the end of this paper) and obtained on 27 zoos through the International Species Inventory System (ISIS) were collated and information on 1055 Addax in a total of 32 zoos was analysed to obtain basic data on various aspects of captive reproduction in the species. A total of 1014 births (including stillbirths) was reported from 31 collections between 1975 and 1981; all but one of the collections lay in the Northern hemisphere. Unfortunately we were unable to ascertain the exact number of ♀♀ to which the births referred because of inadequate record keeping by some of the zoos.

BIRTH SEASON

In contrast to Addax in the wild which calve only in winter or early spring (Nowak & Paradiso, 1983) captive Addax may calve in any month of the year. The frequency of 986 births in 30 zoos in the Northern hemisphere varied from month to month, with fewer than the mean number of 82·2 births (range, 53–115) occurring from July to November (Fig. 1a). This distribution of births differs