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Water Consumption and Watering Behavior of Przewalski Horses (*Equus ferus przewalskii*) in a Semireserve

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Water consumption by 12 female Przewalski horses was automatically measured in a semireserve for 17 months. Average daily consumption on a yearly basis was between 2.4 and 8.3 liters, but significant individual variation in water consumption and drinking frequency was recorded throughout the observation period. Individual differences were more clearly detectable during periods of hot and dry weather. Individuals with high water demands initiated herd movements toward watering places independent of their social rank. Discussed as possible reasons for individual differences in water demand are: acquired preferences, distinct food selection, and genetically determined physiological differences. Watering behavior should not be regarded as an important factor only in re-introduction projects, but also with respect to animal welfare in general. Zoo Biol 17:181–192, 1998. © 1998 Wiley-Liss, Inc.

Key words: social behavior; reintroduction; equids; drinking

INTRODUCTION

Przewalski horses (*Equus ferus przewalskii*) have been kept in zoological gardens from the beginning of this century. The species has been extinct in its natural habitat since the late 1960s. At present, a population of ~1,600 individuals is kept in zoos and elsewhere under protected conditions [Volf, 1996]. Selection for breeding in zoos has been based on anatomical criteria, but more recent efforts have been oriented toward preservation of genetic diversity. Selection for functional characteristics, although important to survival under natural conditions, was not possible in zoos.

"Semireserves" were created by the European Conservation Project for scientific research in preparation for return to wild habitat. They are defined as enclosures large enough to maintain groups of Przewalski horses throughout all seasons of the year without any supplemental provisioning. As far as possible, the horses are kept totally isolated from external influences, except for necessary interventions such as

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veterinary care. Hence, the purpose is not limited to preparing animals for survival under natural conditions, but is equally related to the need to gain experience in establishment of free-ranging populations [Zimmermann, 1997].

Several management groups are preparing Przewalski horses for reintroduction into protected natural environments in Mongolia. Large enclosures are being set up in Mongolia and China, but since the national park program in Mongolia has not yet been put into practice, installation of a totally free-ranging population is, for the time being, difficult [Bouman et al., 1994; Van Dierendonck et al., 1996b; Volf, 1996]; in the meantime, Przewalski horses living in these enclosures have become well adapted to climate and general living conditions in Mongolia [Van Dierendonck et al., 1996a].

The ability to survive in an arid environment is of critical importance for animals in Mongolia. Natural selection for low water demand may be assumed for Przewalski horses in their natural habitat, and restricted access to natural water sources played a major role in the extinction of the species [Bannikov, 1967]. Water requirements have not been used in selecting individuals for zoo breeding. Since competition for access to water has been observed in the semireserves, it seemed important to investigate drinking behavior and water consumption of individual animals under close-to-the-wild conditions.

MATERIALS AND METHODS

The Semireserve

The semireserve of Schorfheide, initiated in 1992, is located some 70 km north of Berlin. It consists of a 0.42 km^2 enclosure, with a large meadow and some smaller plots of woodland (pine and oak). It is largely surrounded by forest and on one side is bordered by a path and an observation point. A smaller fenced area, located in the northern part, is normally available to the animals. This area includes a small wooden house, an open shelter, a salt lick, and the only water source. Twelve mares were kept in the semireserve during our investigation. Individual body mass of the animals varied between 268.0 and 360.9 kg, the mean value being 315.7 kg at the time of investigation (Table 1). They originated from several zoos in Germany. These animals remained completely isolated during the investigation, with no additional feed being provided.

TABLE 1. Body mass and age of horses in the study

Animal	Live Weight, kg	s	Age (yrs)
Bulgania	291.4	12.5	5
Ashnai	319.9	11.6	5
Mida	293.5	9.9	5
Mada	300.4	12.3	5
Lulu	292.0	4.1	4
Sprille	387.6	14.3	6
Barbarina	360.9	10.9	5
Sirena	352.6	13.0	5
Duma	268.0	4.5	4
Spirre	316.3	8.9	5
Alina	296.5	11.7	8
Nomin	309.6	4.7	5

Recording of Water Consumption and Environmental Conditions

We developed an automatic water measurement system for this investigation, in cooperation with IMF Technology (Frankfurt/O) (Fig. 1). The water trough could be accessed only through a narrow stall, one animal at a time. On entering, a system of three light monitors precisely located the position of the animal for the subsequent recording procedure. An external collar-mounted transponder was attached to each of the animals, and a reader attached to the stall's wall provided individual identification. The amount of water consumed from an automatic water bucket was measured by an electronic water meter (Farnell, Munich, Germany, type 170–795). The animals were accustomed to the water trough for half a year before observations began.

Instrument error was <1.0%, verified by a series of tests before actual data recording. The animal identification code and the amount of water consumed were recorded by a computer and were saved together with the date and time of day in monthly dBase format files. Also contained in the installation was an electronic weighting machine; weight data were automatically stored in the same file. The water feeder was automatically de-iced by a controlled heater, which ensured full function throughout the whole year.

Ambient air temperature was continuously measured (sensor: PT 100, shielded against radiation) and was recorded by the same computer used for water recording. Rainfall records were obtained from two representative meteorological stations nearby. The results presented here were obtained from 17 months of automatic recording.

Dry matter (DM) was measured from feed samples taken twice a month and dried to constant weight under laboratory conditions. The samples were taken from the very same spots in the pasture used by the horses for grazing. We watched the horses and selected the samples according to their feeding behavior.

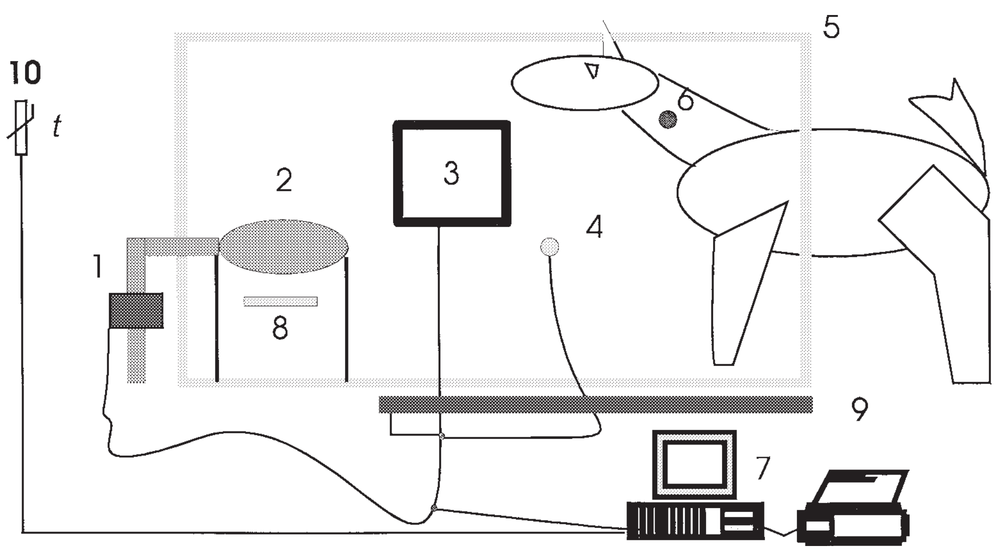

Fig. 1. Automatic water consumption recording equipment for Przewalski horses. 1. electronic water meter, 2. automatic water bucket, 3. identification antenna, 4. light barrier, 5. stall, 6. transponder, 7. PC and software, 8. controlled heater, 9. electronic weighing machine, 10. sensor for temperature.

Statistical Analysis of Water Consumption

The data files were analyzed by dBase procedures. Mean water consumption per day was calculated together with the mean daily number of drinks for each animal during each month of observation. Individual water consumption and number of drinks were thus described by a series of 17 values for 17 consecutive months. Individuals were clustered for water consumption and, in a second cluster analysis, for number of drinks. The data for each month had previously been standardized (z-transformation) to ensure equality of monthly weights. Clusters were checked for validity by Wilks' Lambda [Backhaus et al., 1994].

For each month, mean daily water consumption was averaged for all animals. Averaged monthly values were calculated for air temperature, rainfall, and dry matter of forage. A regression analysis was made, using water consumption as the dependent variable and temperature, rainfall, and dry matter as independent variables.

An overall mean value of daily water consumption over 12 months (referred to as annual mean) was calculated for each of the horses in order to make our results more easily comparable with those obtained from other investigations. As observations were carried out for more than a full calendar year (17 months), the two data points for the months that were represented twice were averaged to provide one mean value. The Spearman correlation coefficient was calculated between mean daily water consumption and body weight.

Analysis of Social Structure

The social structure of the herd was investigated during an observation period lasting 3 months. Dominant and subdominant behaviors in social interactions were recorded (threatening, displacement, biting, kicking, avoidance, flight: total of 641 observations). Individual dominance values [Bowen and Brooks, 1978] were calculated and the linearity of the rank order was tested by Landau's index of linearity [Martin and Bateson, 1986]. Bowker's index of symmetry [Sachs, 1992] was applied for significance testing of the rank order. Activities at the water place were additionally recorded ($n = 212$) and were evaluated by the same procedure. Spearman's rank correlation was also used to look for a correlation between social rank order and order at the water trough.

Initiation of Herd Movements

Herd members were visually monitored for their locomotor behavior for 8 hours daily on 10 random days. Animals who initiated a herd movement were individually identified, and the direction of the movement was recorded. These movements ($n = 56$) were subsequently classified either as leading away from or approaching the water trough. The relatively low number of observations permitted no statistical tests for individual differences in initiating herd movement.

RESULTS

Individual Water Consumption

Body weight and mean water consumption were not correlated (Spearman's coefficient = 0.16, $P = 0.62$). Cluster analysis revealed three clusters of individuals with regard to water consumption ($P < 0.00001$, Fig. 2) and slightly different clustering for the number of drinking bouts ($P < 0.0001$, Fig. 3).

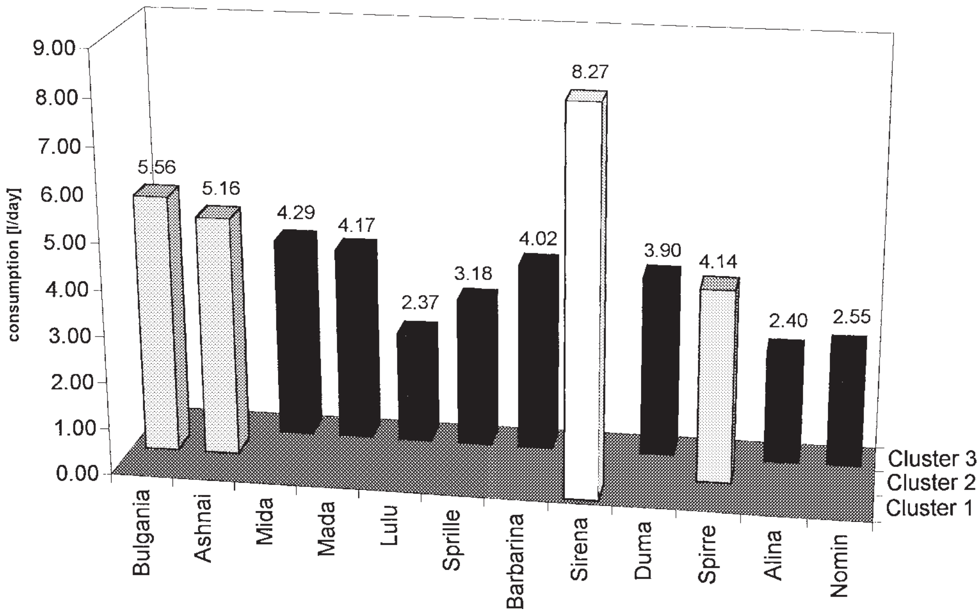

Fig. 2. Mean daily water consumption of individual Przewalski horses. Individuals are separated in three clusters, by low (cluster 3, black), medium (cluster 2, shaded) and high (cluster 1, open bar) consumption.

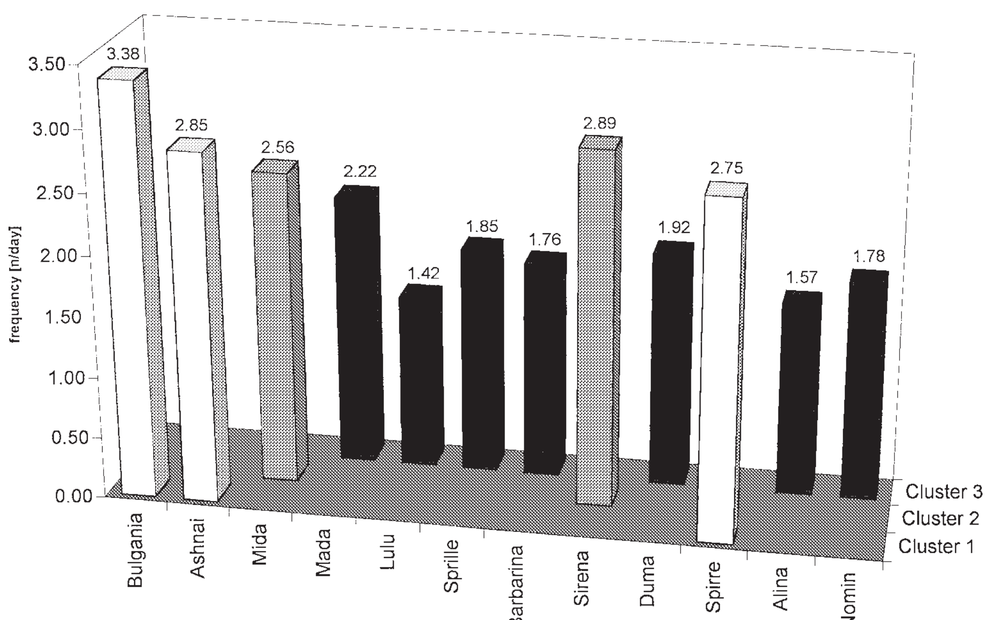

Fig. 3. Mean daily drinking frequency of individual Przewalski horses. Individuals are grouped as in Figure 2.

Annual mean water consumption varied between 2.4 and 8.3 liters/day. Individual variation throughout the observation period is depicted in Fig. 2. One of the horses, Sirena, drank considerably more water on a daily basis than other herd members. Individual differences in rates of water uptake per day differed slightly from the amount of water consumed (Fig. 3). For example, Sirena, who drank the most water, ranked in the middle in terms of frequency of drinking. The animals of the second cluster in Fig. 2 were intermediate in quantity consumed, but had the highest frequencies of drinking (Fig. 3). One animal (Mida), who was found in Cluster 3 for amount of water consumed (Fig. 2), was in Cluster 2 for drinking frequency (Fig. 3). Individual differences in water consumption and drinking frequency were generally much more strongly pronounced in periods of high water demand than in periods of generally low consumption.

Effects of Forage (Dry Matter), Temperature, and Rainfall

Stepwise multiple regression was performed on mean monthly water consumption as a dependent variable and monthly mean values of dry matter, temperature, and rainfall as independent variables. None of the three predictor variables were significant, even though temperature ($P = 0.10$) and dry matter ($P = 0.13$) were nearly significant in simple regression equations. The relationship of mean daily water uptake to forage (dry matter) and air temperature is shown in Figs. 4 and 5. Water consumption was high in warm periods, but also in dry periods when the latter coincided with cold weather. Hence, in a hot and dry period, water consumption reached the maximum level, accompanied by high individual differences in the amount of water consumed and in drinking frequency.

Social Rank Order

Individual dominance relationships are shown in Fig. 6. The Landau index of linearity was found to be h = 0.84. As is illustrated by this value, the herd did not

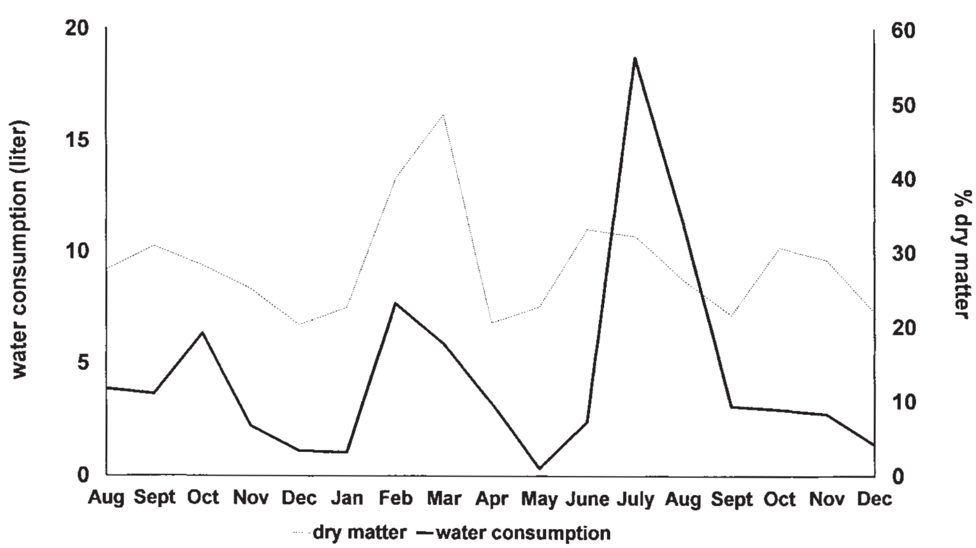

Fig. 4. Water consumption of Przewalski horses in relation to dry matter content of forage.

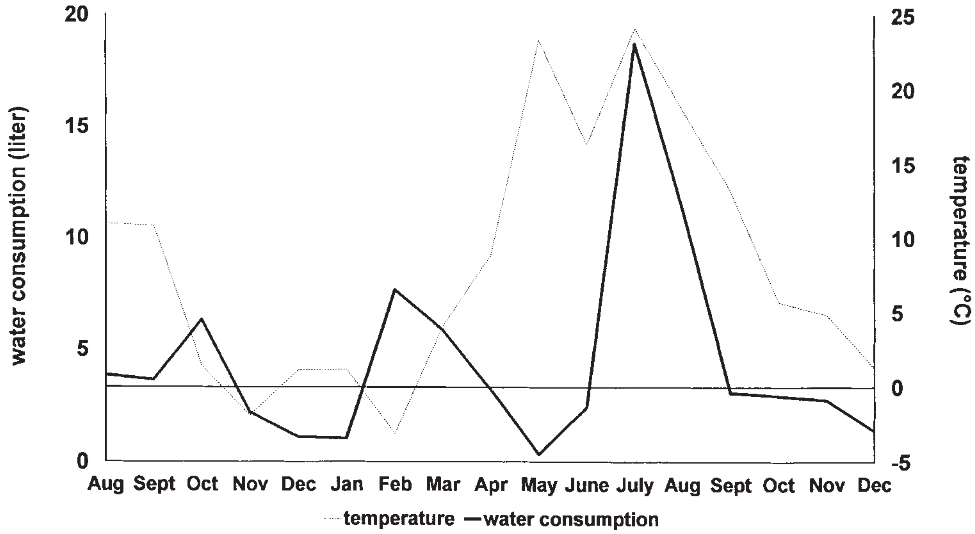

Fig. 5. Water consumption of Przewalski horses in relation to air temperature.

have a strictly linear rank order. The rank order itself was highly significant (Bowker's index of symmetry, ≤0.001). There was no significant correlation between the social rank order of horses and their rank order at the water trough (Spearman's rank correlation [Sachs, 1992]).

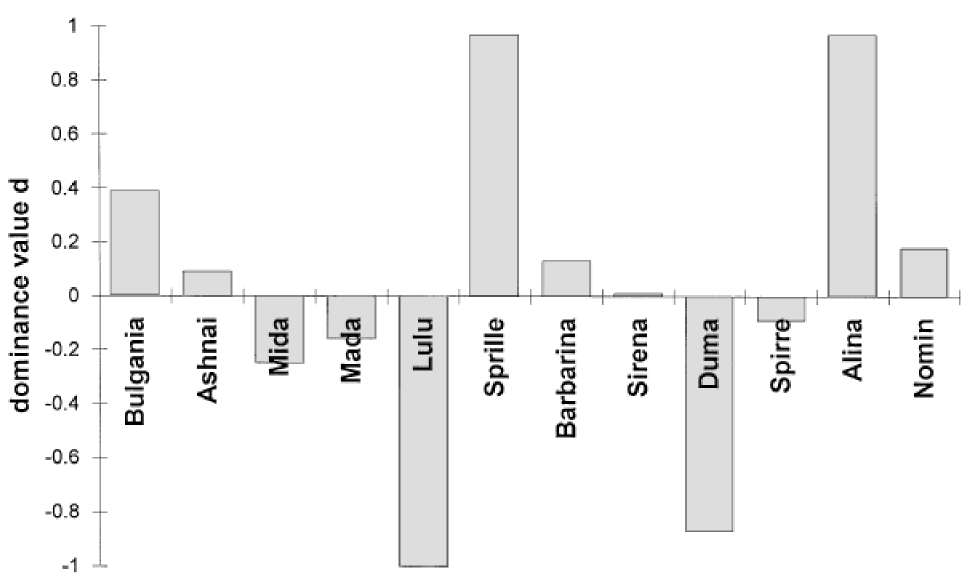

Fig. 6. Individual dominance values for the study population.

Initiation of Herd Movements

Animals with high water demand and high drinking frequency appeared to initiate the majority of herd movements, especially toward the water trough (Fig. 7). However, this could not be statistically proven because of the low number of observations. Most of the movements in that direction were initiated by Sirena, the individual with the highest water consumption.

Three individuals, Sirena, Bulgania, and Spirre, formed a top group for mean water consumption, frequency of water uptake, and initiation of herd movements to the water trough. However, Lulu and Alina were representative for low consumption, low frequency of drinking, and low frequency of initiated herd movements.

DISCUSSION

The water trough was regularly used by the horses without any problem. They had no recognizable difficulties with the automatic water dispenser and easily entered and exited the narrow stall. There were occasional social interactions, but even low-ranking animals had no problems in entering the stall and gaining access to water. The herd usually stayed close to the water trough for extended periods of time and quite often rested in its vicinity. All animals therefore had opportunity to visit the water source as often and as long as they desired. Consequently, we had no indication of possible effects of the watering apparatus on water uptake, the more so as no correlations between social rank order and rank order at the water trough were

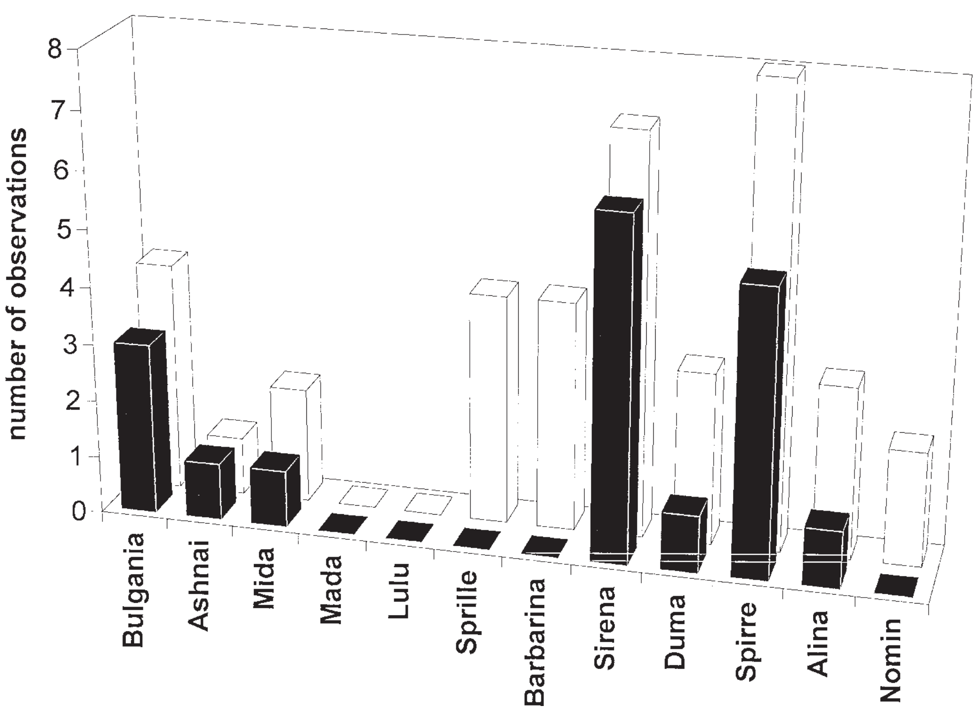

Fig. 7. Initiation of herd movements by individuals. Black bars = movements in the direction of the watering site; open bars = movements in all other directions.

found. Automatic identification of individuals worked satisfactorily, although in 5–10% of all drinking episodes each month, an individual was not identified and was excluded from the analysis.

No accurate measurements have been undertaken to date to determine the water requirements of Przewalski horses. The guidelines for keeping them in captivity [Zimmermann and Kolter, 1992] merely emphasize the need for constant access to fresh water. In a study of time budgets, Boyd et al. [1985] found that 0.47% of a 24-hr observation period was used for drinking. A very low time budget for drinking during the daylight hours is also described by Van Dierendonck et al. [1996a].

Mean daily water consumption by most of the Przewalski horses in this study was relatively low, compared to domestic horses. Following the values for domestic breeds reported by Gürtler et al. [1989] and Meyer [1992], we anticipated that the Przewalski horses would drink 7–12 liters per day. However, the individual with the highest consumption (Sirena, 8.6 liters/day on annual average) was virtually similar to the lowest amount (8.4 liters/day) recorded for the domestic horse [Heilmann, 1985]. This individual was a Norwegian Fjord horse of approximately the same body weight as Sirena and was fed a wet mixed feed during the experiment, which was more or less equivalent to our mean pasture conditions. In an experiment with ponies under controlled conditions, the animals drank between 5.4 and 11.3 liters/day [McDonnell et al., 1996]. These animals were slightly lighter than the Przewalski horses and were fed hay only. The results from these studies suggest that only Przewalski horses with highest water uptake corresponded to the findings for domestic horses obtained under more controlled conditions.

The low quantity of water consumed during this study should not be surprising. First, the animals were able to use dew and rain on the surface of vegetation and stones, as well as accumulations in small pools. Snow was occasionally consumed, and the water content of vegetation varied over the day and year. Our results may reflect primarily the influence of close-to-nature conditions and may not be reliably used as guidelines for water demand under zoo conditions.

In all our observations, water consumption rose in proportion to dry matter levels of the vegetation and, particularly, in proportion to air temperature. Dry matter levels were highest in dry winter seasons, and it was at this time that high water demand was recorded. However, the regression equation among water consumption, air temperature, dry matter, and rainfall does not fully explain the variability in water uptake. A linear model can only describe relations among these factors in an approximate way. Additional factors assumed to have an impact on water consumption are, e.g., mineral uptake, locomotor activity, and meteorological factors. Crowell-Davis et al. [1985] showed the relevance of ambient temperature to drinking frequency in noting that drinking dropped nearly to zero at temperatures below 10°C for Welsh ponies kept on pasturing conditions.

No explanation is offered for the interindividual variability in water consumption found in this study, but we mention several factors that may be of significance. High water consumption may be a learned behavior, acquired under conditions of abundance, although it seems unlikely these would persist over an extended period of time under natural conditions. The ability to select food with high water content or the preference for such food may also differ individually. However, the horses usually grazed close to each other, and the pasture quality was fairly homogeneous. There may also have been interindividual differences in the utilization of dew and snow for moisture, even when these factors were the same for all animals. Uptake during the night and in early morning hours of more strongly hydrated plant material, furthermore, is well known for animals adapted to a dry environment [Grenot, 1992]. Interindividual differences in dry periods were more strongly pronounced than in wet ones and thus may be indicative of differential behavioral reactions. Differences in body weight did not correspond to differences in water uptake, and individual differences in locomotor activity were not significant. Running was rarely observed and if it occurred, all animals displayed this behavior at the same time.

Drinking frequency in this context was not as important as the amount of water consumed. When the herd visited the water source, it usually remained close by for an extended period of time. All horses had the opportunity to drink several times during such visits; some did so in short intervals, whereas others drank the amount desired during a single visit to the trough.

In light of the foregoing, differential consumption appears to be attributable to a genuine variance in physiological need, as seen from initiation of movements to the water trough. The animals with the highest consumption were seen on several occasions to move from the herd in the direction of water, but to return if the herd did not follow. Repetition of this pattern suggested an attempt to move the entire herd to water. Success in initating herd movements to water bore no relationship to social rank. Although the herd consisted of mares only, there was a well-developed rank order, resembling a natural herd structure with leading stallion. This role was held by the oldest female, Alina. She kept the herd together but, as a very quiet animal, rarely determined the behavior of the herd as a whole. The mare Sprille was fairly aggressive and frequently determined the behavior of the herd. Nevertheless, these two high-ranking animals were rarely seen to determine herd movements and if they did, it usually was not in the direction of the watering site. However, those animals with high water demand (Sirena, Spirre, Bulgania) initiated herd movements both toward and in directions away from the watering trough. These observations suggest that, in a more natural herd structure and in the far larger home ranges of wild herds, individuals may influence the travel and location of the herd on the basis of their water requirements.

For a free-ranging group in a dry habitat, the usable range area is determined by the longest distance from the water source that the horses are able to travel in 1 day [Fraser, 1992]. Animals with high water demand, as we have observed, may reduce the range area of the whole herd, and frequent visits to a water site may increase the risk of predation. A reduction in herd range size will, in cases of overgrazing, also reduce the available food resources.

The importance of water for Przewalski horses is known from observations in the wild [Bannikov, 1967], indicated in part by the fact that the last sightings of record were near natural springs [Bouman and Bouman, 1994]. The species' tolerance level for relatively dry environments may be the product of long-term adaptation, possibly resulting from individually acquired experiences or from knowledge passed from generation to generation. Such tradition-related adaptations cannot be expected in zoo animals that are candidates for reintroduction.

Also, since different breeds of horses are differently adapted to hot and dry climates, as shown by Sneddon et al. [1991], the possibility of genetic adaptation, no doubt a major element in the evolutionary strategy of the species, cannot be ruled out for Przewalski horses. However, the interindividual variation found in our study is not supportive of this conclusion. For reintroductions, therefore, selective human intervention seems to be required to preclude failure in such efforts and to avoid unnecessary suffering of inadequately adapted animals.

CONCLUSIONS

1. Although access to sufficient water is an essential factor for the survival of Przewalski horses in arid regions, the individual differences in water demand found in our study indicate the need for further study of the species' physiological requirements.

2. Physiological and genetic bases for varying water demands may be assumed but cannot be verified at this time.

3. As differences in water consumption may be primarily attributed to selection of wet or dry food for consumption, acquired preferences may be important and should be given the opportunity to develop in animals envisaged for reintroduction to wild habitat.

4. Selecting individuals with low water demand for reintroductions may be the best way to ensure to avoid unnecessary suffering, loss and failure.

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