DIPLOMARBEIT

Titel der Diplomarbeit

Differences of movement pattern between Asiatic wild ass (*Equus hemionus*) and Przewalski's horse (*Equus ferus przewalskii*)

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1. Abstract

Analysing animal movement reveals how animals interact with their environment and is necessary to understand their foraging behaviour. Due to landscape heterogeneity, species differences, various resource selection and physical features animals show various movement tactics.

I analysed the GPS data of 6 Przewalski's horses and 3 Asiatic wild asses collected in the Mongolian Gobi from 2001 to 2007. Using the variables travel distance and turning angle I analysed individual datasets to look for possible species-specific (wild asses versus P-horses), area-specific (wild asses in the SE Gobi versus the SW Gobi) and management specific (established versus newly released P-horse groups) trends in movement strategies. Due to the small sample size of different individuals my focus was on a first qualitative assessment of movement strategies as a basis for future hypothesis testing.

Species: Asiatic wild asses had home ranges from 4784 km² to 42776 km². Contrary to the Przewalski's horses, the Asiatic wild asses showed an almost linear relationship between the travel distance and the time interval between successive locations suggesting a high mobility. Mean daily distance travelled averaged 8451 m. The wild asses moved in larger turning angles than Przewalski's horses. Przewalski's horses covered home ranges from 290 km² to 1357 km² and located near watering places. Mean daily distance covered averaged 3177 m. The horses tended to be more resident because they preferred moving in turning angles less than 90°. The autocorrelation of travel distances and turning angles and the correlation between these parameters were not significantly stronger for wild asses than for wild horses.

Area: No significant differences in travel distances were found between the 2 wild asses in the SE Gobi (range: 9646 m – 7606 m) and the wild ass in the Great Gobi B (8102 m) and also no noticeable differences in turning angles were detected between the animals in the SE (mean: 90,22°) and the ass in the SW (88,6°). The autocorrelation of daily travel distances and daily turning angles were stronger for the asses in the SE than for the ass in the SW. The Asiatic wild asses in the SE Gobi exhibited a stronger correlation between travel distance and turning angle than the wild ass in the Great Gobi B.

Management: Of the Przewalski's horses, the established horses (mean: 428 km²) did not show significant larger home ranges than the newly released horses (mean: 591 km²). However, between the two groups there were statistical differences in daily travel distances,

but not so in daily turning angle. Established wild horses did not revealed a stronger autocorrelation of daily travel distances and daily turning angles and a stronger correlation between distance and angle than the newly released wild horses.

2. Zusammenfassung

Das Analysieren von Bewegungsmustern verschiedener Tiere gibt Aufschlüsse darüber, wie Tiere mit ihrer Umwelt interagieren. Aufgrund Artunterschiede, Umweltheterogenität, unterschiedlicher Ressourcenauswahl und physikalische Eigenschaften zeigen Tiere verschiedene Bewegungsstrategien.

Ich wertete GPS-Daten, gesammelt im Zeitraum von 2001 bis 2007 in der Mongolei, von drei Asiatischen Wildeseln und sechs Przewalski-Pferden aus. Unter Verwendung der Variablen "zurückgelegte Strecke" und "Abweichwinkel" analysierte ich individuelle Datensätze um mögliche Tendenzen von Bewegungsstrategien hinsichtlich Artenunterschieds (Przewalski-Pferd versus Asiatischer Wildesel), Gebietsunterschieds (Wildesel im SW der Gobi versus Wildesel im SE der Gobi) und Management (etablierte versus kürzlich ausgesetzte Przewalski-Pferde) festzustellen. Aufgrund des geringen Stichprobenumfangs der verschiedenen Individuen legte ich meinen Schwerpunkt auf eine erste qualitative Einschätzung der Bewegungsstrategien als Grundlage für weitere Hypothesen.

Art: Das Revier, in dem sich die Asiatischen Wildesel aufhielten, war mit durchschnittlich 22624 km² deutlich größer als jenes der Przewalski-Pferde, das nur durchschnittlich 510 km² betrug. Im Gegensatz zu den Przewalski-Pferden zeigten die Wildesel eine nahezu lineare Beziehung zwischen zurückgelegter Distanz und Zeitintervall. Dies deutet auf eine hohe Mobilität seitens der Wildesel. Die Esel legten mit 8451 m höhere Tagesstrecken als die Pferde mit 3177 m zurück. Die Asiatischen Wildesel bewegten sich in größeren Abweichwinkeln als die Wildpferde. Die Pferde tendierten eher zu Residenz; sie bevorzugten Bewegungen mit Abweichwinkeln von weniger als 90°. Die Wildesel zeigten keine höhere Autokorrelation der Distanzen und Abweichwinkel. Weiters war die Korrelation zwischen Tagesdistanzen und Winkel bei den Eseln nicht stärker ausgeprägt als bei den Pferden.

Gebiet: Innerhalb der Gruppe der Wildesel legten die Esel im Südosten der Gobi (Bereich: 9646 m – 7606 m) keine signifikant längeren Tagesstrecken zurück als der Esel in der Great Gobi B (8102 m). Weiters konnten keine merklichen Unterschiede im Abweichwinkel zwischen den Tieren im Südosten (Mittelwert: 90,22°) und dem Esel im Südwesten (88,6°) festgestellt werden. Die Esel im SO wiesen eine höhere Autokorrelation der Tagesdistanzen und Abweichwinkel auf als der Esel im SW. Auch konnte bei den Eseln im südöstlichen Teil der Gobi ein stärkerer Zusammenhang zwischen Tagesdistanz und Abweichwinkel ermittelt werden.

Management: Innerhalb der Wildpferde besiedelten die bereits etablierten Pferde mit durchschnittlich 428 km² keine signifikant größeren Flächen als die erst kürzlich entlassenen Tiere mit durchschnittlich 591 km². Die etablierten Pferde zeigten jedoch größere Tagesdistanzen und Abweichwinkel als die unlängst ausgesetzten Tiere. Keine auffallenden Unterschiede gab es allerdings bei der Autokorrelation von Tagesdistanz und Abweichwinkel und bei der Korrelation zwischen Distanz und Abweichwinkel.

3. Introduction

Movement is crucial for the survival of animals in order to find resources, mates or escape from predators (Bergman et al. 2000). Due to differences in tropic level, live history and physiological traits on the one side and environmental characteristics or heterogeneity on the other side, different species or individuals show different movement patterns (Milne et al. 1989). Differences in movement can also be related to differences among sexes (e.g. Lindzey and Meslow 1977), years (e.g. Ralls et al. 1996), and temporal activity such as diel, nocturnal or seasonal changes (e.g. Beier and McCullough 1990) and different behaviours like foraging, hunting or breeding (e.g. Beier et al. 1995).

Previously, animals were tracked using the very high frequency (VHF) and satellite telemetry (Bowman et al. 2000) to record movement patterns. Since the development of the Global Position System (GPS) it is easier to follow the movement path of large and vagile mammals (Johnson et al. 2002; DeCesare et al. 2005), because it does not involve a person on the ground following the animal and thus is less costly. Furthermore data is very precise and can be collected at regular intervals during day and night largely unaffected by adverse weather or difficult terrain (Rempel et al. 1995; Bowman et al. 2000).

The study of movement patterns gives insights into how animals' respond to environmental heterogeneity (Johnson et al. 1992) and is important to understand animals' foraging behaviour (Smith 1974; Jones 1976; Bond 1980; Pyke 1984; Crist et al. 1992). Variations in movement patterns have implications for population structure and dynamic (Shorrocks and Swingland 1990; Johnson et al. 1992; McIntyre and Wiens 1999). Analysing animal movements is also essential to understand how habitat fragmentation affects ecology, behaviour and interspecific interactions (Kareiva 1987; Gehring and Swihart 2004). To detect how behaviours encompass individual movements several theoretical models have been developed (Bergman et al. 2000).

Kernel methods were used to assess home range and density estimate (Worton 1989) but they do not illustrate 'the decision rules which led the animal to move across the landscape in such a manner' (Austin et al. 2004). For conducting comparative studies of animal's trajectories (random or directed), ignoring the underlying habitat, only two parameters are necessary: movement length and turning angle (Kareiva and Shigesada 1983). The movement length is

the distance covered from one location to the next, whereas the turning angle is the change in direction between 3 successive locations (Austin et al. 2004).
The pure random walk is the simplest model where turning angles between consecutive movements are completely random (Dai et al. 2007), in other words, the animal shows no intention to keep moving in the same direction (Kareiva and Shigesada 1983). Contrary, in a correlated random walk the turning angles between successive steps are not statistically independent (Johnson et al. 1992) leading to 'persistence' of direction (Patlak 1953) and thus a somewhat directed trajectory. The Lévy walk is a special case of random walk, which is characterized by a heavy-tailed distribution of step lengths (Plank and James 2008) and scale-invariant moves (Codling et al. 2008).

Habitat suitability depends on many factors like abundance of food, shelter, predators and competitors (Krebs 2009) and leads to various movement strategies. Animals move nomadically in habitats with high spatiotemporal variability of resources (Mauritzen et al. 2001; Schwarzkopf and Alford 2002; Roshier et al. 2006). In areas with few resources, animals have to cover longer distances in search of food (Turner et al. 1993). Because of the change of resources many animals are forced to seasonal movements, especially birds (Levey and Stiles 1992; Berthold 1993). But also many large herbivores undertake seasonal migrations to increase access to areas of high food resources (Fryxell and Sinclair 1988). Besides the availability of pasture land, the distribution of water has a major impact on movement patterns of many large herbivores, particularly equids (Saltz et al. 2000; Scheibe et al. 1998).

The genus *Equus* can be divided into seven recent species. The Grévy's zebra (*Equus grevyi*) occurs in Ethiopia and Kenya and is adapted to arid and semi-arid regions (Klingel 1974; Rubenstein 1986; Williams 2002). The home ranges of the Mountain zebra (*Equus zebra*) are mountainous landscapes of Namibia and South Africa (Novellie 2008). The Plains zebra (*Equus quagga*) occurs in the Southeast of Africa and is found in a large variety of habitats (Moehlman 2002). The Kiang (*Equus kiang*) is distributed in China, India, Nepal and Pakistan and inhabits desert-steppes (Schaller 1998) as well as hills with grasses and sedges (Bhatnagar et al. 2006). The African wild ass (*Equus africanus*) exists in Eritrea, Ethiopia and Somalia and inhabits arid and semi-arid bushland and grassland (Moehlman et al. 2008).
The Asiatic wild ass (*Equus hemionus*) is globally threatened and listed as 'endangered' by the IUCN (Moehlman et al. 2008). The distribution range includes Iran (Feh et al. 2002),

Turkmenistan (Lukarevski and Gorelov 2007), India (Sha and Qureshi 2007), China (Yang 2007) and Mongolia (Lhagvasuren 2007). The wild ass is adapted to arid desert-steppes and semi-deserts (Kaczensky et al. 2008) and does not seem to need daily access to water (Bahloul et al. 2001; Kaczensky et al. in press).

The most recent estimates suggest a population of 20000 asses throughout the Gobi regions of Mongolia, with the majority of animals living in the SE Gobi and smaller subpopulations in the SW and central Gobi (Lhagvasuren 2007). Home ranges in the SE Gobi are considerably larger than those in the SW. Due to differences in water availability and rainfall patterns asses seem to roam over much large areas in the SE as compared to the SW Gobi (Kaczensky et al. 2006; Kaczensky et al. 2008). Contrary to Przewalski's horses wild asses do not seem to prefer any particular plant communities and have been found to cover longer distances searching for water and pastures than Przewalski's horses (Kaczensky et al. 2008).

The Przewalski's horse (*Equus ferus przewalskii*), the only remaining species of true horses (Wakefield et al. 2002), became extinct in the wild but survived due to captive breeding. The species has been reintroduced to Mongolia and China since the early 1990s (Zimmermann 2005). There are only a few areas where different equid species overlap, one of the areas where species do overlap is the Mongolia Gobi. Here both the Asiatic wild ass and the Przewalski's horse occur sympatrically (Kaczensky et al. 2008).

In Mongolia Przewalski's horses can presently found in two free-ranging populations. About ~250 horses live in the mountain steppe of Hustain Nuuru in central Mongolia (Masuda et al. 2007; Bandi pers. comm. 2009) and ~150 horses in the desert steppe of Great Gobi B Strictly Protected Area (SPA) in SW Mongolia (Walzer et al. 2010). Recent analyses of habitat use data support the view that the dry Gobi areas likely constitute an edge habitat for Przewalski's horses (van Dierendonck and Wallis de Vries 1996; Kaczensky et al. 2008). However, permanent oasis in Great Gobi B SPA guarantee daily access to surface water and provide productive habitat to support a species primarily adapted to more mesic steppe habitats (Bahloul et al. 2001; Kaczensky et al. 2008). The wild horses show a clear preference for riparian and oasis vegetation (Kaczensky et al. 2008). Home ranges of Przewalski's horses are centred around the most productive habitat types, but are only about 1/10 of the size of those found used by sympatric Asiatic wild asses (Kaczensky et al. 2008).

Between 1997 and 2005, a total of 11 different Wild horse groups of captive origin have been released into the Great Gobi B SPA. Wild horses, which were recently released into the Gobi, initially seemed to stay close to the release site (Souris et al. 2007) and possibly also move less or shorter distances than established groups.

The aim of this study was to analyse movement patterns of 3 Asiatic wild asses from two different areas and 6 Przewalski's horses with different release backgrounds. Given the large difference in range sizes, Asiatic wild asses should show different movement patterns than Przewalski's horses and I expected to find the following pattern:

1. Asiatic wild asses have longer daily travel distances, a stronger partial autocorrelation in daily travel distances, larger turning angles, a stronger partial autocorrelation in turning angles, or show a stronger positive autocorrelation between distance travelled and turning angle than Przewalski's horses.
2. Of the 3 Asiatic wild asses, the 2 animal from the SE have longer daily travel distances, a stronger partial autocorrelation in daily travel distances, larger turning angles, a stronger partial autocorrelation in turning angles, or show a stronger positive autocorrelation between distance travelled and turning angle than the 1 animal from the SW Gobi.
3. Of the 5 Przewalski's horses, established horses have larger ranges, longer daily travel distances, a stronger partial autocorrelation in daily travel distances, larger turning angles, a stronger partial autocorrelation in turning angles, or show a stronger positive autocorrelation between distance travelled and turning angle than newly released horses.

4. Materials and methods

4.1. Study area

The study areas were located in the SW and SE of the Mongolian Gobi (Fig. 1). The study area in the SE covered about 90000 km² (for details see Kaczensky et al. 2006), the one in the SW encompassed the 9000 km² Great Gobi B Strictly Protected Area (for details see Kaczensky et al. 2004).

The Mongolian climate is continental with long cold winters and short hot, summers. Average annual temperature is around 0-2°C. The annual precipitation largely falls in the summer months and averages 100 mm in the Great Gobi B region and up to 250 mm in the SE Gobi (von Wehrden and Wesche 2008).

The dominant vegetation zones are steppe and semi-desert in the SE and semi-desert and desert in the SW of Mongolia (von Wehrden and Wesche 2008). Surface water in the SE is much more dependent on local rainfall patterns making oasis and water holes more ephemeral than in the SW Gobi where rivers and oasis are fed from the surrounding high mountain ranges (Kaczensky et al. 2006; Kaczensky et al. 2008).

The Mongolian Gobi is primarily used for livestock grazing of camels, cattle, yaks, cattle-yak hybrids, horses, sheep and goats (Johnson et al. 2006). Semi-nomadic pastoralism constitutes the main source of income for rural people and pasture competition between livestock and wild ungulates is a serious conservation concern (Kaczensky et al. 2007). Although wild equids are strictly protected (Shiirevdamba et al. 1997), illegal hunting poses a major threat to Asiatic wild asses (Clark et al. 2006).

Other ungulates which occur in the Gobi region are the Mongolian gazelle (*Procapra gutturosa*), goitered gazelle (*Gazella subgutturosa*), argali wild sheep (*Ovis ammon*) and Siberian ibex (*Capra sibirica*). Large or medium sized predators are the grey wolf (*Canis lupus*), lynx (*Lynx lynx*), pallas cat (*Otocolobus manul*), red fox (*Vulpes vulpes*) and corsac fox (*Vulpes corsac*) (Zhirnov & Ilyinsky 1986; Kaczensky et al. 2006).

Before releasing the Przewalski's horses in the Great Gobi B SPA, the horses were kept in the adaptation facilities for one year in order to allow adaptation to local condition, enable disease monitoring and facilitate veterinary treatment (Slotta-Bachmayr et al. 2004; Robert et al. 2005). In the year 2005 a release was arranged in the north-central part of the Great Gobi B SPA to increase the distribution range of the wild horses in the SPA. In this case, the horses were transported by truck from the adaptation enclosure at Takhin Tal to the release site at the oasis "Takhin us". The group was held there in an enclosure with electric fence for six weeks. Afterwards the fence was removed.

4.2. Animals & Data collection

Between October 2001 and July 2007, three Asiatic wild asses, one female and two males, and six Przewalski's horses, all females, were captured (for details see Walzer et al. 2007) and radio-collared with GPS/ARGOS collars (TGW-3580, Telonics, Mesa; USA). All collars were equipped with pre-programmed drop-off devices (CR-2a, Telonics). A total of 7757 GPS locations were obtained (Tab. 1). The duration of the GPS fix sampling intervals for the individual animals ranged from 5 hours to 13 hours.

The asses Khushaat, Khuyg from the SE Gobi and Leroy from the SW Gobi were born and collared in the wild. The female Khushaat was not accompanied by a foal. The area covered by Khushaat was 42776 km² and by Khuyg 20313 km² (Tab. 1). The home range of Leroy covered 4784 km² and was situated in the Great Gobi B Strictly Protected Area.

The 6 Przewalski's horses were also resident in the Great Gobi B Strictly Protected Area. Their individual home ranges varied from 290 km² to 1357 km². Three horses (Uugan, Toodog and Orchon) were considered established animals as they had already been free-ranging for at least 2 years. Uugan was actually the first horse born in the adaptation facility in Takhin Tal. The remaining three horses (Shazgai, Mondor and Shandas) were collared upon or very shortly after release from the adaptation enclosure. Shandas was a member of the group released in the north-central part of the park (Takhi us).

Table 1. Study group composition and location statistics.

ID	Group	Sex	Age (yrs)	Start date	End date	GPS fix interval (h)	N GPS fixes	MCP** (km²)	Area	Origine (Release year)
Wild asses										
Khushaat	NA*	F	5	03.07.2005	20.10.2006	7	1570	42776	SE Gobi	NA
Khuyg	NA	M	4	09.07.2005	25.05.2007	7	1168	20313	SE Gobi	NA
Leroy	NA	M	7	16.07.2003	03.08.2004	12	648	4784	Great Gobi B	NA
Wild horses										
Established groups (>2 years since release)										
Uugan	Pas	F	17	27.10.2003	28.07.2005	12	580	707	Great Gobi B - NE	Takhin Tal enclosure (1998)
Toodog	Mundol	F	15	20.01.2002	27.05.2002	5	456	442	Great Gobi B - NE	Takhin Tal enclosure (2000)
Orchon	Tuulai	F	9	12.05.2003	17.09.2003	5	290	135	Great Gobi B - NE	Takhin Tal enclosure (2000)
Newly released										
Shazgai	Tuulai	F	12	30.10.2001	02.05.2002	11	352	152	Great Gobi B - NE	Switzer-land (2001)
Mondor	Tayan	F	11	11.05.2003	01.05.2005	12	1357	223	Great Gobi B - NW	Germany (2003)
Shandas	Khubsgul	F	10	26.06.2005	09.07.2007	13	1336	1398	Great Gobi B - NE	Nether-lands (2005)

*NA = not applicable
**MCP = minimum convex polygon

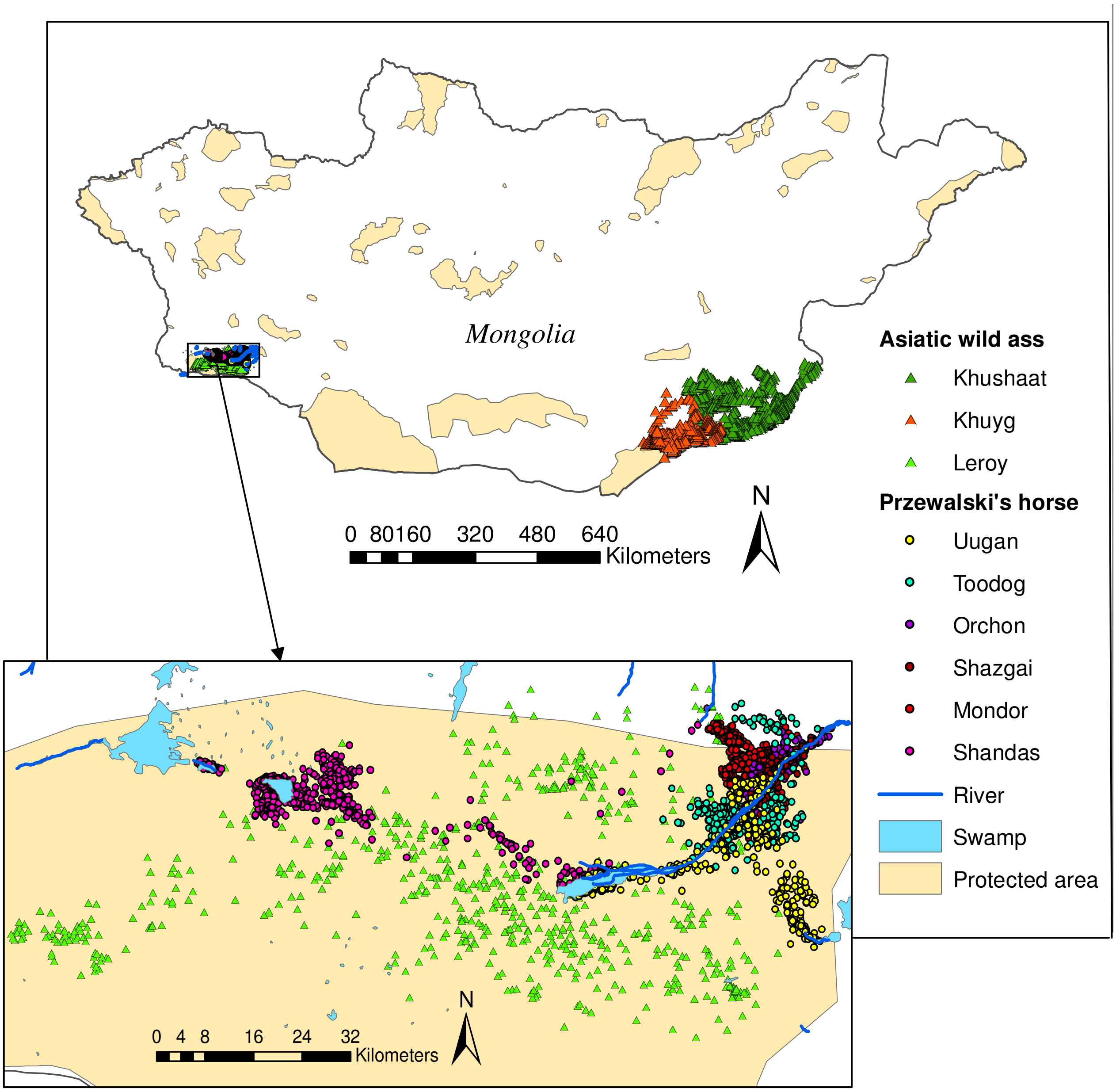

Figure 1. Study location and spatial distribution of GPS fixes of the 9 study animals.

4.3. Statistical analysis

To determine the spatial distribution and calculate the surface area I used the 100% minimum convex polygon (MCP) option in Hawth's Analysis Tools for ArcGIS version 9.3.

The travel distance c I calculated using Pythagora's theorem:

$$c = \sqrt{(x_{bn} - x_a)^2 + (y_{bn} - y_a)^2}$$

$$a = x_{bn} - x_a$$

$$b = y_{bn} - y_a$$

where x_a and y_a are the x/y-coordinates from the starting point and x_{bn} and y_{bn} the x/y-coordinates from the position after n intervals (Knauer 2000).

The turning angle α_t presents the angle between the new direction and the direction before (Turchin et al. 1991) and was derived from the direction angle α_D (Fig. 2) as follows:

$$\alpha_D = 360 - (arccos\frac{b_2 + c_2 - a_2}{2bc} / Pi * 180°) \qquad \text{if a > 0} \qquad \text{or}$$

$$\alpha_D = (arccos\frac{b_2 + c_2 - a_2}{2bc} / Pi * 180°) \qquad \text{if a} \leq 0$$

and

$$\alpha_t = 180 - (\alpha_{D1} - \alpha_{D2})$$

where α_{D1} and α_{D2} are consecutive direction angles (Knauer 2000).

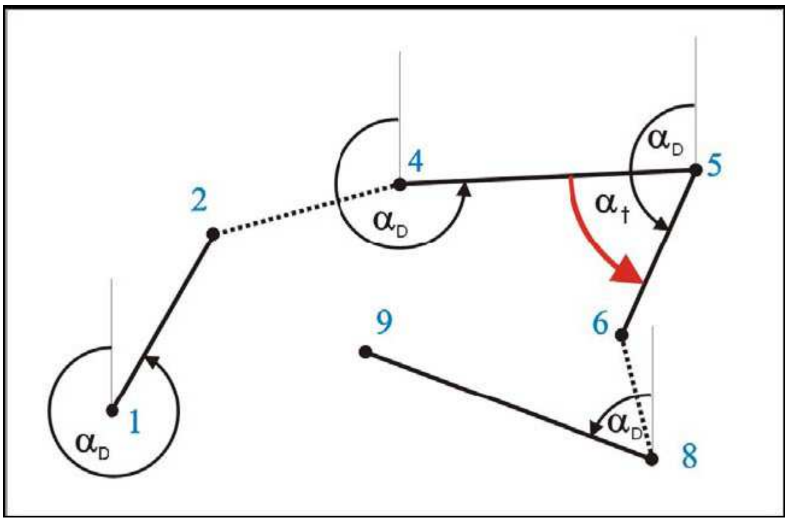

Figure 2. Schematic view of turning angle α_t and direction angle α_D. The blue numbers represent the consecutive positions and the continuous thick lines the travelled distances. Continuous thin lines illustrate north direction. Dotted lines indicate the path covered between two sequent distances. (Source: Knauer 2000)

Unfortunately the sampling intervals were different among the 9 study animals. Because I expected travel distances and turning angles to be depended on the time interval between successive GPS fixes, I calculated for every GPS fix also the turning angle and travel distance to the second next, third next, forth next GPS position and so on, up to time intervals 75-78 hours (~3 days = max interval) apart:

$$a_n = x_{bn} - x_a \,;\; b_n = y_{bn} - y_a \qquad \text{(n-fold)}$$

To obtain values for the turning angle and the straight line distance within 24 hours I fitted a power function through the cloud of distances of all possible intervals up to the max interval.

$$y = b_0 * x^{b1}$$

where b_0 and b_1 are the parameters to be estimated and x is the independent variable.

For comparing daily distances/turning angles I calculated the values only for fixes that were 21 – 26 hours apart.

Frequency distribution, boxplot, partial autocorrelation and correlation were done with SPSS 16.0.

Daily distances and daily turning angles were plotted over time in Excel 2002 to visualize the periodicity of successive distances travelled and successive turning angles. The base line represents the mean value of either daily distances (Fig. 9, Fig. 10) or daily turning angles (Fig. 15). I calculated the data of the y-axes by subtracting the mean value from the individual daily distance or daily turning angle.

For comparative analysis of differences in home ranges, travel distances and turning angles between Asiatic wild asses and Przewalski's horses I used T-tests and mixed models with the individual as random variable and log transformations for distances and angles. I subsequently checked for an approximate normal distribution of the residuals. To determine which variables influence home range size I also used a mixed model approach with species as random variable. P-values less than 0,05 were considered statistically significant.

5. Results

5.1. Home range

Home ranges, expressed as minimum convex polygons (MCP), were largest for the wild asses in the SE Gobi, followed by the wild ass in the SW Gobi. However, home range sizes of Przewalski's horses did not follow an easily recognizable pattern with established groups being larger than newly released groups (Fig. 3, Tab. 1).

The differences in home range size were statistically significant between Asiatic wild asses and Przewalski's horses (T-test: $t = 3{,}06$; $df = 7$; $P < 0{,}05$) but not so between established and newly released horses (T-test: $t = -0{,}37$; $df = 2{,}65$; $P = 0{,}737$).

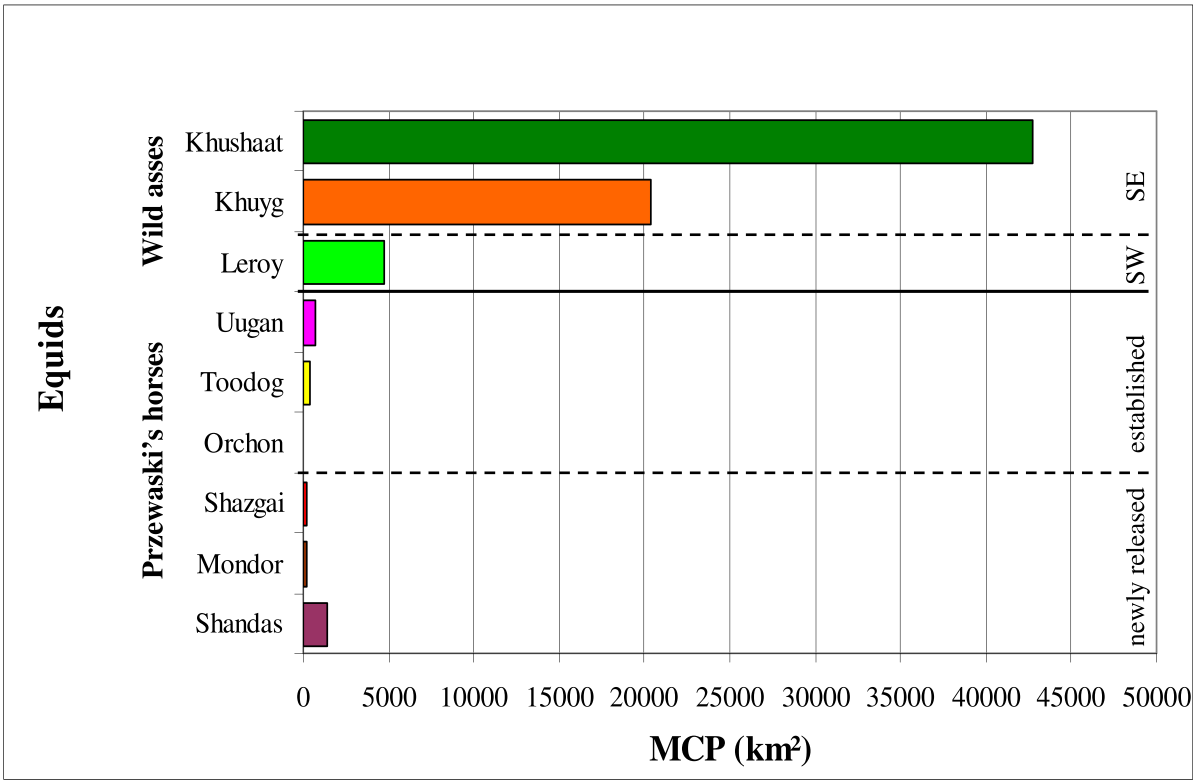

Figure 3. Home range size, expressed as minimum convex polygons (MCP), of the equids.

5.2. Travel distance

5.2.1. Distances covered in relation to time

Whereas travel distances, quickly levelled out for Przewalski's horses and already reached a plateau after 10-20 hours, distances kept increasing for wild asses and no plateau was reached even after 3 days (Fig. 4). This was true for all three asses, regardless of study area. For Przewalski's horses there seems to be a tendency for newly released horses to reach a lower plateau, than the established groups.

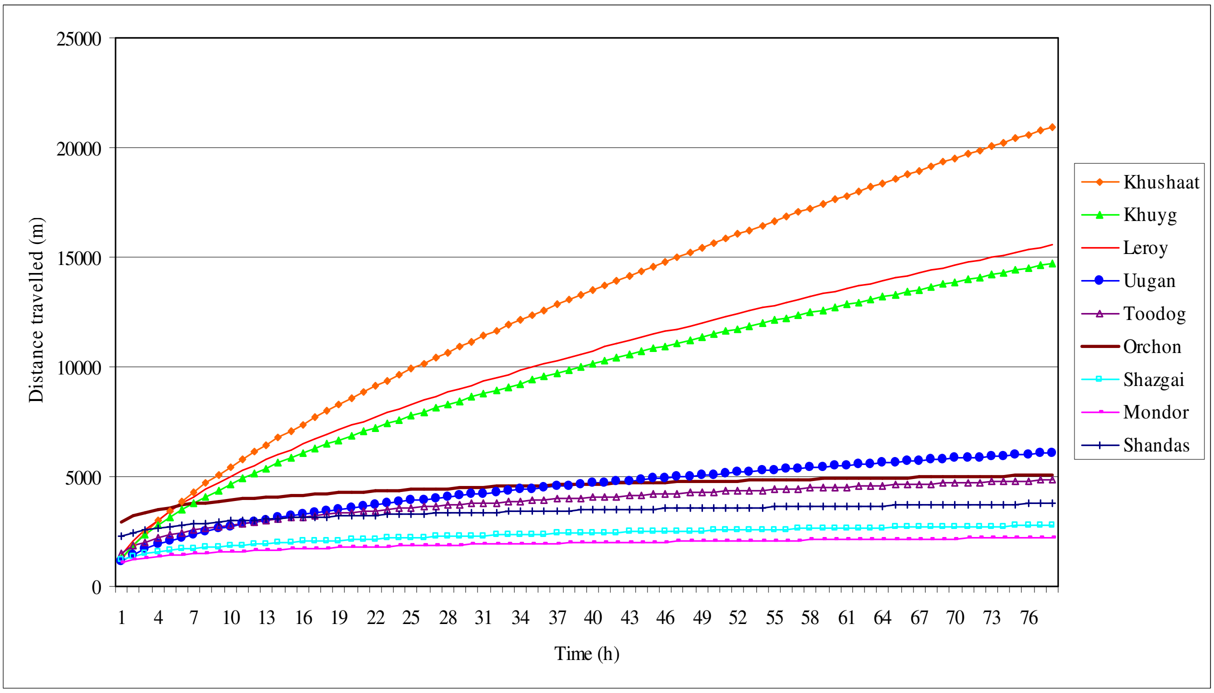

Figure 4. Relationship between distances travelled (m) and time (h).

Data extrapolation based on a power function through all possible intervals generally shows a good fit (Tab. 2). Average distance travelled within 24 hours averaged 8451 m (range: 7606 – 9646 m) for the asses and 3177 m (range: 1826 – 4377 m) for the horses (Tab. 3).

There were significant differences in travel distance between Asiatic wild asses and Przewalski's horses (T-test: $t = 7{,}2$; $df = 3{,}78$; $P < 0{,}01$). The established horses did not show significant longer travel distances within 24 hours than newly released horses (T-test: $t = 2{,}96$; $df = 3{,}16$; $P = 0{,}056$).

Table 2. Parameters estimate due to curve fitting for travel distances by a power function ($y = b_0*x^{b1}$).

ID	b_0	b_1/exponent	r^2	F
Asiatic wild asses				
Khushaat	1191,64	0,658	0,999	6439,34
Khuyg	1279,01	0,561	0,999	9058,477
Leroy	1397,47	0,553	0,999	3357,101
Przewalski's horses				
Uugan	1110,61	0,390	0,958	91,846
Toodog	1518,94	0,266	0,974	454,646
Orchon	2951,48	0,124	0,439	9,402
Shazgai	1182,50	0,196	0,926	62,255
Mondor	1080,66	0,165	0,939	61,758
Shandas	2269,54	0,116	0,770	13,368

Table 3. Mean distances covered (m) within 24 hours by all 9 equids.

	Asiatic wild asses			Przewalski's horses					
	Khushaat	Khuyg	Leroy	Uugan	Toodog	Orchon	Shazgai	Mondor	Shandas
Mean distance covered (m) within 24 h	9646	7606	8102	3836	3537	4377	2205	1826	3281

5.2.2. Daily distance travelled

5.2.2.1. Frequency distribution

5.2.2.1.1. Asiatic wild ass

The distributions of the data were highly skewed. The majority of the segments were less than 8000 m (Fig. 5). The most frequently travelled distances were between 1000 m and 3000 m. The maximum of distance covered by Khushaat within 24 hours was 52783 m, by Khuyg 43385 m and by Leroy 34835 m.

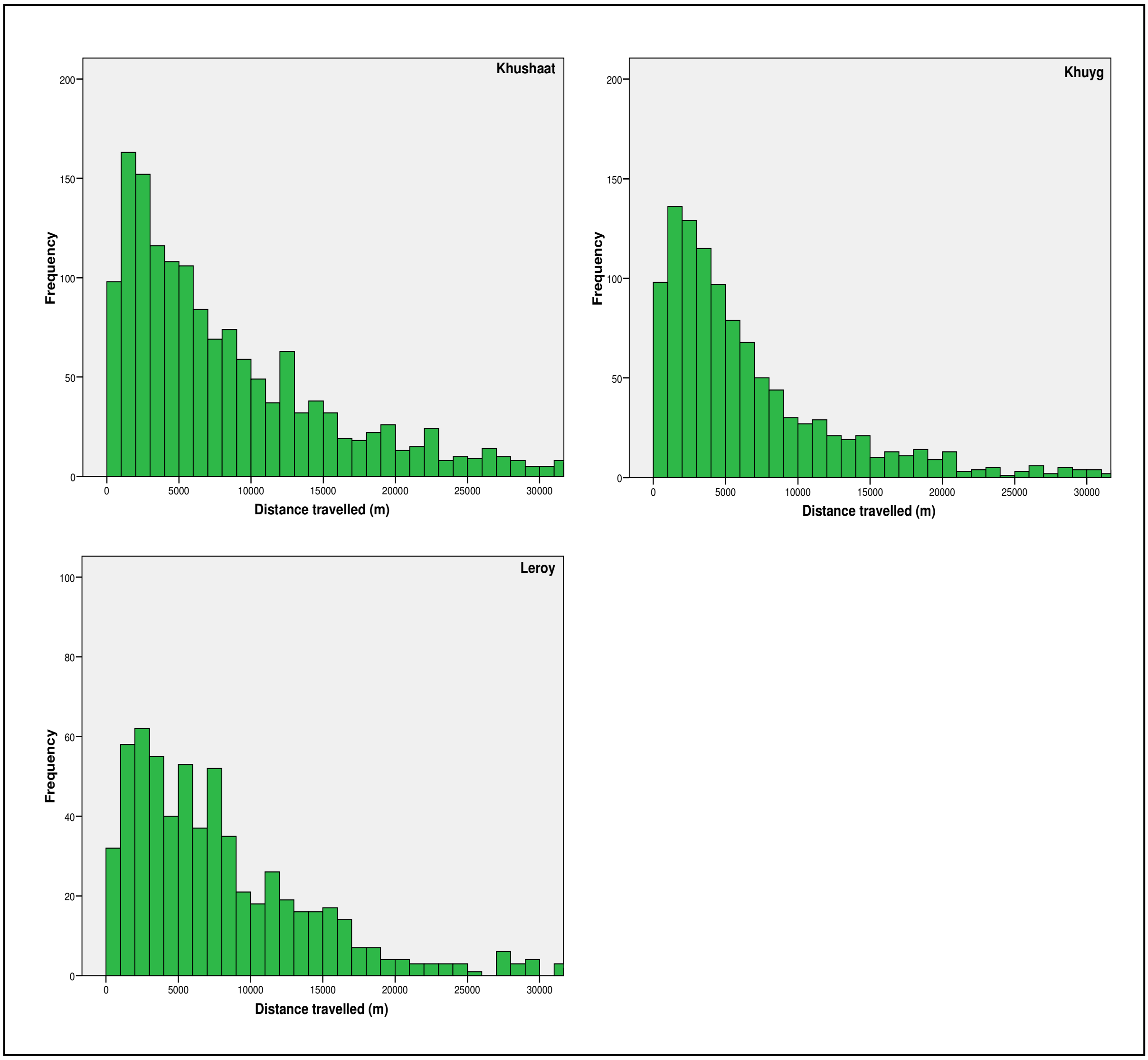

Figure 5. Absolute frequency distributions of daily distance covered by Khushaat (N = 1526), Khuyg (N = 1087) and Leroy (N = 627). Note the differing scales for Khushaat, Khuyg and Leroy.

5.2.2.1.2. Przewalski's horse

The frequency distributions illustrate that Toodog and Uugan covered most frequently distances up to about 3500 m within 24-h intervals (Fig. 6). The maximum daily distance travelled by Toodog was 29317 m and by Uugan 22837 m.

Mondor, Shandas and Shazgai travelled most commonly distances up to about 2000 m within 24 hours (Fig. 6). The maximal daily distance covered by Mondor was 10482 m, by Shandas 56506 m and by Shazgai 12673 m. Orchon showed a different pattern than the other horses with a maximum at 14074 m.

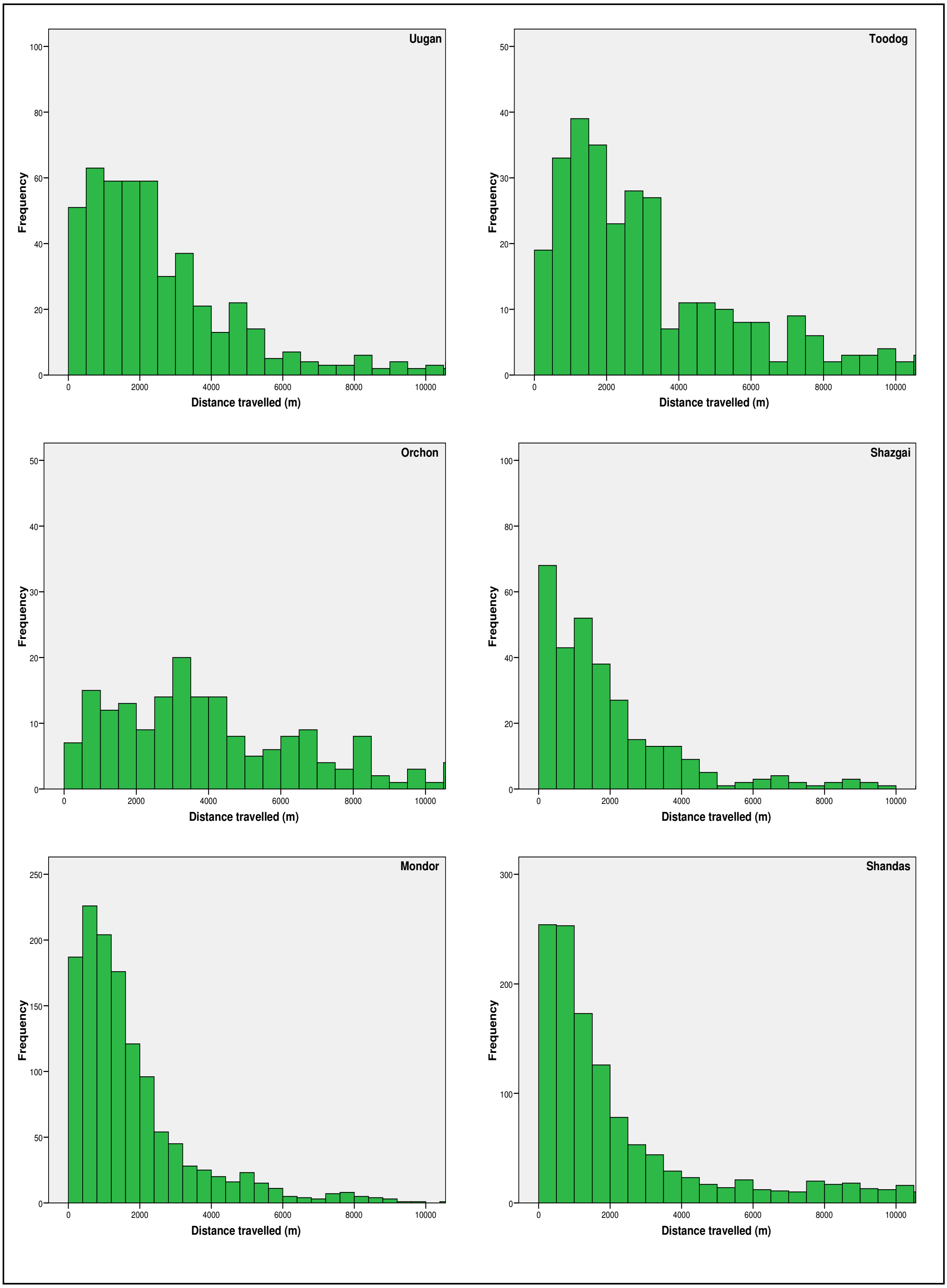

Figure 6. Absolute frequency distributions of daily distance covered by Uugan (N = 505), Toodog (N = 304), Orchon (N = 186), Shazgai (N = 307), Mondor (N = 1289) and Shandas (N = 1300). Note the differing scales for Uugan, Shazgai, Toodog, Orchon, Mondor and Shandas.

5.2.2.2 Boxplot

The data of the frequency distributions of daily distances were clearly summarized as boxplot in Figure 7. Daily distances were significantly longer for Asiatic wild asses than for Przewalski's horses (mixed model: $F_{1,6.77} = 18,57$; $P < 0,01$). Differences in daily distances between established and newly released horses were also statistically significant (mixed model: $F_{1,3.83} = 20,69$; $P < 0,05$).

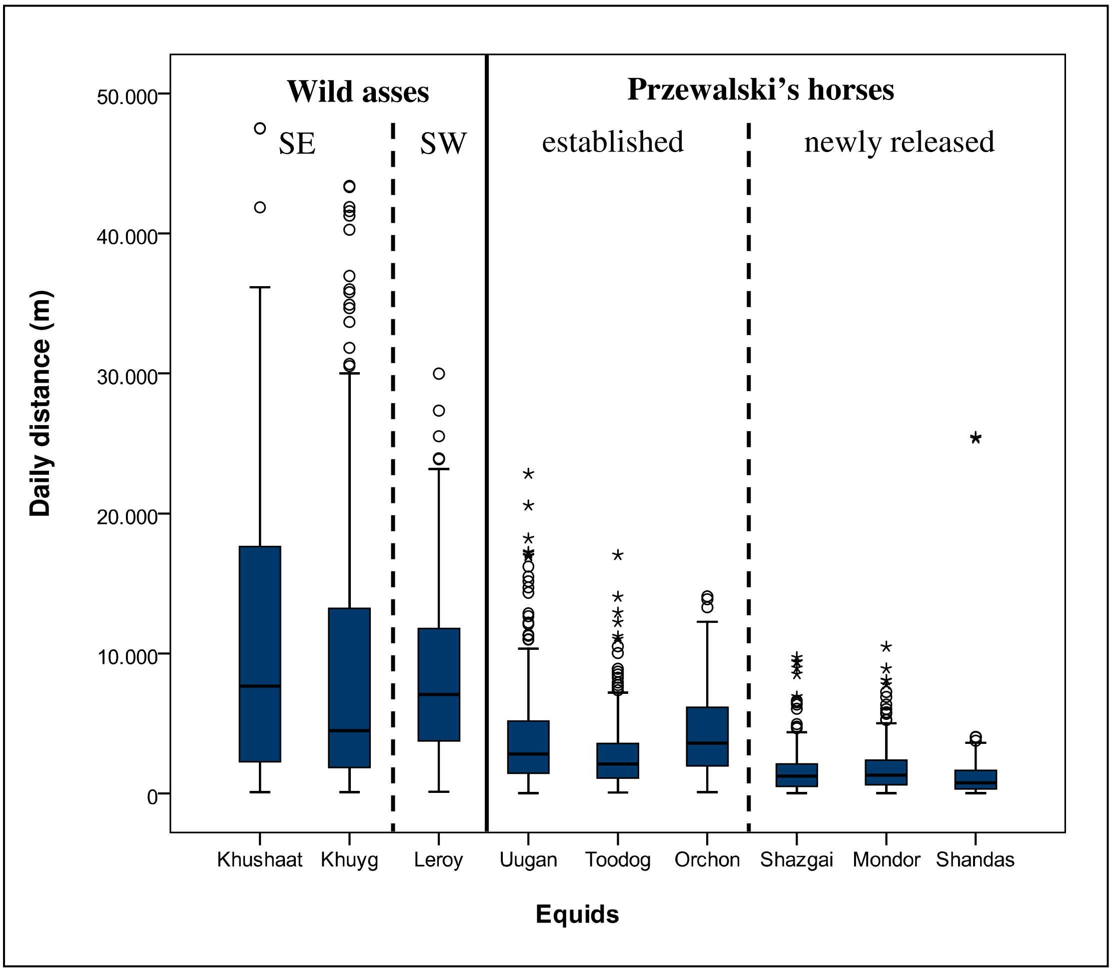

Figure 7. Boxplot comparing daily distances travelled by the equids. The box shows the median, 25% and 75% quartiles. oo represent outliers, which are more than 1,5 times the interquartile interval from the 75% quartiles. ** mark significant differences, which are more than 3 times the interquartile interval from the 75% quartiles.

5.2.2.3 Partial autocorrelation

All study animals showed a significant positive partial autocorrelation between travel distances of successive days, but hardly beyond. Although, the two animals with the largest home ranges, Khushaat and Khuyg, showed the strongest positive autocorrelation, no general trend between the strength of autocorrelation and the size of the range could be detected (Tab. 4, Fig. 8).

There were no significant differences in partial autocorrelation of travel distance from one day to the next between Asiatic wild asses and Przewalski's horses (T-test: t = 2,56; df = 3,15; P = 0,079) and between established and newly released horses (T-test: t = 0,27; df = 3,34; P = 0,804).

Table 4. Partial autocorrelation of daily distances covered, up to lags of 16. (95% confidence interval)

Lag	Asiatic wild asses			Przewalski's horses					
	Khushaat	Khuyg	Leroy	Uugan	Toodog	Orchon	Shazgai	Mondor	Shandas
1	0,752 *	0,733 *	0,483 *	0,471 *	0,534 *	0,252 *	0,298 *	0,397 *	0,481 *
2	-0,197 **	-0,039	0,010	-0,007	0,087	-0,077	0,115	0,228 *	0,227 *
3	0,117 *	0,126 *	0,053	0,046	0,044	0,129	0,152 *	0,024	0
4	0,011	0,088 *	0,064	0,084	-0,093	0,032	0,065	0,068 *	0,097 *
5	-0,009	0,039	0,130 *	-0,047	-0,001	-0,054	0,001	0,061	0,143 *
6	0,021	0,065	0,085	-0,025	-0,015	0,065	0,04	0,005	0,076 *
7	-0,005	-0,003	0,001	0,067	-0,001	-0,045	0,045	0,028	0,018
8	-0,002	0,008	-0,052	0,103 *	-0,017	0,068	0,011	0,095 *	0,044
9	0,019	-0,042	-0,016	0,075	0,061	-0,025	0	0,039	0,082 *
10	0,017	-0,038	0,050	-0,061	-0,031	0,039	0,012	0,027	-0,031
11	0,032	-0,021	0,003	0,046	0	0,086	0,064	-0,018	0,016
12	-0,016	-0,045	0,094 *	0,065	0,011	-0,097	0,082	0,096 *	0,058
13	0,019	-0,019	0,056	0,019	-0,036	-0,046	-0,02	0,059 *	0,059
14	0,038	-0,059	0,024	-0,130 **	0,019	0,014	0,002	0,022	0,005
15	-0,002	-0,076 **	0,056	-0,032	-0,019	0,160 *	-0,01	0,063	0,058
16	0,039	0,002	-0,006	-0,021	0,005	0,065	0,028	0,027	0,058

* Significant positive ACF
** Significant negative ACF

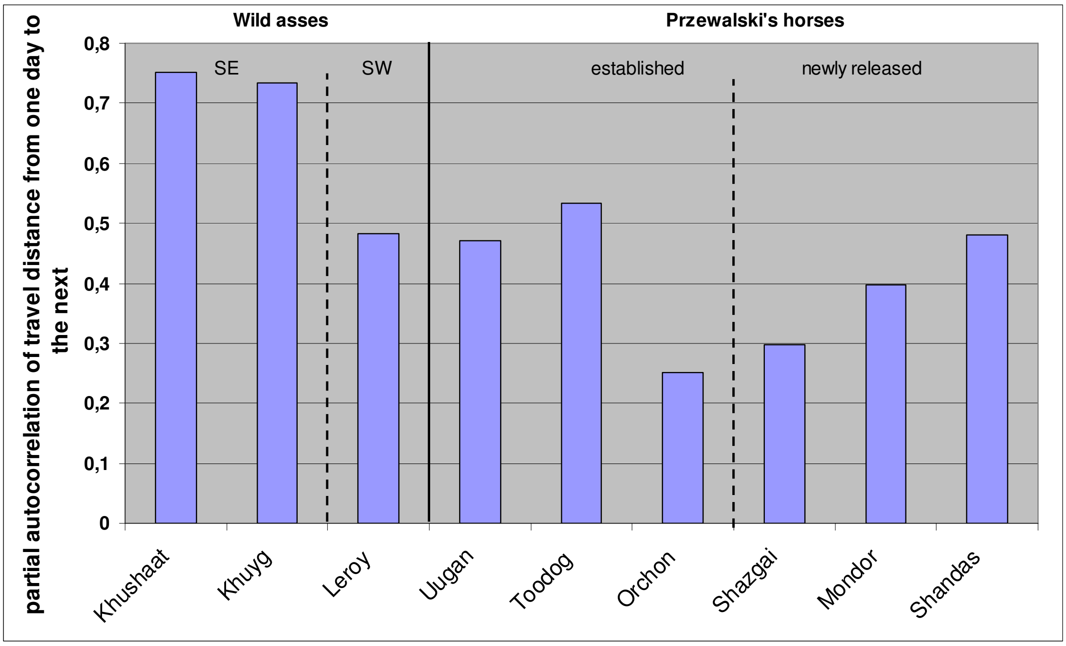

Figure 8. Partial autocorrelation of travel distance from one day to the next.

In respect to the daily distances travelled, the data suggests that from November until March wild asses may be less likely to do long distance daily travels than during the reminder of the year (Fig. 9).

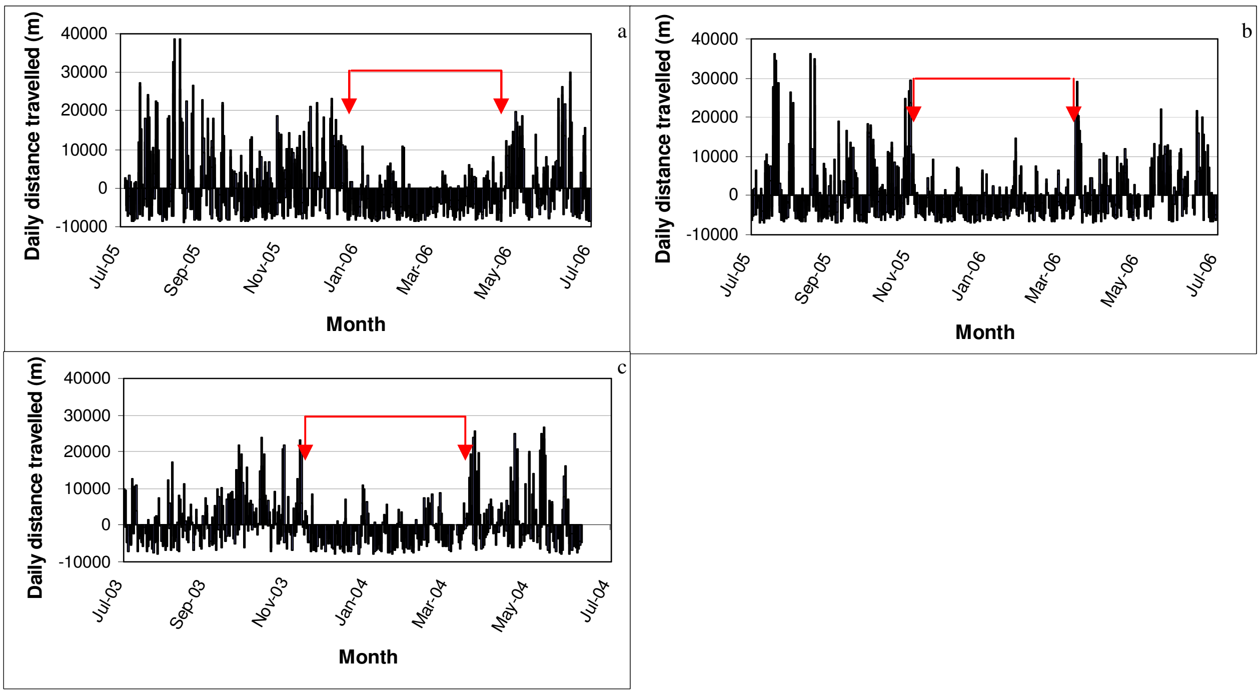

Figure 9. Daily distances travelled (m) over time by Asiatic wild ass Khushaat a), Khuyg b) and Leroy c). The base line represents the mean value. The red line with arrows highlights extended periods of shorter than average daily movement distances.

Except for Shandas, horses did not show any obvious periodicity, but rather had irregular bouts of longer daily distances (Fig. 10).

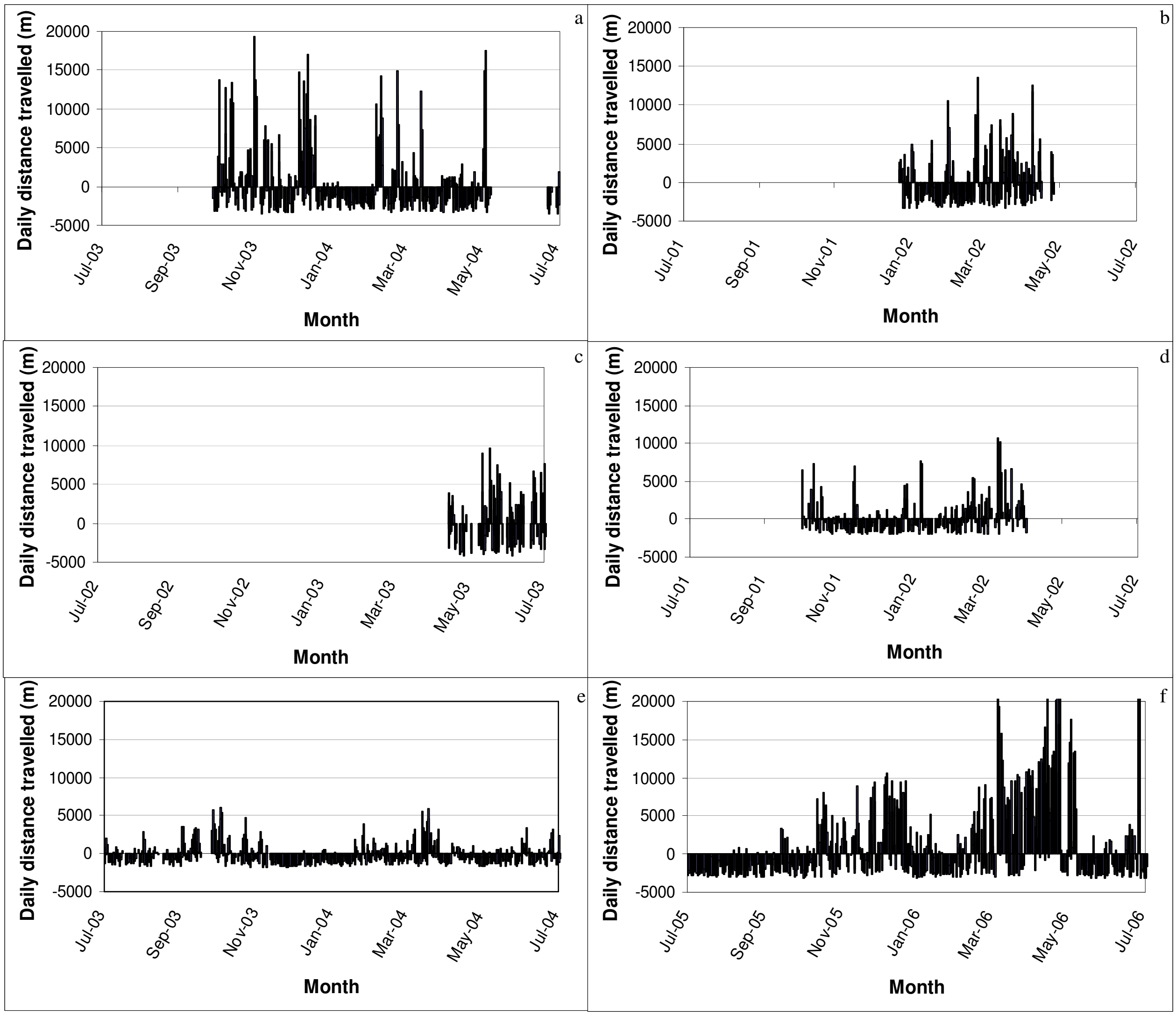

Figure 10. Daily distances travelled (m) over time by Przewalski's horse Uugan a), Toodog b), Orchon c), Shazgai d), Mondor e) and Shandas f). The base line represents the mean value.

5.3. Turning angle

5.3.1. Turning angle in relation to time

For both species and most individuals the turning angle quickly reached a plateau after 10-20 hours. At smaller intervals angles did not follow a common trend and for some animals kept increasing with time or decreasing with time (Fig. 11).

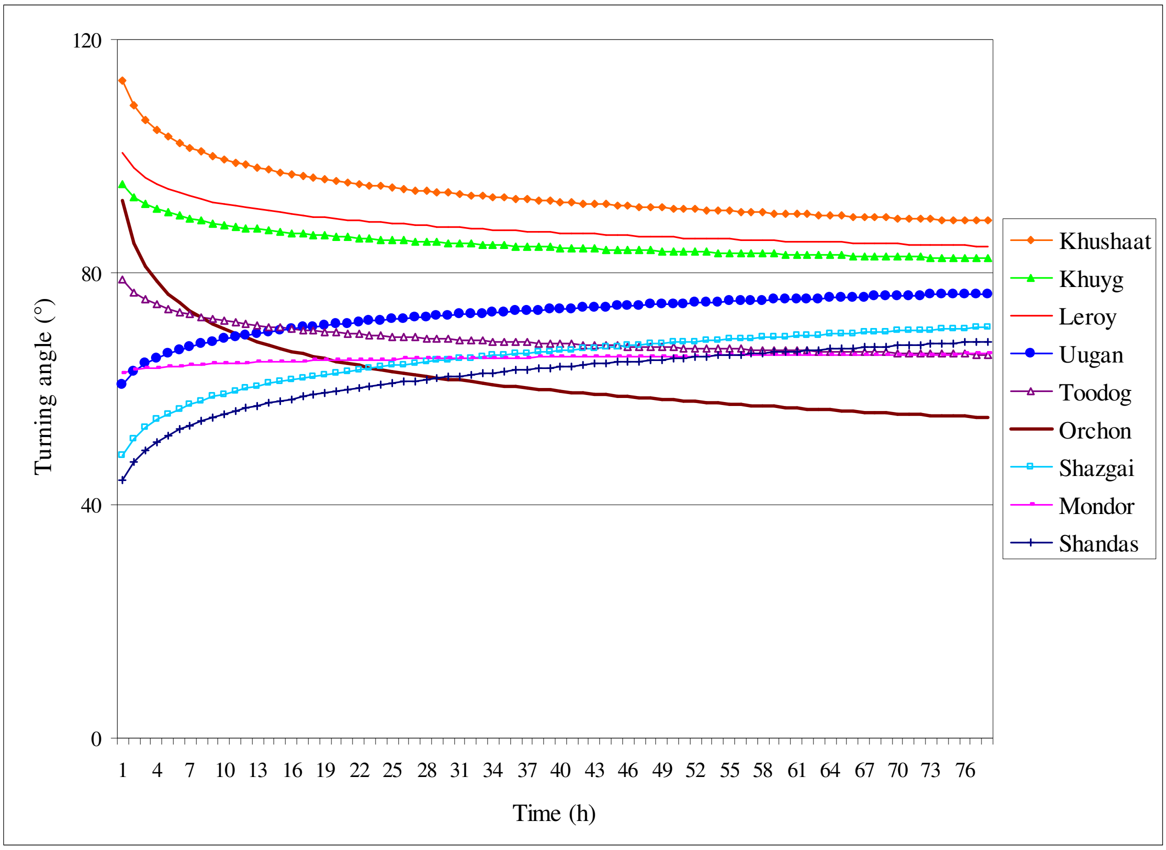

Figure 11. Relationship between turning angle (°) and time (h).

Based on the extrapolation of the underlaying power function (Tab. 5), the turning angle within 24 hours averaged 89,68° (range: 85,67° - 94,77°) for asses and 65,61° (range: 60,67° - 71,71°) for horses (Tab. 6).

The differences in turning angle between Asiatic wild asses and Przewalski's horses were significant (T-test: $t = 7{,}62$; $df = 3{,}63$; $P < 0{,}01$). The established horses did not exhibit significant larger turning angles than newly released horses (T-test: t = 1,75; df = 3,01; P = 0,177).

Table 5. Parameters estimate due to curve fitting for turning angle by a power function ($y = b_0*x^{b1}$).

ID	b_0	b_1/exponent	r^2	F
Asiatic wild asses				
Khushaat	112,88	-0,055	0,780	28,422
Khuyg	95,14	-0,033	0,230	2,392
Leroy	100,60	-0,040	0,446	3,225
Przewalski's horses				
Uugan	60,63	0,053	0,274	1,506
Toodog	78,77	-0,041	0,213	3,252
Orchon	92,43	-0,119	0,215	3,283
Shazgai	48,51	0,086	0,443	3,977
Mondor	62,59	0,012	0,046	0,193
Shandas	44,43	0,098	0,555	4,988

Table 6. Mean turning angle (°) within 24 hours for all 9 equids.

	Asiatic wild asses			**Przewalski's horses**					
	Khushaat	Khuyg	Leroy	Uugan	Toodog	Orchon	Shazgai	Mondor	Shandas
Mean turning angle (°) within 24 h	94,77	85,67	88,60	71,75	69,15	63,33	63,76	65,02	60,67

5.3.2. Daily turning angle

5.3.2.1. Frequency distribution

5.3.2.1.1. Asiatic wild ass

The distributions of all the turning angles were rather even for the three wild asses (Fig 12).

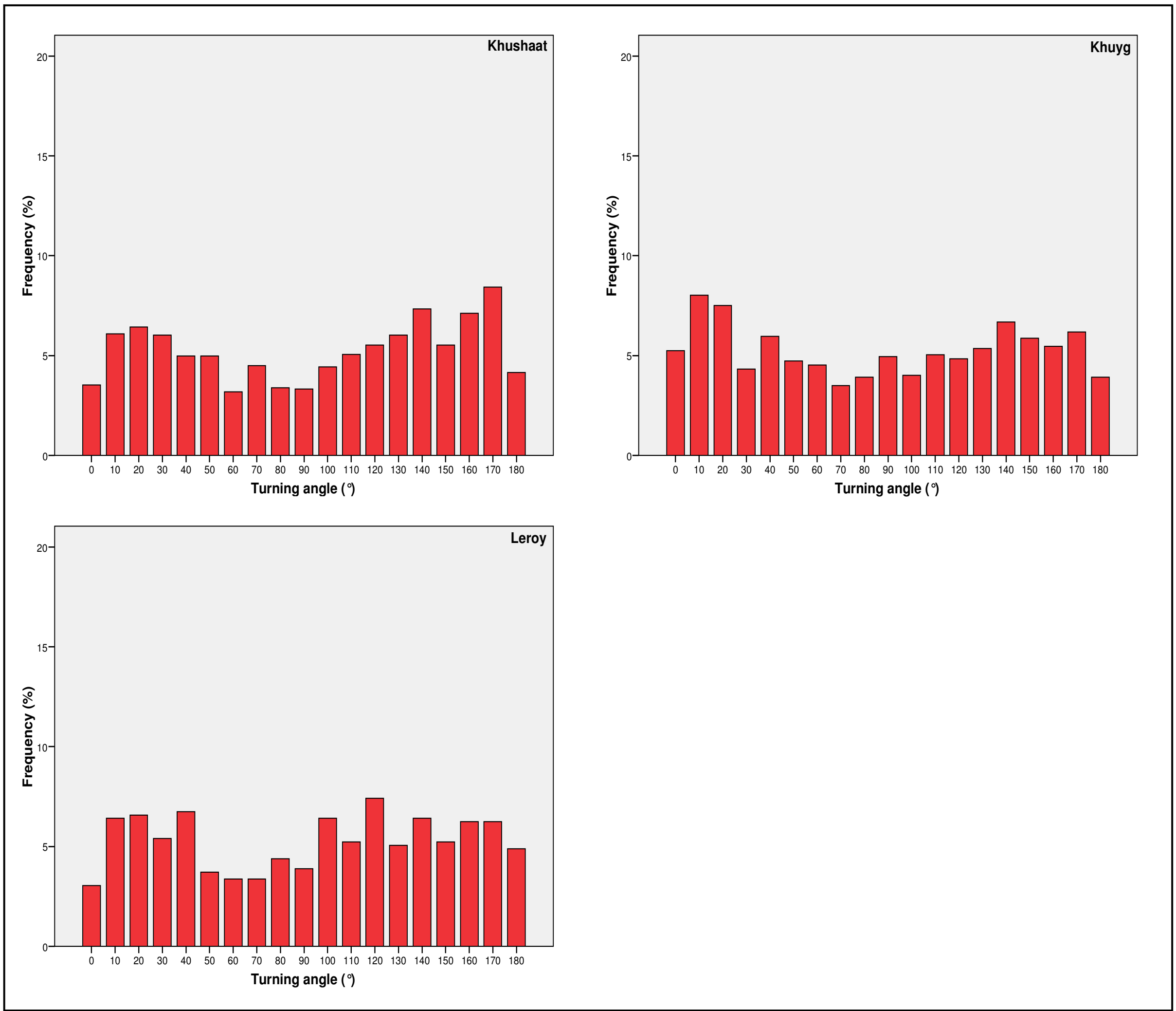

Figure 12. Relative frequency distributions of daily turning angles by Khushaat (N = 1446), Khuyg ((N = 972) and Leroy (N = 593).

5.3.2.1.2. Przewalski's horse

The distributions for the wild horses were more skewed towards smaller turning angles (Fig. 13).

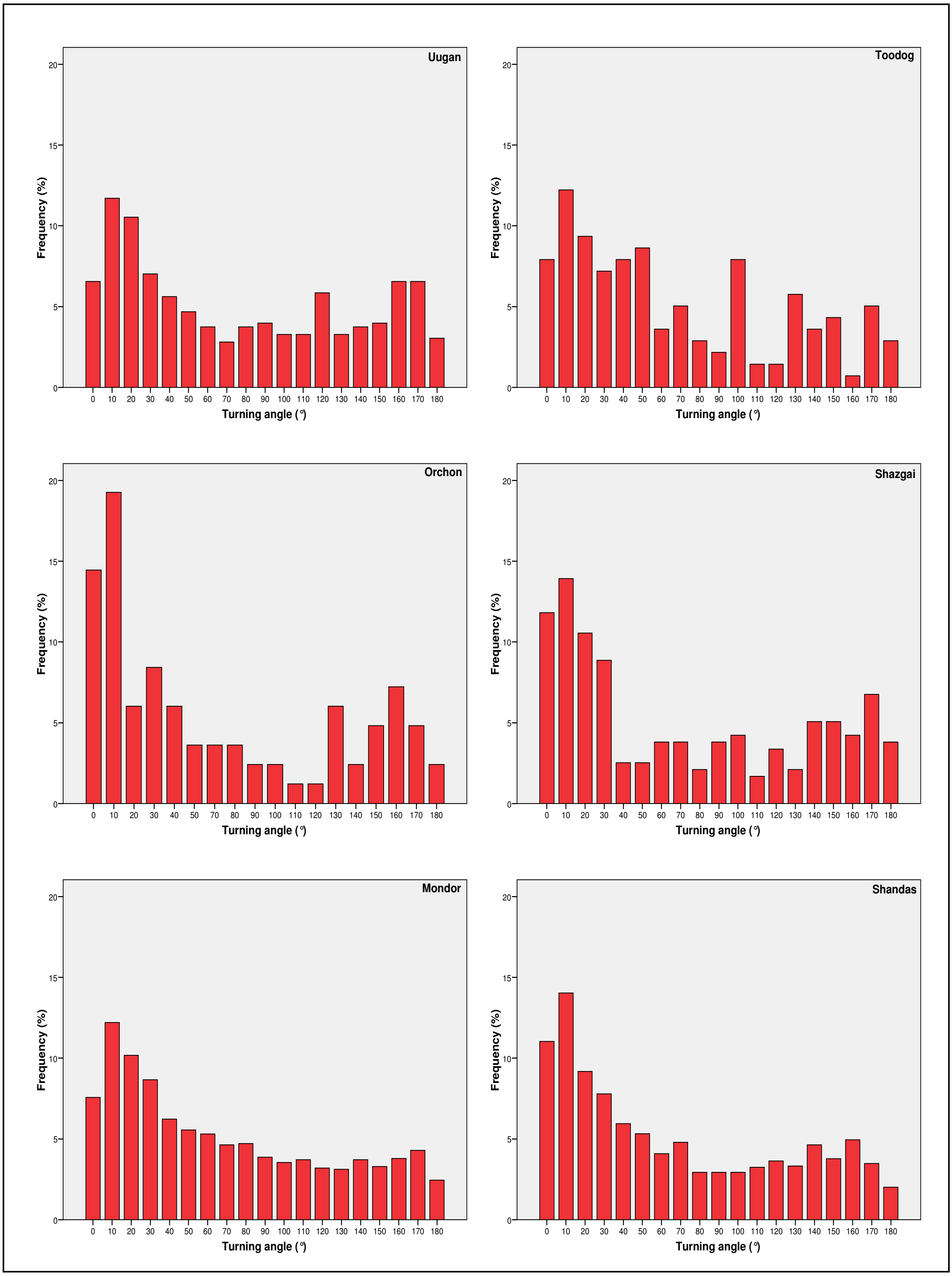

Figure 13. Relative frequency distributions of daily turning angles by Uugan (N = 427), Toodog (N = 139), Orchon (N = 83), Shazgai (N = 237), Mondor (N = 1188) and Shandas (N = 1296).

5.3.2.2 Boxplot

The data of the frequency distributions of daily turning angles were clearly summarized as boxplot in Figure 14.

Daily turning angles were significantly larger for Asiatic wild asses than for Przewalski's horses (mixed model: $F_{1,4.87} = 40{,}04$; $P < 0{,}01$), but not between established and newly released horses (mixed model: $F_{1,2.8} = 0{,}46$; $P = 0{,}549$).

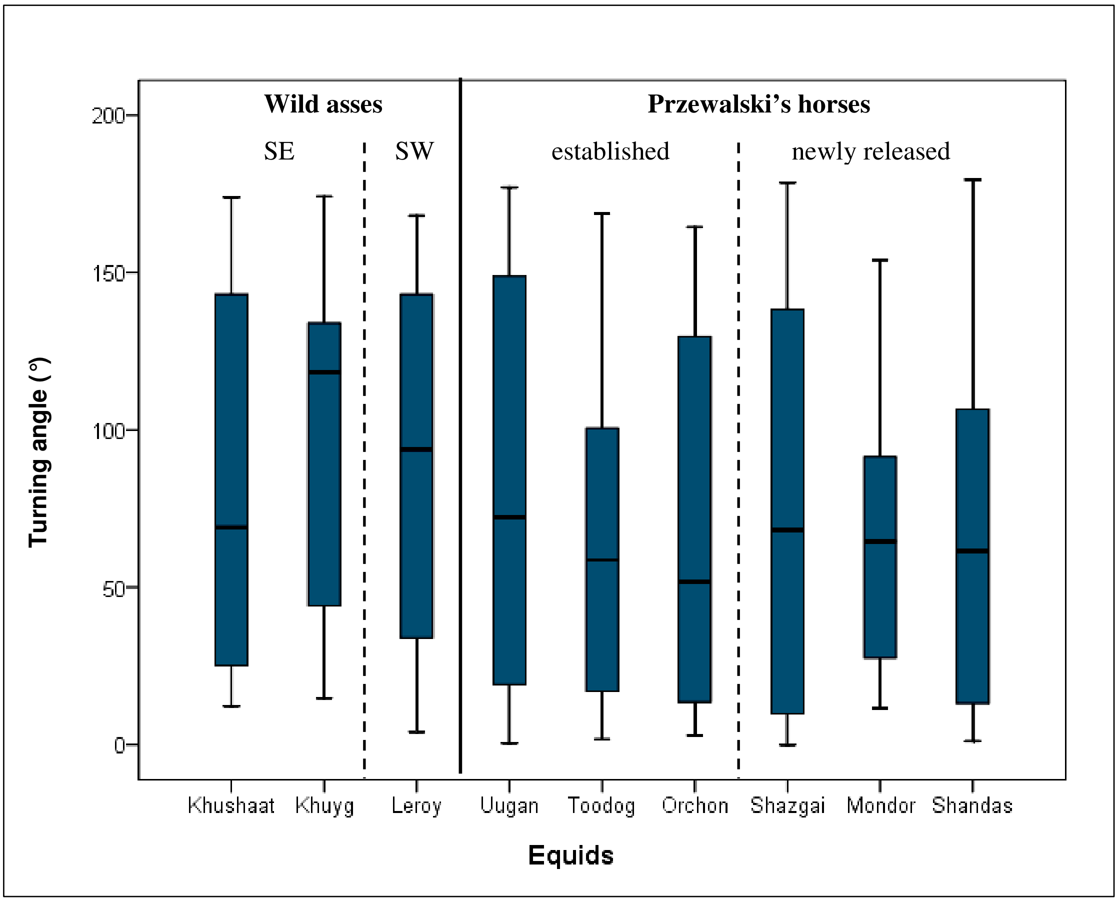

Figure 14. Boxplot comparing daily turning angles moved by the equids. The box shows the median, 25% and 75% quartiles.

5.3.2.3 Partial autocorrelation

Turning angles were significantly positively autocorrelated at lag 1 for the asses, but hardly so for the Przewalski's horses, except for Uugan, Orchon and Mondor (Tab. 7).

Table 7. Partial autocorrelation of daily turning angles, up to lags of 16.

Lag	Asiatic wild asses			Przewalski's horses					
	Khushaat	Khuyg	Leroy	Uugan	Toodog	Orchon	Shazgai	Mondor	Shandas
1	0,441 *	0,356 *	0,253 *	0,131 *	0,156	0,265 *	0,013	0,074 *	-0,007
2	-0,068 **	-0,036	0,013	0	-0,043	-0,119	-0,123	-0,064 **	0,004
3	0,057	0,037	0,049	0,008	0,048	-0,021	-0,124	0,033	0,092 *
4	-0,014	0,062	0,017	0,006	-0,012	0,017	0,030	0,027	-0,018
5	-0,008	0,037	0,013	0,003	0,063	0,084	0,054	-0,022	-0,005
6	-0,011	0,023	0,027	-0,035	-0,076	-0,052	0,032	0,006	0,050
7	0,013	0,012	0,018	0,033	-0,007	0,100	-0,074	0,083 *	0,055
8	0,022	-0,009	0,050	-0,056	0,003	0,121	0,015	0,017	-0,009
9	-0,016	0,038	0,040	0,023	-0,051	-0,132	-0,126	0,021	0,021
10	0,039	0,044	0,031	0,019	-0,036	0,004	0,003	-0,003	0,045
11	0,042	-0,023	0,053	0,025	0,007	-0,084	-0,011	0,017	0,011
12	0,019	0,052	0,009	-0,070	-0,040	0,030	-0,067	0,020	0,052
13	-0,018	-0,035	-0,042	0,032	0,026	0,006	0,029	0,046	0,045
14	0,016	-0,016	-0,025	0,031	-0,004	-0,061	-0,052	0,060	0,039
15	0,018	-0,005	0,061	-0,034	-0,072	0,090	-0,053	0,018	0,020
16	0,028	0,029	0,024	0,015	0,010	0,088	-0,012	0,011	-0,017

* Significant positive ACF
** Significant negative ACF.
(95% confidence interval)

No obvious periodicity could be detected for the turning angle in wild asses (Fig. 15a - c) or Przewlaski's horses (Fig. 15d - i).

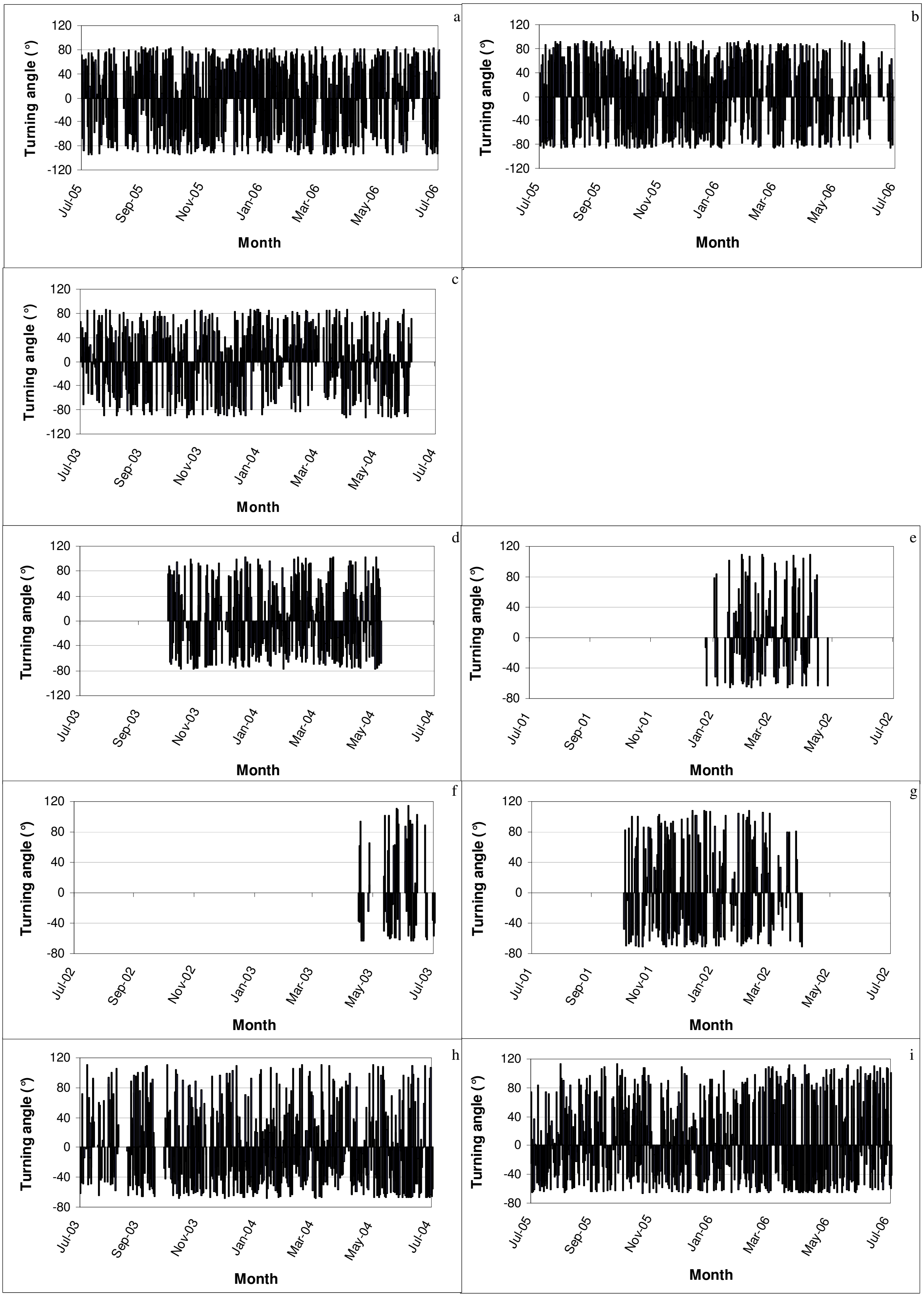

Figure 15. Daily turning angles (°) over time by the asses Khushaat a), Khuyg b) and Leroy c) and horses Uugan d), Toodog e), Orchon f), Shazgai g), Mondor h) and Shandas i). The base line represents the mean value.

5.4. Correlation daily distance travelled – daily turning angle

From the two groups only Khushaat, Khuyg and Shandas exhibited a significant positive correlation between daily distance covered and daily turning angle and this correlation was rather small (Tab. 8).

Table 8. Correlation between daily distance covered and daily turning angle.

	Asiatic wild asses			**Przewalski's horses**					
	Khushaat	Khuyg	Leroy	Uugan	Toodog	Orchon	Shazgai	Mondor	Shandas
Pearson Correlation	0,104**	0,109**	0,038	-0,046	0,040	-0,063	0,019	-0,047	0,104**

** Correlation is significant at the 0.01 level.

5.5. Predictor variable of home range size

The daily travel distance was identified as a significant predictor variable of home range size (mixed model: $F_{1,7} = 13,62$; $P < 0,01$).

5.6. Summary

All results were once more summarized in Tab. 9 and confirmed or rejected my hypotheses in Tab. 10.

Table 9. Summary of the results.

name	Group	MCP	24h-distance	daily distance: mean	daily distance: median	daily distance: max	daily distance: auto-corre-lation at lag 1	24h-turning angle	daily turning angle: mean	daily turning angle: median	daily turning angle: auto-corre-lation at lag 1	correlation between daily distance & turning angle
Khushaat	Khulan-SE	42.776	9.646	8.908	7.597	52.783	0,752	94,77	94,72	0,21	0,441	0,104
Khuyg	Khulan-SE	20.313	7.606	7.016	4.594	43.385	0,733	85,67	87,33	90,60	0,356	0,109
Leroy	Khulan-SW	4.784	8.102	8.081	6.430	34.835	0,483	88,6	92,84	99,00	0,253	0,038
Uugan	horse-established	707	3.836	3.480	2.128	22.837	0,471	71,75	76,77	64,81	0,131	-0,046
Toodog	horse-established	442	3.537	3.494	2.592	29.317	0,534	69,15	67,26	49,45	0,156	0,04
Orchon	horse-established	135	4.377	4.305	3.595	14.074	0,252	63,33	64,37	39,37	0,265	-0,063
Shazgai	horse-released	152	2.205	2.037	1.389	12.673	0,298	63,76	70,79	54,13	0,013	0,019
Mondor	horse-released	223	1.826	1.748	1.255	10.482	0,397	65,02	67,66	53,88	0,074	-0,047
Shandas	horse-released	1.398	3.281	3.131	1.408	56.506	0,481	60,67	65,77	47,40	-0,007	0,104

Table 10. Confirmation or rejection of my hypotheses.

Hypothesis	**Trend confirmed by data**
Species specific differences - wild asses versus P-horses	
longer daily travel distances	yes
a stronger partial autocorrelation in daily travel distances	no
larger turning angles	yes
a stronger partial autocorrelation in turning angles	somewhat
a stronger positive autocorrelation between distance travelled and turning angle	no
Area specific - asses in the SE versus asses in the SW	
longer daily travel distances	no
a stronger partial autocorrelation in daily travel distances	yes
larger turning angles	no
a stronger partial autocorrelation in turning angles	yes
a stronger positive autocorrelation between distance travelled and turning angle	yes
Management specific - established versus newly releases P-horses	
larger home ranges	no
longer daily travel distances	yes
a stronger partial autocorrelation in daily travel distances	no
larger turning angles	no
a stronger partial autocorrelation in turning angles	there seems to be a tendency
a stronger positive autocorrelation between distance travelled and turning angle	no

6. Discussion

6.1. Data quality and interpretation

My analysis of equid movements had some limitations imposed by the very small sample size that rather describes case studies and so I may have been unable to catch more general patterns. Secondly, individual outliers may “spoil” the picture including the asses’ representation of both sexes and possibly Shandas, who was released in the central SW Gobi as opposed to the other horses and did several “homing trips” in the direction of the adaptation enclosure. Furthermore, the data sampling intervals were different; some of them were rather short. The sampling interval had a great influence on the parameters turning angle and daily distance, but seemed to level out for P-horses after 10-20 hours. Thus daily distances seem a suitable interval to describe differences in movement strategies. However, data could only approximate to 24 hour intervals. However, the focus of my thesis was a first qualitative assessment of movement strategies as a basis for future hypothesis testing

6.2. Species specific differences – Asiatic wild asses versus Przewalski’s horses

As expected, Asiatic wild asses covered longer daily distances than Przewalski’s horses. The shorter distances of the wild horses may be a result of the horses needs to stay closer to water resources (Kaczensky et al. 2008) in order to have daily access to drink water (Duncan 1992; Scheibe at al. 1998). Contrary to Przewalski’s horses where travel distances between successive fixes reach a plateau at 10-20 hours, the travel distance in wild asses still keeps increasing even beyond 75 hour intervals. This means that asses are likely to keep moving away from a given location in a somewhat directed manner. Within species home range size and daily distances travelled are correlated. A significant positive autocorrelation of daily distance indicates a propensity to cover sequential distances of the same length, e.g. a long distance move is likely followed by another long distance move, while a short distance move is more likely by another short distance move. In both species a significant positive partial autocorrelation was found for consecutive locations, but hardly beyond. This autocorrelation was not significantly stronger for wild asses than for wild horses. In respect to the daily distances travelled horses show no obvious periodicity whereas asses seem to be less likely to do long distance moves in the winter. This may indicative of a lower activity level in winter

(Berger et al. 1999) because of reduced metabolic rate as has been found in Przewalski's horses in a semi-reserve (Arnold et al. 2006). Furthermore, the asses can fulfil their water demand by consuming snow (Feh et al. 2002) and do not have to cover long distances to find water resources or move back and forth between pastureland and water.

The data suggest that turning angles are highly variable depending on the sampling interval at short intervals and may not follow an easily detectable pattern. However, turning angles quickly reach a plateau after 10-20 hours for all individuals. However, asses have significantly larger turning angles than horses. This finding further confirms my hypothesis that Asiatic wild asses are moving in a more directed manner than Przewalski's horses. The frequency distributions of turning angles moved by Asiatic wild asses reveal that the part of the turning angles less than 90° and more than 90° were almost balanced. The distributions by Przewalski's horses, on the other hand, suggest a tendency to a more tortuous path. They prefer moving in angles less than 90°. There was a significant positive autocorrelation between successive turning angles for all three asses and three of the six horses. However, the relationship was weak. The wild asses showed stronger autocorrelation than the wild horses. This means that the asses were more likely to move in similar turning angles from one day to the next. Daily turning angles, plotted on a daily basis, showed no obvious periodicity for both groups. This indicates that there were no phases in which the animals did prefer to move directed versus non-directed for an extensive period. Two asses and one horse had a significant although small positive correlation between travel distances and turning angles. Thus these animals were more likely to turn when covering a short distance and less likely to turn when covering a long distance, suggesting a more directed movement path (Dai et al. 2007). Commonly, the asses did not exhibit a stronger correlation between distances and angels.

6.3. Area specific - asses in the SE versus asses in the SW

Of the 3 asses, those from the SE Gobi did not travel longer daily distances than the one from Great Gobi B, but exhibited a stronger partial autocorrelation in travel distance from one day to the next. Contrary to my assumption, only one of the two asses in the SE showed a larger daily turning angle than the ass from Great Gobi B. However, the asses in the SE had a stronger autocorrelation in turning angles. According to my expectation, the wild asses in the SE revealed a stronger positive autocorrelation between distance travelled and turning angle.

6.4. Management specific - established versus newly releases P-horses

In the group of the horses the size of the home ranges varied by as much as a factor 10, ranging from 135 km² in Orchon to 1398 km² in Shandas. Contrary to my expectations, these dissimilarities cannot be related to the date since release, because Orchon was a member of an established group, whereas Shandas was a member of a newly released group. Consequently, the size of the home range does not necessarily increase with the time of release. However, my sample size was very small and rather describes case studies and I may have been unable to catch more general patterns. If and how differences in home range size of individual harem groups can be explained by e.g. habitat quality, disturbance potential, competition with livestock and other variables should be addressed by further studies.

As predicted, established horses covered longer daily travel distances than newly released horses. This result thus supports the assumption from Souris et al. (2007) that recently released horses stay close to the release site. Daily travel distances were not stronger autocorrelated for established horses. Within the horses I could not determine larger daily turning angles moved by established animals and shorter daily turning angles by newly released animals. There seems to be a tendency that established horses had a stronger autocorrelation than newly released equids but it was not that clearly differentiated. The established horses did not showed a stronger positive autocorrelation between distance travelled and turning angle than the newly released horses.

7. Conclusion

My data suggest that the two equid species, Asiatic wild ass and Przewalski's horse, can be distinguished based on their movement pattern by means of travel distance and turning angle.
For analysis between areas or among individuals with different management background more data are needed. Equal sampling intervals and equal seasons will be desirable for seasonal analysis in order to see whether the availability of water certainly will have an effect.

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