ELSEVIER

Applied Animal Behaviour Science 50 (1996) 95–114

APPLIED ANIMAL BEHAVIOUR SCIENCE

Behavioural observations of reintroduced Takhi or Przewalski horses (*Equus ferus przewalskii*) in Mongolia

M.C. van Dierendonck *, N. Bandi, D. Batdorj, S. Dügerlham, B. Munkhtsog

MACNE, Mongolian Association for Conservation of Nature and Environment GPO Box 1160, Ulaan Baatar, Mongolia

Accepted 9 May 1996

Abstract

During 1992 and 1993, 14 reintroduced Przewalski Horses or Takhi (*Equus ferus przewalskii*) were studied in the Hustain Nuruu Mountain Steppe reserve in Mongolia. Most of the individuals did not know each other before reintroduction. These Takhi were the first of five groups due to be released in the reserve after an acclimatisation period of at least 1 year. During acclimatisation the Takhi, lived visually and acoustically separately, in fenced enclosures of approximately 45 ha each. The observations, mostly scan-sampling, were carried out in each season. The observation bouts were divided over six periods and over two harem herds. Two of the periods were in the same consecutive seasons, so comparison over the years was possible.

Social integration within the Takhi herds was very high from the beginning, as described by the spatial relation and synchronisation data. Between 50 and 89% of the observation time, the behaviour of all herd members was synchronised. The amount of time spent grazing by the Takhi (30–68% of the daylight period) was similar to that of feral horses and Takhi in captivity and semi-reserves. The Takhi tended to rest in the morning and have a bimodal period of grazing at dawn and in the afternoon. The Takhi displayed clear habitat preferences for certain activities. They had a strong preference to rest at the highest point in their enclosure. They fed preferably on two or three different vegetation types (with five types available in each enclosure). The amount of time spent grazing during the non-growing seasons (49 $\pm$ 15%) indicates that the feeding value and availability of food were sufficient. Health changes were detected adequately using condition scoring sheets. No supplementary food or water was supplied during the harsh winters. Moreover,

* Corresponding author at: FIRE, Jollenpad 20, 1826 AT Alkmaar, Netherlands. Tel. +39 72 5623098; Fax +39 72 5646486.

PII S0168-1591(96)01089-1

low mortality rates and high reproductive success show that the mountain steppe is a habitat which is potentially suitable for establishing a healthy Takhi population. Takhi is the first species to return to its native habitat after living only in zoos for so many generations.

Keywords: Horse; Przewalski's horse; Reintroduction; Time budget; Social organisation; Basic reference dataset

1. Introduction

For many conservationists the Przewalski Horse or Takhi [1] (*Equus ferus przewalskii*) is the best example of a species which has been successfully saved from extinction by breeding in captivity. However, management practices (carried out in ignorance of current genetic and behavioural knowledge) during the first decades of the century, further reduced the small genetic basis (Bouman et al., 1982; Ryder, 1994; Volf, 1994). Today the detrimental impact of inbreeding on reproduction has been largely overcome (Volf, 1988), but careful selection of potential partners is still needed. World-wide, there are five regional breeding programmes for some 1300 captive Takhi, established in North America, continental Europe, the United Kingdom, the former USSR and Australia.

Many reasons can be given for their extinction in the wild (summarised and discussed by Boyd and Houpt, 1994 and Van Dierendonck and Wallis de Vries, 1996). There is an ongoing debate concerning the 'historic range' of this species and whether this range should be determined based only on the recent past or rather on a broader period encompassing the entire known history of the species. (Mongolia Takhi Strategy and Plan Work Group, 1993; Boyd and Houpt, 1994; Van Dierendonck and Wallis de Vries, 1995, 1996). After reviewing the available evidence, Van Dierendonck and Wallis de Vries (1996) concluded that the Takhi are primarily a steppe herbivore which can survive under arid conditions. The last refuge, the Dzungarian Gobi in Mongolia, is probably a marginal habitat rather than part of their optimal habitat.

After 10–14 generations in captivity the breeding programmes have had some success, with a surplus of (mainly) stallions. Takhi are the first species to return to their native habitat after living only in zoos for so many generations. Because of the long and unnatural selection in captivity, an intermediate step in semi-reserves before sending individuals to central Asia has been advocated (Bouman and Bouman, 1992; C. Feh, personal communication, 1993). Semi-reserves have been set up in several countries with the aim of pre-adapting the Takhi physically and socially to their release in the wild (Duncan, 1992a; Bouman and Bouman, 1992). Almost all information concerning their ethology and ecology is from zoos, wild parks and semi-reserves. Most scientists assume that in the wild their behaviour does not differ greatly from that of feral horses. However, some predict a more aggressive role of the stallions, based on observations in semi-reserves and zoos (Kolter and Zimmermann, 1988; Boyd, 1991). All new informa-

[1] We use the Mongolian name Takhi, because the name Przewalski Horse is misleading, owing to its association with the domesticated horse.

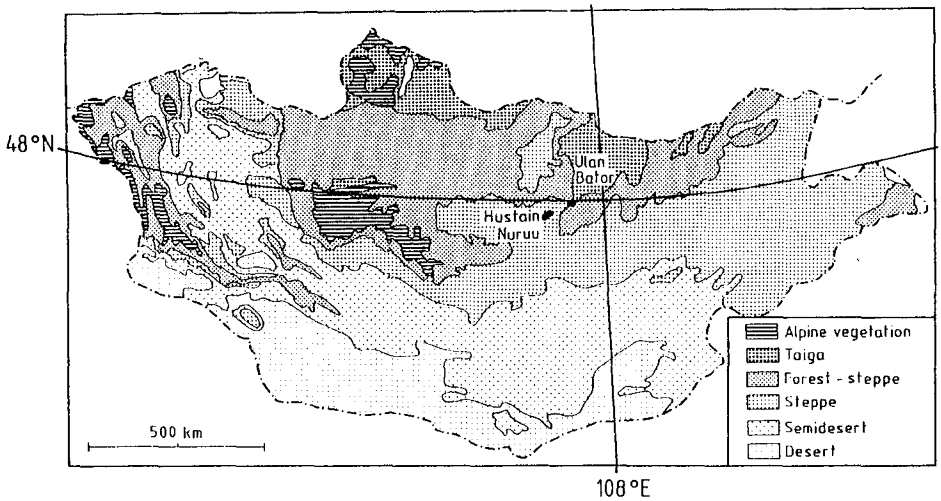

Fig. 1. Map of Mongolia, with main vegetation zones.

tion available on the development of their ethology and ecology in the reintroduction projects is important for the understanding of their ecological requirements and ethology.

Currently three reintroduction projects are planned in Mongolia, two have Takhi adapting on site (Mongolia Takhi Strategy and Plan Work Group, 1993; Van Dierendonck and Wallis de Vries, 1996). The project described below advocates the Takhi as a true steppe species. It organised the reintroduction of the species in the Hustain Nuruu Mountain Steppe Range, about 130 km west of Ulaan Baatar (Fig. 1). The reintroduction is embedded in the broader perspective of a nature reserve with a much wider perspective than a merely biological one (Foundation Reserves Przewalski's Horse, 1992; Germeraad et al., 1993).

The aim of the part of the project concerned with the reintroduction of Takhi is to send and manage five times, every other year, about 15 Takhi (carefully genetically and behaviourally screened second generation animals (their dams are born in a semi-reserve)) from western semi-reserves to Hustain Nuruu. The first group of 16 Takhi arrived 6 June 1992 (Germeraad et al., 1993). A second group of 16 Takhi was sent in July 1994.

The goal of the research and training was to establish a basic reference dataset as well as to provide the scientists with reliable methods of monitoring the Takhi, wildlife, livestock and vegetation suitable for use in the Mongolian context. As a result, the staff should be able to carry out realistic multidisciplinary research to provide the management with reliable and useful information. Therefore, the Takhi could only be intensively observed during one short period per season. Because many observers (foreign, Mongolian senior and junior scientists, rangers) of different backgrounds, experiences and educational levels are involved, relatively simple methods and behavioural definitions were chosen to enhance the chances of making sure the collected data are comparable for present and future studies.

The aims of this paper are (a) to present the results of the time budget, habitat use, synchronisation, spatial relations and physical adaptation observations; (b) to evaluate the suitability of methods of studying and monitoring the Takhi in Mongolia. This will extend our knowledge of Takhi behaviour and habitat use in its original range. In this paper advanced analyses of the data are presented.

2. Animals, materials and methods

The Hustain Nuruu Reserve (base camp office: 47°42′722″N 105°51′355″E, 1117 m altitude) is an area of upland steppe, mountain steppe and some forested patches, covering 570 km^2. The vegetation was described by Germeraad et al. (1993) and Wallis de Vries et al. (1996). Three visually and acoustically separated acclimatisation enclosures (about 45 ha each) were established in 1992. All enclosures are surrounded by electric fencing with four lines between about 0.75 and about 1.75–2.00 m. The lower 75 cm is covered by 10 cm × 10 cm wire netting in area 1 and irregular wire netting 10–30 cm × 10–30 cm in areas 2 and 3. All enclosures have year-round access to fresh running water from natural springs. All enclosures have been furnished with a wooden shed, which can be opened on two sides (by the rangers). It was usually open at one side. Supplementary (European) salt/vitamin lick blocks and natural Mongolian salt are provided, the latter offered loose in a large bowl a few metres from a block. The amounts presented of both salts were roughly the same.

The vegetation cover of each enclosure is presented in Table 1.

The Ridge Mountain Steppe (RMS, type 6), exists mainly on dry mountain ridges and upper slopes (for type descriptions see Wallis de Vries et al., 1996). The Upland Steppe (US, type 4) is generally situated on foot slopes. The Lowland Steppe (LS, type 3) is the most widespread in the whole reserve, but unfortunately not represented in area 2. The Slope Mountain Steppe (SMS, type 7) is, within the enclosures, only found in limited amounts in the second enclosure. The Tussock Grassland (TG, type 2) is usually a sign

Table 1
Cover of the different vegetation types of the three enclosures in Hustain Nuruu (HN), Mongolia. The Hustain Nuruu reserve contains 11 vegetation types

Type description	Code/area	Hectares (% of area)			Whole HN
		Area 1	Area 2	Area 3	(%)
Ridge Mountain Steppe	RMS	5.0 (10.6)	4.9 (9.9)	1.9 (5.2)	24.9
Slope Mountain Steppe	SMS	–	1.0 (2.1)	–	7.0
Upland steppe	US	11.4 (24.4)	33.9 (69.1)	15.6 (42.0)	18.1
Lowland Steppe	LS	22.7 (48.5)	–	11.4 (30.7)	30.9
Tussock Grassland	TG	5.3 (11.4)	4.2 (8.6)	6.9 (18.7)	1.0
Mountain Meadow	MM	–	5.0 (10.3)	–	4.0
Streamside Meadow	SM	2.4 (5.1)	–	1.3 (3.4)	0.5
Total		46.8 (100)	49.0 (100)	37.1 (100)	83.4

Table 2
Group composition of the Takhi herds in Hustain Nuruu (HN). The Takhi originated from the Netherlands (NL) or from Askania Nova (AN) in the Ukraine. Magnai (Khaan × Riska) was conceived and born in Hustain Nuruu

Herd	Name	Sex	Year of birth	Origin
1	Khaan	m	1988	NL
	Belka	f	1989	AN
	Vetochka	f	1990	AN
	Svetlaya	f	1990	AN
	Riska	f	1990	AN
	Magnai	m	1993	HN
2	Goboj [a]	m	1988	AN
	Patron [b]	m	1989	AN
	Hjalgana	f	1989	NL
	Hatan	f	1989	NL
	Zaluu	f	1989	NL
	Tanaa	f	1990	NL
	Altan	f	1990	NL
Bachelors	Amgalan	m	1989	NL
	Bayan	m	1989	NL
	Patron [b]	m	1989	AN
	Paritet	m	1989	AN

[a] Goboj died in October 1992 due to wounds received during a fight with an outside source.
[b] Patron replaced Goboj in herd 2 on 20 June 1993.

of previous human occupation and clearly visible by the high bunches of *Achnaterum splendens*. Both the Mountain Meadow (MM, type 9) and the Streamside Meadow (SM, type 1) represent the high (summer) feeding value vegetations. All enclosures lack the ecologically important woodland and shrubs. These occur only on the north slopes at higher altitudes.

In Table 2 the composition of all herds is described. After some training, it was possible to visually identify Takhi individuals on the basis of size, coat colour and markings. All had a freeze brand number, but from a distance that was not always very clear.

The observations were made every 3 months: in July 1992 (VII-92), October 1992 (X-92), January 1993 (I-93), April 1993 (IV-93), July 1993 (VII-93) and October 1993 (X-93). The equipment used restricted the observation time to the daylight period. Observations were made by scan sampling (Lehner, 1979) every 10 min and, during the

X-93 period, every 5 min. Four replicates of each observation time point in each period were aimed at. The order of observation periods and herds was scheduled at random to exclude weather and other systematic effects. During scan sampling, behaviour (see below) and vegetation type in which the individual was located were recorded. Every half hour the spatial relations were recorded: all individuals within two 'horse' lengths of each other (Van Dierendonck et al., 1995) were noted. Throughout the whole observation period a few distinct behaviours were also recorded: (sexual) mating, allogrooming and outside disturbances such as passing wolves, etc. All observations have been standardised/normalised (per individual, per period) for the actual observation frequency to make them comparable. Beside these scientific eco-ethological observations the Takhi were observed daily by rangers.

A simple ethogram was constructed by the principal author and was used during scan sampling. It contains ten behaviours, defined as follows:

1. grazing: eating grasses and herbs, not separated by more than 10 s of rest, move or other;
2. resting: standing or lying relaxed, usually with ears sideways;
3. moving: all kinds of moving, longer than 10 s if occurring during grazing;
4. other feeding: browsing or eating non grasses and herbs;
5. drinking: drinking water from a stream, etc.;
6. positive social interaction: allogrooming, play, nursing, etc. (partner also recorded);
7. negative social interaction: fight, chase, kick, etc., usually with ears flattened (partner also recorded);
8. sexual interactions: all types of sexual interaction;
9. submission: all forms of submission, avoiding, tooth clapping;
10. other: all behaviours not described above.

If an animal of the group could not be seen it was recorded as 'out of sight' (os). The frequency of os was calculated per individual and used in the standardisation procedure (see below) to make the data comparable.

Simple weather notes were taken during the observation periods when the weather changed. Daily records of basic weather characteristics (minimum and maximum temperatures, precipitation, wind and cloud coverage) were made at the base camp.

To follow the physical adaptation of Takhi, all animals were reviewed biweekly. A special sheet was designed for quick and standardised observations by different level observers (scientists, reserve managers or rangers). Physical condition was judged on several aspects separately. The criteria were developed with reference to Pollock (1980), Riney (1982), Rudman and Keiper (1991), Duncan (1992b), the principal author's personal experience and a personal communication (1992) of H. Bos and A. Leboucher. Where applicable, the item on the sheet was accompanied by drawings and tick boxes. The items were:

1. fat: cover (normal, fat or thin) and mane (upright or hanging);
2. muscles/fat: protuberance of the backbone as seen from behind (four levels) and ribs (visible or not);
3. feeding condition: belly (filled, flat or sunken) and flanks (filled, flat or sunken);
4. coat condition: shiny, dull, moulting and remarks;
5. movements: normal, slow, stiff or lame (specified per leg);

6. hoof condition: normal or abnormal (specified per leg);
7. respiration: normal, fast, coughing or nose excretion;
8. dung: colour, consistency (soft, hard or normal);
9. general behaviour: isolated, not alert, not interacting, no ear play, extreme aggression, foal not suckling or sexually active;
10. visible injuries.

Per item each criterion was scored. Negative deviations from the normal standard were scored as -1, -2 or -3, according to severity. Positive deviations from the normal standard were scored as $+1$ or $+2$. Normal was scored as 0. The sum of all scores gave an indication of the physical condition per animal. A negative total score could be interpreted as an attention signal for the reserve scientists to monitor this individual more regularly.

Additionally monthly helmintic analyses were scheduled of the dung of a representative selection of Takhi (Germeraad et al., 1993).

Synchronisation, a tool for measuring the degree of social integration in a newly formed herd, was calculated by counting (per period) the number of observation time points in which all group members performed the same behaviour and were not out of each others' sight. Thereafter, the score was standardised by dividing by the number of actual (minus os) observation points.

For spatial relations the frequency of being within two horse lengths was counted per dyad and divided by the total number of observations per herd, per period.

For the time budget and habitat use analyses the standardised scores (score/(number of observations − os)) per individual were summed per (combination of) element(s) analysed, per herd, per period. Where necessary, these scores were corrected for the number of herd members, in order to make the herds comparable. For the analysis of the distribution of resting and grazing over the day the standardised individual data were summed per hour (17 daylight hours for period VII; 12 for X; 9 for I; 12 for IV) per herd, per period.

To assess whether a 10 min interval between observations was sufficient to describe the time budget of the animals, a 5 min interval scan sampling period was performed in period X-93. The results of the 5 min interval observations were divided into two. Observations in the 'odd' sample (5, 15, 25 min, etc.) were compared with adjacent observations in the 'even' sample (0, 10, 20 min, etc.) as well as with the whole data set. In principle, both split datasets are independent.

To determine whether the Takhi had any habitat preference the following index was used: $(o-e)/(o+e)$, where e is the expected value and o is the observed value (Loehle and Rittenhouse, 1982). The expected value was calculated by assuming there was no preference for any habitat. Thus, the distribution of the (expected) frequencies of use of the habitats would be the same as the distribution of percentages of the area the habitats covered (see Table 1). An index of 0 would indicate that there is no deviation from the expected value, an index close to -1 that the area is actively avoided, and an index close to $+1$ that the area is actively sought out.

The condition scores were calculated per individual, per measurement day, as described on the standard sheet. For the herd scores, the individual scores were averaged per measurement day.

The statistical methods used were the *G* log likelihood-ratio test, the *t*-test, the χ^2 test and Pearson's linearity correlation (Lehner, 1979; Sokal and Rohlf, 1981; Lee and Lee, 1982).

3. Results

From the 15 Takhi which arrived in good condition in 1992, 14 survived the harsh winter of 1992–1993 very well without supplementary feeding or water.

A colt was born in June 1993. This rather low reproduction rate in 1993 is due to several factors: the animals were transported to Mongolia at the beginning of June 1992. Transportation and adaptation to the new social and ecological environment cost energy and it was already halfway through the mating season when the stallions joined their mares. Five of the nine mares were only 2 years old. However, these factors cannot entirely explain the low reproduction. They only explain lower opportunities. Additional factors were as follows.

1. The stallion of herd 2 died in October 1992 after being wounded during a fight with an outside source, most likely a wolf (or a domesticated stallion). The autopsy showed he was cryptogenious and had severe (genetic) skull malformations. The cryptogenia most likely caused low fertility. A stallion from the bachelor herd replaced the lost one in June 1993. All these mares produced a foal in 1994.
2. All mares of the first area had severe or slight malnutrition on arrival in 1992. All these mares produced a foal in 1994.

It is interesting to note that the Takhi preferred natural Mongolian salt. The European salt/vitamin blocks were only touched when their Mongolian salt bowl was empty. The bowls were refilled several times, only one block was replaced in one herd.

Insufficient knowledge and experience at the higher organisational level limited the possibilities for collecting complete data sets in some periods. This resulted in (among other things) a (much) lower observation frequency of herd 2 in general, causing higher variation and less consistent findings in all results presented below. Four periods have reasonably complete data sets: for herd 1 periods VII-92, VII-93 and X-93 and for herd 2 period X-93. These periods enable comparison for the same period in different years (herd 1: VII-92 vs. VII-93) and between herds in the same period (X-93).

Both harem herds were released from their acclimatisation areas in 1994 and members for new herds were flown in, so, additional data can only be provided from the new herds.

3.1. Observation frequency

Data gathered at 10 min intervals did not differ significantly from that gathered at 5 min intervals nor from the total (Table 3). There was no difference between even and odd counts and their expected values (based on the total) (*G* log likelihood ratios were not significant). One would expect the low frequency elements to differ the most. This was confirmed, only one element (feeding) was scored in the even observations and not in the odd observations. The standard deviation of the normalised grazing frequency per

Table 3
Occurrence of behaviours during observations made at 5- and 10-min intervals, expressed as a percentage of total observed time during period X-93. The *G* log likelihood between all groups of data was not significant

	Graze	Rest	Move	Drink	Other	Neg. soc.	Pos. soc.	Feeding	Out of sight
All counts [a]	66.8	21.4	7.3	1.5	1.5	0.4	0.5	0.1	0.9
Even counts [b]	67.9	20.7	6.6	1.8	1.3	0.4	0.4	0.1	0.7
Odd counts [c]	65.6	22.0	8.0	1.1	1.7	0.4	0.6	0.0	1.1

[a] Counts made at 5 min intervals.
[b] Counts made at 10 min intervals (at 0, 10, 20 min, etc.).
[c] Counts made at 10 min intervals (at 5, 15, 25 min, etc.).
Neg. soc., negative social behaviour; pos. soc., positive social behaviour.

hour was marginally higher in the 10 min observations (SD of 0.2053 and 0.1925 for the even and odd periods, respectively) than in the 5 min observations (SD 0.1912). The coefficients of variance were respectively: 28.7%, 30.0% and 28.7%. These figures support the conclusion that observations at 10 min intervals are as accurate as those at 5 min.

Because of the low overall values of some elements, the ethogram could possibly be reduced to six elements: grazing, feeding/browsing, moving, resting, drinking and other. These are the most important in respect of analysing the time used for the different maintenance behaviours.

3.2. Synchronisation

Synchronisation of the behaviour of individual herd members was high. Between 50 and 89% of the observed time points showed full synchronisation of all herd members (see Table 4). Herd 1 showed more homogeneity during the year than herd 2 (owing to the lower observation frequency). For herd 1, the frequencies of synchronisation during the comparable periods VII-92/VII-93 and X-92/X-93 are almost identical (respec-

Table 4
Percentage of full synchronisation within herds 1 and 2 in all periods (numbers of observations are given in parentheses)

Period	Percentage (*n*)	
	Herd 1	Herd 2
VII-92	57 (257)	60 (45)
X-92	53 (68)	71 (55)
I-93	75 (56)	70 (70)
IV-93	70 (76)	50 (64)
VII-93	58 (375)	89 (18)
X-93	54 (521)	66 (281)
Total	57 (1353)	65 (533)

Table 5
Spatial relationships between mares and stallions. Presented as a fraction of the total number of observations per period

Herd	Period	No. obs.	Relations	Mean	*n*	*t*-test	d.f.	*P*
H1	VII-92	96	Mare–mare	0.45 ± 0.102	6			
			Mare–stallion	0.28 ± 0.115	4	−2.175	8	< 0.1
H1	VII-93	138	Mare–mare	0.36 ± 0.028	6			
			Mare–stallion	0.30 ± 0.057	4	−2.141	8	< 0.1
H2	VII-92	17	Mare–mare	0.53 ± 0.115	10			
			Mare–stallion	0.41 ± 0.054	5	−2.047	13	< 0.1

tively 57%/58% and 53%/54%), indicating that the herd was well integrated and the method reliable. Synchronisation during the winter (periods I and IV) was somewhat higher than during the summer within herd 1. This was not observed in herd 2.

3.3. Spatial relations

Social integration within all herds proceeded remarkably quickly: within a few days (both harems) and a few weeks (bachelor stallions). Spatial relations could be analysed between years (comparing VII-92 and VII-93 for herd 1) and herds (VII-92).

In all periods, mares tended to be near other mares more often than they were near to the stallion (Table 5). There was no significant difference between periods or herds. There were clear individual (pair) preferences.

3.4. Time budget

Time budgets are used to analyse the time needed for the different maintenance behaviours. Time budgets for the first and second herds are shown in Figs. 2 and 3. In

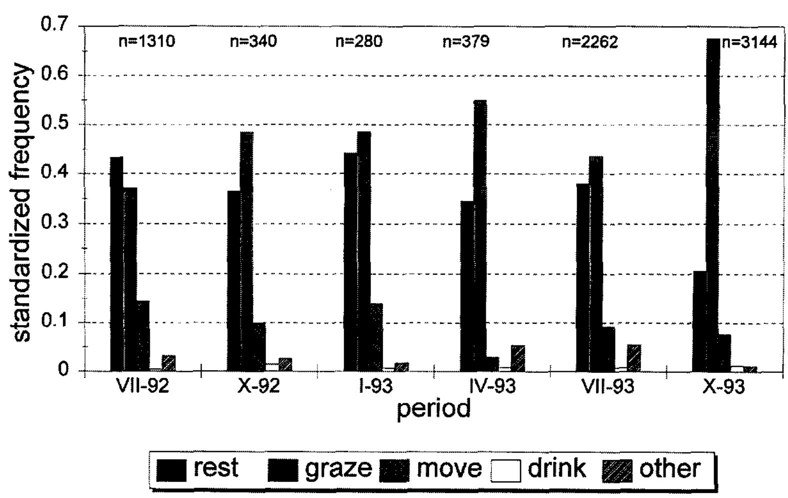

Fig. 2. Time budget distribution of the adults of herd 1 between dawn and dusk.

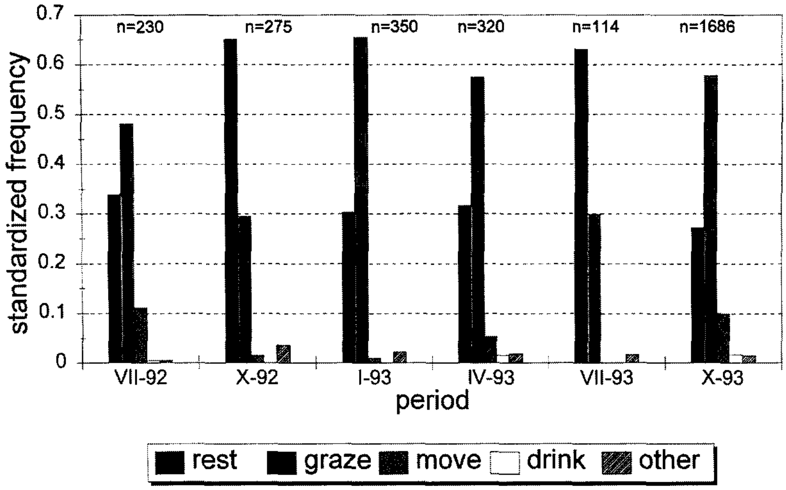

Fig. 3. Time budget distribution of the adults of herd 2 between dawn and dusk.

all cases the Takhi spent their time mainly on grazing and resting, like most feral horses. Grazing took 37–68% (mean 50 ± 9.5%) of the observed time (between dawn and dusk) for herd 1 and 30–58% (mean 48 ± 13.9%) of the observed time for herd 2. The Takhi rested for 20–44% and 27–65% of the observed time in herds 1 and 2, respectively.

Mean temperatures were: VII-92, 18 ± 2.2°C; X-92, unknown; I-93, about −24°C; IV-93, unknown; VII-93, 19 ± 5.3°C; X-93, partly unknown, but around 0°C with lasting snow. The temperature differences do not seem to result in a different time budget pattern. In all herds and all periods, the members were recorded drinking at least once a day, usually more often.

Only during the first period (VII-92) did resting time (44%) exceeded grazing time (37%) in herd 1. There was no climatological reason. Probably the Takhi needed time to recover from transportation. Resting time exceeded grazing time in periods X-92 and VII-93 in herd 2. This may indicate that the habitat quality in these periods was very good, allowing relatively low grazing time. However, a bias in data gathering is more probable.

For almost all meaningful comparisons within herd 1 (periods VII-92 vs. VII-93 and X-92 vs. X-93) and between herds (herd 1 X-93 vs. herd 2 X-93), the time budgets did not differ significantly.

Grazing, resting and moving were responsible for more than 90% of the time spent in all periods. When only these three behaviours were taken into account there was no significant difference between the periods within any of the herds (herd 1: $\chi^2 = 0.2891$, d.f. = 10, NS; herd 2: $\chi^2 = 0.8461$, d.f. = 10, NS).

The resting/grazing ratios give interesting information. Ratios of the same period (VII) of different years were respectively 1.17 (1992) and 1.08 (1993) within herd 1. The ratios in period X-93 were 0.32 in herd 1 and 0.47 in herd 2. In both cases the ratios are comparable, indicating that it is a reliable evaluation measure. The lower scores in

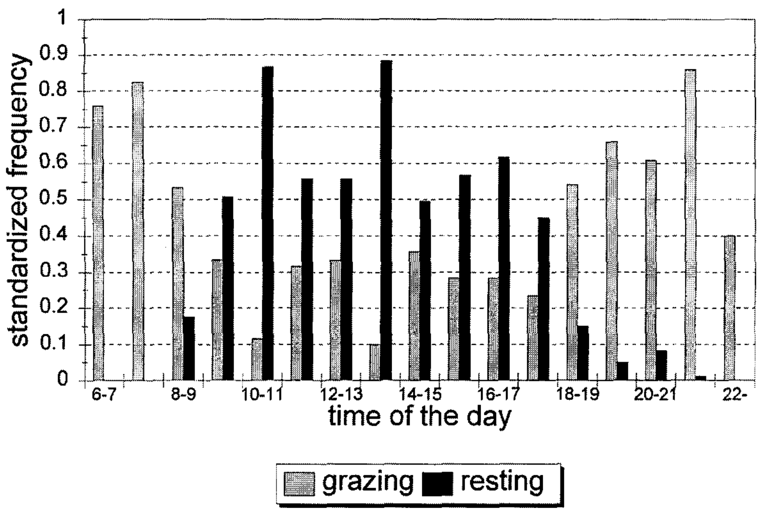

Fig. 4. Distribution of grazing and resting over the day. Only period VII-93 for herd 1 is shown as an example.

period X-93 point to a relatively higher proportion of time spent grazing in this period. This was probably caused by the need for a higher intake of food with a lower feeding value in order to accumulate fat reserves for the winter. This is in line with the start of the decline of the feeding value of the vegetation in Hustain Nuruu in early September (Germeraad et al., 1993).

When the distribution of grazing and resting over the day were analysed the Takhi tended to rest in the morning and have a bimodal period of grazing at dawn and in the afternoon. This was consistent over most periods and both herds. Between years (VII-92 vs. VII-93) the distribution of resting over the day was significantly correlated within herd 1 (Pearson's $R = 0.539$, $n = 17$, $P \leq 0.05$) and the grazing distribution was almost significantly correlated ($R = 0.467$, $n = 17$, $0.05 \leq P \leq 0.1$) (Fig. 4). Grazing and resting distributions over the day were strongly correlated between herds (X-93, herd 1 vs. herd 2) (resting: $R = 0.992$, $n = 12$, $P \leq 0.001$; grazing: $R = 0.932$, $n = 12$, $P \leq 0.001$). There was no significant correlation between herds in the other periods owing to the low overlap in observed hours and low observation frequencies in these periods in general.

3.5. Habitat use

The Hustain Nuruu reserve contains 11 different vegetation types (Germeraad et al., 1993; Wallis de Vries et al., 1996). Five are represented in the acclimatisation area of herd 1 and five in the area of herd 2. Three vegetation types are present in both areas (see Table 1). If the representation of the vegetation types in relation to their distribution over the whole reserve is compared, it can be concluded that area 1 is reasonably comparable and that in area 2 there is an over-representation of upland steppe.

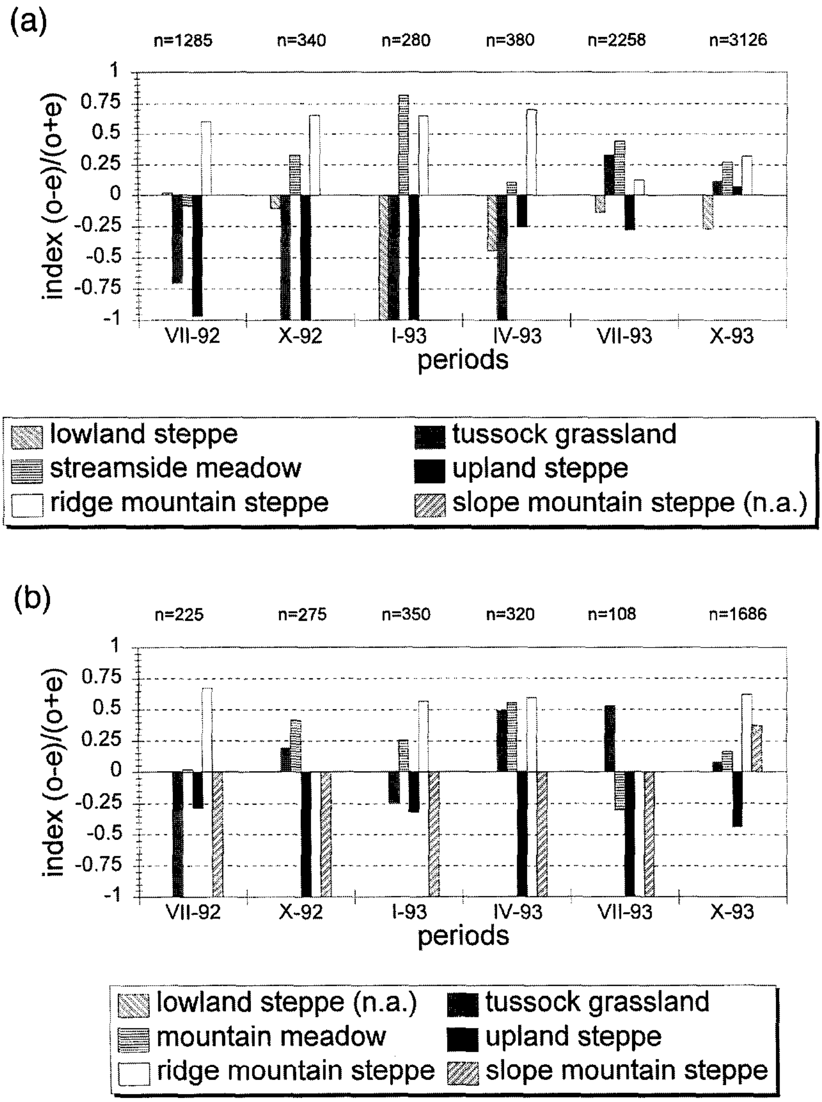

Fig. 5. (a) Habitat use of the adult members of herd 1 between dawn and dusk. The slope mountain steppe is not available (n.a.) in the area of herd 1, but was included to make this figure comparable with (b). (b) Habitat use of the adult members of herd 2 between dawn and dusk. The lowland steppe is not available (n.a.) in the area of herd 2, but is included to make this figure comparable with (a).

The habitat use of herd 1 shows clear preferences in all periods (Fig. 5(a)). In all periods the G log likelihood ratio is significant at $P \leq 0.025$, meaning the herd made active choices for using or avoiding certain vegetation types. The ridge mountain steppe was preferred in all periods. This vegetation type is found at the highest elevation in the area. The streamside meadow was preferred during the last five periods. Although lowland steppe is the most common vegetation type in area 1 as well as throughout the Hustain Nuruu reserve, it was used less than expected in the last five periods.

Active avoidance of lowland steppe could not be confirmed by the data from herd 2, because this vegetation type did not exist in area 2. Like herd 1, herd 2 often preferred the ridge mountain steppe (also at the highest elevation in their area) (Fig. 5(b)). The streamside meadow in area 1 is comparable to the mountain meadow in area 2 in terms

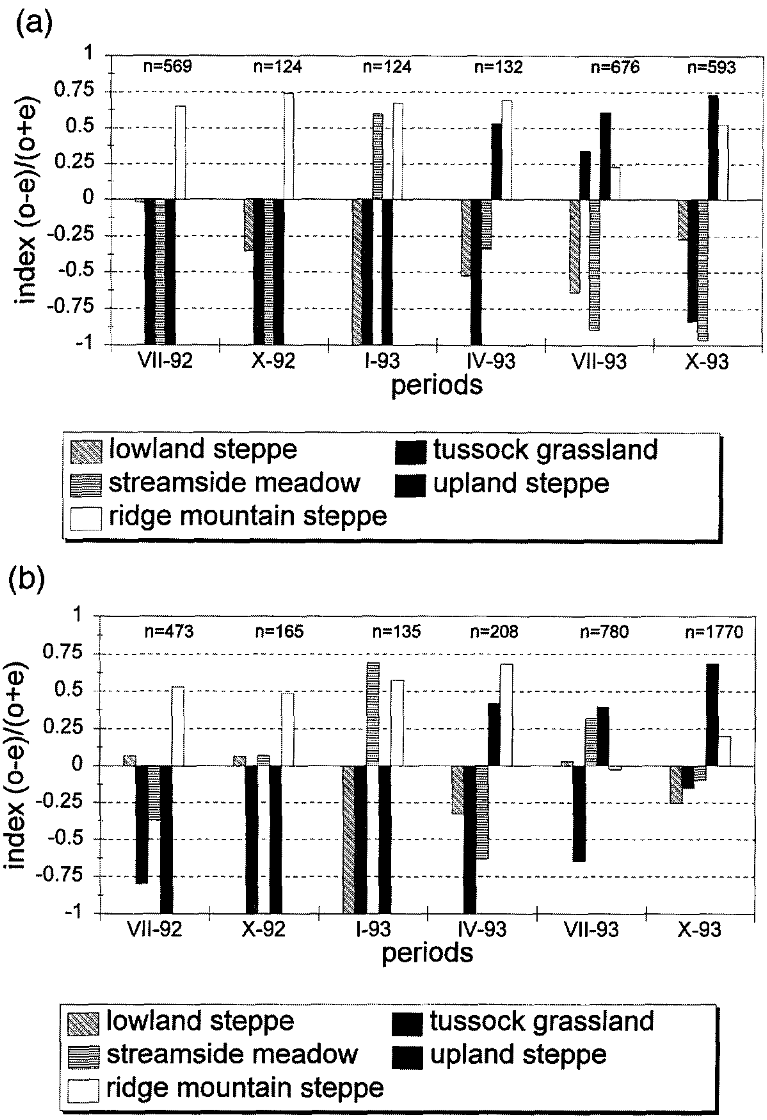

Fig. 6. (a) Habitat use while resting of the adult members of herd 1 between dawn and dusk. (b) Habitat use while grazing of the adult members of herd 1 between dawn and dusk.

of the relatively high standing crop and high feeding values. Herd 2 also used this vegetation type more than expected (except in period VII-93, due to low observation frequency). Like herd 1, the members of herd 2 showed clear preferences in all periods (G log likelihood ratios in all periods $P \leq 0.05$ or stronger).

Analysis of behaviour in relation to habitat use reveals that resting was strongly non-randomly distributed among the vegetation types in herd 1 (Fig. 6(a)) (all G log likelihood ratios $P \leq 0.01$), while herd 2 only had preferences during periods I-93 and X-93. For both herds the preferred vegetation for resting was the ridge mountain steppe, shared during the last three periods with the adjacent uplands steppe in herd 1.

Grazing was preferred in specific habitats by both herds (G log likelihood ratios $P \leq 0.05$, four periods $0.05 \leq P \leq 0.1$) in most periods (for herd 1 see Fig. 6(b)). The highest preferences were for the meadow types and the ridge mountain steppe. In five periods, tussock grassland was preferred by herd 2, but was always avoided by herd 1. This preference of herd 2 can partly be explained by the fact that their (much used) shed was in this vegetation type. During the first four observation periods use of the shed was not separately noted, probably causing some bias in the data.

In both herds there was a visible shift in preference: herd 1 shifted preference from the ridge mountain steppe to the uplands steppe during the last three periods. The slope mountain steppe was highly preferred only during the last period in herd 2.

3.6. Condition scoring

Use of the sheets and indices was basically satisfactory, but showed considerable differences during a period the observers did not align regularly (September 1992–July 1993). Specifically, they had a different view of the severity of certain aspects compared with the 'normal reference Takhi'. The regular control and alignment observation sessions were rescheduled. In these, all observers participated at the same time with the same herd. (Re)alignment was (and will be) necessary in all observations to prevent shifting of the interpretation of 'indistinct' behaviours/conditions. After rescheduling, the differences between condition scoring observers disappeared.

Changes in the condition of a herd and/or individuals were detected directly from the scores. The mean score of all herds was below 0 during the first observation after their release (herd 1, -2.6; herd 2, -0.35; bachelors herd, -1.75). During the following two observations the mean scores of herd 2 and the bachelor herd, rose to above zero. This was mainly due to the good recovery of the relatively few Takhi from Askania Nova in these groups and the relatively obese condition of the other Takhi. After six observations, in September 1992, the mean for all herds was zero. From the end of January until May the mean herd score was on or below zero, ranging from 0 to -2.25. The users of the score sheets considered them helpful.

4. Discussion and conclusions

The 14 remaining Takhi withstood the long, severe winters in good condition. Their reproductive success in 1993 and 1994 was satisfactory. Data from these initial 2 years support the opinion that the acclimatisation areas of the Hustain Nuruu reserve are a suitable habitat for the Takhi. From a biological standpoint, the reserve seems to be suitable for their release.

Social integration, as shown by the spatial relation results, as well as the high degree of synchronisation in both harem herds gives hope for good co-operation between the herd members during the critical stages of the future release of the animals.

4.1. Time budget

The time budget results give good indications of the adaptation and health of individual Takhi. They give valuable basic reference information concerning the analyses of their activity patterns. These can be used as future reference data.

In general, grazing time was rather low compared with the observations of other authors. For feral horses many data are known. Jarrige and Martin-Rosset (1987) report that feral horses spend 51–61% of 24 h grazing and 50–73% of their time during daylight. Salter (1978) reported for western Alberta, 75% of time spent grazing during daylight in winter and spring. Camarque horses spend 51–63% of their time grazing over all seasons (Duncan, 1980) while the horses studied by Berger (1986) grazed for 30–35% during the growing season and about 60% (30–87%) of the daylight period over the whole year. Feral Koniks (Polish primitive horses) spend between 40 and 71% of their time during daylight grazing (Stockmann, 1986). Time budget data are also known for Takhi in captivity or in semi-reserves: in an extensive comparative study by Boyd and Houpt (1994) Takhi housed on 31 pastures in different zoos spent $54 \pm 0.6\%$ of the daytime feeding while Takhi in the Minnesota Zoo pasture fed $62 \pm 2.2\%$ of the time (Skiff Hogan et al., 1988) and in the Denver Zoo, 65% (Griffitts, 1985, cited in Boyd et al., 1988). Stallions in a Dutch semi-reserve spend $69 \pm 2.4\%$ of the time feeding during the winter (Leboucher, 1992) and for yearlings in another Dutch semi-reserve it was $56 \pm 3.4\%$ (Sauerland, 1991). In the study carried out by Leboucher (1992) the stallion of herd 1 (Khaan) in Hustain Nuruu was in the sample.

Distribution over the day gives a good indication of the optimal observation times. The observations of peak grazing during dawn and late afternoon are in line with those made by Tyler (1972), Salter (1978), Boyd (1988), Boyd et al. (1988) and Kaseda (1983).

When time spent grazing in the vegetation growing season (period VII; mean $\pm$ SD, $40 \pm 7.9\%$) is compared with grazing time in the non-growing season (other periods) ($49 \pm 14.8\%$), there is a clear but not strong significant trend towards higher grazing times in the non-growing season (t-test: $t = -2.107$, d.f. = 10, NS). This could reflect the higher energy demands and lower food quality during the very cold winters (mean January temperature -23°C; Germeraad et al., 1993). This agrees with the results of Tyler (1972), Duncan (1980), Kaseda (1983) and Berger (1986). Despite this higher food intake frequency, the animals were still able to rest for about one-third of the daylight period, as demonstrated by the rest/graze ratio. Together with the condition score observations and high reproduction rate it is concluded that the availability and quality of the food were sufficient during these first two winters.

Drastic changes in the daily activity of the Takhi could reflect problems in their health, reproductive success, the success of the reintroduction effort in Hustain Nuruu and ultimately the survival of the species (see also Boyd, 1988; Skiff Hogan et al., 1988). Long periods of grazing during the normal morning rest period can point to under-nourishment and should alert the management (see also Klimov, 1988).

4.2. Habitat use

Habitat use analyses point to clear preferences for certain vegetation types. The preference of both groups for resting on the ridge mountain steppes can probably be explained by the fact that this vegetation is at the highest point within their fenced area. A cool breeze during the summer keeps flying insects at a low level (Duncan, 1992b). It could also be a good place to scan for possible threats (wolves etc.). This high preference of both herds for high elevations for resting suggests that after release in the reserve they will probably go even higher. Similar observations were made by Berger (1986) of the feral horses in the mountainous great Basin Desert in North America.

Shifts between different vegetation type preferences during the first years in a new area, as reported here, have also been seen in other projects (Stockmann, 1986). It seems that feral living equids adopt a conservative feeding strategy with respect to the exploitation of resources in a new environment.

The habitat preference results should be incorporated in the carrying capacity estimates together with other ethological and ecological information on Takhi, wildlife, livestock and vegetation. Active avoidance of the lowland steppe in the enclosure, the most common vegetation type in the whole reserve, can have a severe impact on these estimates (Germeraad et al., 1993). However, many other factors, such as the objective to minimise interactions between Takhi and domestic horses (to prevent hybridisation and the transmission of diseases) should also be taken into account. The calculations need to be updated with data obtained when the Takhi are released and can, theoretically, use all vegetation types. In the short term the preferences presented provide information for the carrying capacity estimates of the enclosures. The enclosures are planned to be used for the acclimatisation of at least five new herds, for around 1 year per new herd. Therefore, the relatively heavy use of these acclimatisation areas necessitates careful monitoring with respect to grazing impact and the requirements of the Takhi. Shifts in use and preferences are expected owing to possible over-grazing of the rare but favoured vegetation types.

4.3. Differences with feral horses

No real differences between the Takhi and feral horses have emerged from this study. Takhi stallions were expected to play a more aggressive role than feral stallions, but this was not observed. The three stallions in Hustain Nuruu were all young and had roughly the same experiences. Khaan (herd 1) showed more harem leading qualities than Goboj and Patron (both herd 2). However, herd 2 acted as a close group and did not become disorganised owing to the lack of a strong stallion, as reported and predicted by Klimov (1988). The low level of fear shown by mares of herd 2 towards humans and cars is considered to lower the chances of successful release in the future (Rodriguez et al., 1995). Management measures should take account of this.

The real role of the stallions can only be studied and possibly confirmed after their release from the acclimatisation areas.

4.4. Evaluation research methods

Despite the fact that it was not possible to observe the Takhi on a regular basis over the course of a full year, the information gathered in short, but intensive periods each season, provided interesting and useful reference results. This leaves enough time to investigate and monitor other biologically important aspects, essential for the set-up and management of the nature reserve in which the Takhi can survive.

The high degree of matching obtained between comparable data sets, between periods and herds, shows a basically good registration of the behaviour of the Takhi. It also means that the observation and analytical techniques used are suitable for this task.

Because some data were missing, the methods of analysis used were complex and could not be carried out under local Mongolian circumstances. This may have the effect of de-motivating the local scientists collecting it. The basis for a good monitoring, research and management project should be competent, experienced, caring and open minded (non-political) bodies who supervise the project (Van Dierendonck and Wallis de Vries, 1996).

To enhance our knowledge of the adaptation and ethological and ecological developments of the Takhi, specialised scientists should be added to the staff, working with and in addition to the project scientists.

5. Conclusion

The first phase of the reintroduction of the Takhi on their native steppes of Mongolia was, in eco-ethological terms, successful. Their reintroduction was monitored as carefully as possible and an extended reference data set was produced. A lot of information has been added to the knowledge of the Takhi in its natural habitat and the feasibility of monitoring them under Mongolian circumstances.

Acknowledgements

The basis for this article was laid in Mongolia, where Drs. Machteld Van Dierendonck worked in 1993 as project-assistant in the Hustain Nuruu Steppe Reserve Program, co-ordinated by FRPH and supported by the Directorate for International Co-operation from the Dutch Ministry of Development Aid. In 1992 the stay of M. van Dierendonck was made possible with the help of the van Tienhoven Stichting, the Netherlands. Dr. N. Bandi, D. Batdorj, S. Dügerlham and B. Munkhtsog were Mongolian biological scientists contracted by the project and collected much of the data. We are very grateful to Dr. Pieter Germeraad, FRPH-project co-ordinator in Mongolia in 1993, for his enthusiasm and inspiring views of conservation project management. We thank Dr. Michiel Wallis de Vries for his optimism and high knowledge of research techniques, flora and fauna. He also made very valuable remarks on drafts of this manuscript. We thank all other staff of Hustain Nuruu for their dedication to the project and for sharing their daily lives with us. P.G.M. Versteeg drew Fig. 1. Vivian Muir corrected the English text. Finally, we thank D. Gansukh for his invaluable assistance as interpreter and English teacher.

References

Berger, J., 1986. Wild Horses of the Great Basin. Social Competition and Population Size. Wildlife and Ecology Series. University of Chicago Press, Chicago, IL, 326 pp.

Bouman, D.T. and Bouman, J.G., 1992. Report on the semi-reserves project IUCN/WWF no. 3077. In: S. Seifert (Editor), Proc. of the 5th Int. Symp. on the Preservation of the Przewalski Horse, Zoologische Garten Leipzig, Leipzig, Germany, pp. 184–190.

Bouman, J., Bouman, I. and Groeneveld, A., 1982. Breeding Przewalski horses in captivity for release into the wild. Foundation for the Preservation of the Przewalski Horse, Rotterdam, Netherlands.

Boyd, L.E., 1988. Time budgets of adult Przewalski horses: effects of sex, reproductive status and enclosure. Appl. Anim. Behav. Sci., 21: 19–39.

Boyd, L.E., 1991. The behaviour of Przewalski's horses and its importance to their management. Appl. Anim. Behav. Sci., 29: 301–318.

Boyd, L.E. and Houpt, K.A., 1994. Przewalski's Horse: The History and Biology of an Endangered Species. State University of New York Press, Albany, USA, 313 pp.

Boyd, L.E., Carbonaro, D.A. and Houpt, K.A., 1988. The 24-hour time budget of Przewalski horses. Appl. Anim. Behav. Sci., 21: 5–17.

Duncan, P., 1980. Time budgets of Camarque horses. II. Time budgets of adult horses and weaned sub adults. Behaviour, 72: 26–49.

Duncan, P., 1992a. Zebras, asses, and horses: An action plan for the conservation of wild equids. IUCN/SSC Equid Specialist Group, Gland, Switzerland.

Duncan, P., 1992b. Horses and grasses: The nutritional ecology of equids and their impact in the Camarque. Ecological Studies 87. Springer, Berlin.

Foundation Reserves Przewalski's Horse, 1992. Hustain Nuruu Steppe Reserve Mongolia. Project Proposal, Rotterdam, Netherlands.

Germeraad, P., van Dierendonck, M.C. and Wallis de Vries, M.F., 1993. Standaard rapport Hustain Nuruu Steppe Reserve Mongolia. DGIS, Den Haag, Netherlands/FRPH, Rotterdam, Netherlands.

Jarrige, R. and Martin-Rosset, W., 1987. Le Cheval: reproduction, selection alimentation, exploitation. INRA, Paris, pp. 333–355, 645–651, 661–683.

Kaseda, Y., 1983. Seasonal changes in time spend grazing and resting of Misaki horses. Jpn. J. Zootech. Sci., 54: 464–469.

Klimov, V.V., 1988. Spatial–ethological organisation of the herd of Przewalski horses (*Equus przewalskii*) in Askania-Nova. Appl. Anim. Behav. Sci., 21: 99–115.

Kolter, L. and Zimmermann, W., 1988. Social behaviour of Przewalski horses (*Equus p. przewalskii*) in the Cologne Zoo and its consequences for management and housing. Appl. Anim. Behav. Sci., 21: 117–147.

Leboucher, A., 1992. Behavioural study of the Przewalski Stallions living in the semi-reserve of the Goudplaat, Netherlands. Int. Rep., FRPH, Rotterdam, Netherlands.

Lee, J.D. and Lee, T.D., 1982. Statistics and Numerical Methods in BASIC for Biologists. Van Nost Rheinholt, London.

Lehner, P.N., 1979. Handbook of Ethological Methods. Garland STPM Press, New York, 403 pp.

Loehle, C. and Rittenhouse, L.R., 1982. An analysis of forage preference indices. J. Range Manage., 35: 316–319.

Mongolia Takhi Strategy and Plan Work Group, 1993. Recommendations for Mongolia's Takhi strategy and plan (released 1995). MTSPWG (sponsored by Mongolian government and UNDP), Mongolian Ministry of Nature and Environment, Ulaan Baatar, Mongolia.

Pollock, J.I., 1980. Behavioural ecology and body condition changes in New Forest Ponies. Sci. Publ. No. 6, Royal Society for the Protection of Animals.

Riney, T., 1982. Study and Management of Large Mammals. John Wiley, Salisbury, UK.

Rodriguez, A., Barrios, L. and Delibes, M., 1995. Experimental release of an Iberian lynx. Biodiversity Conserv., 4: 382–394.

Rudman, R. and Keiper, R.R., 1991. The body condition of feral ponies on Assateague island. Equine Vet. J., 23(6): 453–456.

Ryder, O.A., 1994. Genetic studies of Przewalski's horses and their impact on conservation. In: L.E. Boyd and K.A. Houpt (Editors), Przewalski's Horse: The History and Biology of an Endangered Species. State University of New York Press, Albany, New York, 313 pp.

Salter, R.E., 1978. Ecology of feral horses in western Alberta. Thesis, University of Alberta, Edmonton, 233 pp.

Sauerland, M., 1991. Przewalski Pferde im Semi-Reservat: Ethologische Studien unter besonderer Berücksichtigung der Einbindung des Hengstes in die soziale Organisation des Familienverbandes. Diplomarbeit für das Fachbereich Biologie Westfälische Wilhelms-Universität Münster, 122 pp. Int. Rep., FRPH, Rotterdam, Netherlands.

Skiff Hogan, E., Houpt, K.A. and Sweeney, K., 1988. The effect of enclosure size on social interactions and daily activity patterns of the captive Asiatic Wild Horse (*Equus przewalskii*). Appl. Anim. Behav. Sci., 21: 147–168.

Sokal, R.R. and Rohlf, F.J., 1981. Biometry. W.F. Freeman and Co., New York, USA.

Stockmann, G.L., 1986. Over terreingebruik, voedselkeuze en gedrag van Koniks binnen het Noordelijk raster van het natuurgebied van het landgoed 'De Ennemaborg' te Midwolda. Stichting Groninger landschap, Groningen, Netherlands, 152 pp.

Tyler, S.J., 1972. The behaviour and social organisation of the New Forest ponies. Anim. Behav. Monogr., 5: 85–196.

Van Dierendonck, M.C. and Wallis de Vries, M.F., 1995. Comments to 'Reintroduction of Wild Horses in Mongolia'. Reintroduction News, 11: 19–20.

Van Dierendonck, M.C. and Wallis de Vries, M.F., 1996. Ungulate reintroductions: experiences with the Takhi or Przewalski Horse (*Equus ferus przewalskii*) in Mongolia. Conserv. Biol., 10: 728–740.

Van Dierendonck, M.C., de Vries, H. and Schilder, M.B.H., 1995. An analysis of dominance, its behavioural parameters and possible determinants in a herd of Icelandic horses in captivity. Neth. J. Zool., 45(3–4): 362–385.

Volf, J., 1988. Pedigree Book of the Przewalski Horse. Zoological Garden, Prague, pp. 1207–1312.

Volf, J., 1994. The studbook. In: L.E. Boyd and K.A. Houpt (Editors), Przewalski's Horse: The History and Biology of an Endangered Species. State University of New York Press, Albany, New York, 313 pp.

Wallis de Vries, M.F., Manibazar, N. and Dügerlham, S., 1996. The vegetation of the forest steppe region of Hustain Nuruu, Mongolia. Vegetatio, 122: 111–127.