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The use of high frequency GPS data to classify main behavioural categories in a Przewalski's horse in the Mongolian Gobi

P. Kaczensky & K. Huber

Abstract

Behavioural observations of free ranging animals can provide important insight into many aspects of their biology but are not without problems. The recent development of GPS technology allows to remotely collect high precision location data at fixed intervals. We tested whether it is possible to classify the behaviour of a Przewalski's horse in the Mongolian Gobi into *Resting*, *Grazing* and *Moving* based on GPS locations collected at 15min intervals by comparing GPS data with direct observations. Although behavioural categories lasting for 15 minutes could be fairly reliably separated based on the distances covered between successive fixes, almost half the dataset consisted of mixed intervals. Thus, fifteen minute intervals are too long to catch one behavioural category which makes classification based on GPS fixes alone problematic. Although our present approach was not particularly successful, we believe that using GPS data in combination with activity sensor and additionally including the geometry of locations holds great potential for inferring main behavioural categories in free ranging equids.

Key words: activity budget, behaviour, *Equus ferus przewalskii*, GPS telemetry, Mongolia, Przewalski's horse

1. Introduction

Behavioural observations of free ranging animals can provide important insight into many aspects of their biology (e.g. social organization, time budget, habitat use). However, when working with far ranging species, elusive species or in remote areas the ability for continuous direct observations are very limited (KACZENSKY et al. 2006, SOURIS et al. 2006). In addition, behavioural observations are time consuming as they require the presence of an observer and involve the risk of actually influencing the behaviour of the study animals.

Automatic surveillance tools like video cameras can only be used for species with small activity ranges or may be attached for short periods to large bodied species (<http://www.nationalgeographic.com/crittercam/>). For certain research questions or species, indirect measures which allow inferring behaviour from remotely collected data have been used with success. For example, implanted temperature sensors have been used to document hibernation lengths and arousal frequency in door mice (*Glis glis*; BIEBER & RUF 2009), pressure sensors have been used to document diving depth and length for aquatic species (BIUW et al. 2009, YASUDA & ARAI 2009) and various activity sensors have been used to document circadian rhythms (MERRIL & MECH 2003, YAMAZAKI et al. 2008). However, differentiating between several different behavioural categories has largely remained a challenge.

The recent development of GPS technology allows remotely collecting high precision location data at fixed intervals (HANSEN & RIGGS 2008). As different behaviour is often associated with differences in locomotion activity which results in different distances covered over a certain time period. If the monitoring period is chosen small enough and the precision of the GPS location is high it should be possible to distinguish between different behavioural categories (ADRADOS et al. 2003, MOEN et al. 1996). Differentiation should best work best for highly mobile species like large ungulates which show large differences in distances covered while feeding, travelling or resting.

Here we describe our experience with using GPS telemetry to distinguish between main behavioural categories in a free-ranging Przewalski's horse (*Equus ferus przewalskii*) in the Mongolian Gobi. Our expectation was that we would be able to classify the horses behaviour into *Resting*, *Grazing* and *Moving* based on GPS locations collected at 15 min intervals.

2. Study area

The study was conducted in the Great Gobi B Strictly Protected Area (SPA) in SW Mongolia. The Great Gobi B SPA covers 9,000 km² and is a part of the 53,000 km² Greater Gobi SPA system established in 1975 and declared an International Biosphere Reserve in 1991 (WCPA 2009). The present study was conducted in a 50 km² study area in and around Takhin Tal in the NE corner of the Great Gobi B SPA. The study area includes the Takhin Tal research camp and SPA administration with its adaption enclosures covering 2.6 km². The enclosures were used to house (1) newly arrived Przewalski's horse groups to allow adaption to local conditions and facilitate veterinary treatment (SLOTTA-BACHMAYER et al. 2004) and (2) one breeding and display group. However, the last international transport happened in 2004 and reproduction in the wild became as successful as in the captive breeding group. Consequently, the enclosures were permanently opened from summer 2007 on and the breeding and display group became free-ranging.

The study area receives water from the small intermittent Bij river. Along the river bank the vegetation is rather lush, whereas the rest of the study area is composed of semi-arid to arid desert steppe communities (VON WEHREN et al. 2006). In the entire study area grasses, forbs and bushes rarely reach knee height and trees are absent. Elevations in the study area range from 1,548 m to 1,700 m and the terrain is flat to slightly undulating with few small hills. The climate is continental with long cold winters and short hot summers. In July and August daily temperatures can vary from 3-35 °C, but average 15-20 °C (Hobo data logger at Takhin Tal 04/2003 - 07/2008). Average annual rainfall is about 100mm, with most precipitation during the summer months. Other steppe ungulates in the study area are Asiatic wild ass (*Equus hemionus*) and Black-tailed gazelle (*Gazella subgutturosa*). The only large mammalian predator in the study area is the Gray wolf (*Canis lupus*) (KACZENSKY et al. 2004).

3. Methods

GPS store on board collars (SOB)

We deployed a GPS SOB unit designed and built by our own institute (Research Institute of Wildlife Ecology (FIWI), University of Veterinary Medicine, Vienna, Austria) on a Przewalski's horse. The collar was designed to collect and store a GPS position every 15minutes over a 6 week period in July and August 2008. GPS fixes were collected at 00:00, 00:15, 00:30, and 00:45 each hour. To allow collar retrieval without having to recapture the study animal, we equipped the collars with a pre-programmed drop-off (CR-2a, Telonics, USA) which was programmed to open on 20th August 2008.

To assess location accuracy, we used 1.001 GPS locations of 4 different stationary collars, which had dropped of wild asses in July 2008 after a 12 months period (KACZENSKY & WALZER 2007, KACZENSKY & WALZER *in prep.*). The wild ass collars were designed and programmed in the same way as the collar for the study animal.

Behavioural observations

On 15 July 2008 we radiocollared the yearling stallion *Erhes*, a member of the *Taikhar* harem group. Darting and anaesthesia followed methods described by WALZER et al. (2006). We observed *Erhes* and protocolled his behaviour over 107 hours (6,393 minutes, 426 intervals à 15min) on 18 days between 15 July and 14 August 2008 (fig. 1). Upon his capture *Erhes* was within the *Taikhar* harem group; a harem that had just recently experienced a change in the lead stallion. On 17 July 2008, two days after receiving the radiocollar, *Erhes* was expelled from the group and joint his half brother (*Yalalt*, 1 year old) and father (*Jiguur*, 16 years old).

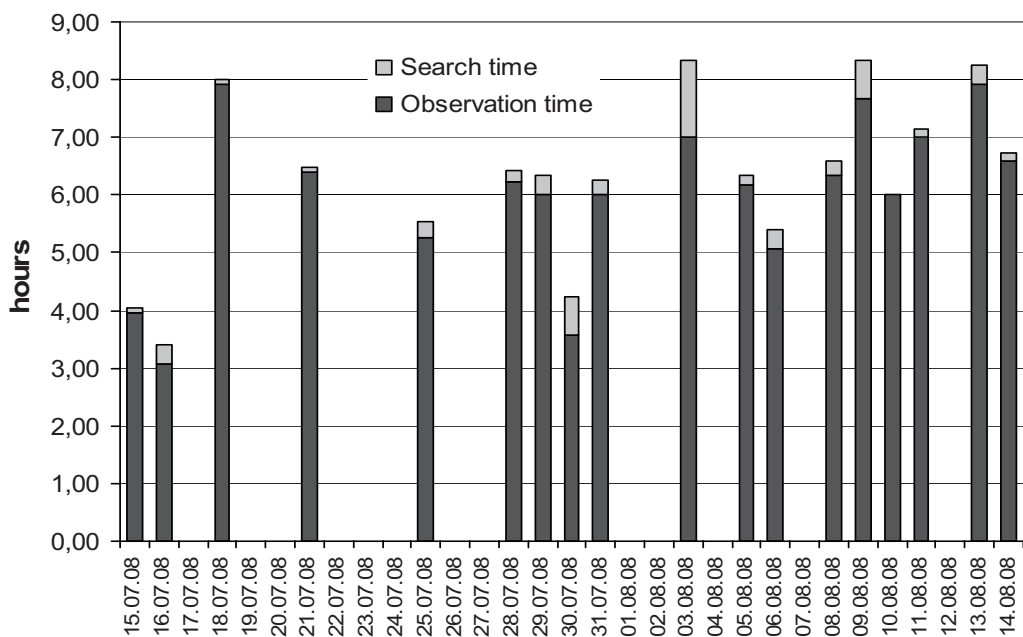


Fig. 1: Distribution and length of the behavioural monitoring data of yearling stallion Erhes in July and August 2008.



Fig. 2: Study horse Erhes with his half-brother Yalalt (left) and father Jiguur (front) feeding along the bank of the Bij river in the adaptation enclosure (Photo: P. Kaczensky).

The three stallions stayed mostly in or close to the acclimatisation enclosures. The harem stallion *Jiguur* and his group had been housed in the enclosure as a breeding and display group until the spring of 2007, when the gates were permanently opened. However, *Jiguur* and his group had remained in the vicinity of the enclosure and often retreated into it to graze along the *Bij* river or use the shelters during adverse weather conditions. When *Taikhar* took over his harem, *Jiguur* remained closely associated with the enclosure and so did his two yearling sons that stayed in his company (fig. 2).

We observed the study horse *Erhes* at distances from 10 to 500 m using a 10 x 42 binocular (Swarovski, Austria) exclusively during daytime hours (8:00 to 22:00). As we did not attempt to come up with a representative ethogram or activity budget, we chose monitoring days and times which were most convenient. Behaviour was protocolled continuously and grouped into three main behaviours:

- *Moving* (M) - fast movement (gallop, trot, or fast walk) with clear directions and not interrupted by feeding bouts
- *Grazing* (G) - feeding interrupted by short steps and short shifts to another spot
- *Resting* (R) - standing still or laying on the ground.

All other behaviour was grouped into the category *Other* and any behaviour that lasted for less than 1 minute was ignored. The time for the behavioural monitoring was read from a hand held GPS unit (GPSMap60, Garmin) to match the GPS time of the collar.

Date analysis

We calculated distances between successive locations separated by 15min using Pythagoras' theorem. To assign distances to the four behavioural categories, we checked how many minutes *Erhes* was involved in what behaviour for the intervals between GPS fixes. To determine threshold values for the three main behavioural categories we used only those 15min intervals where the behaviour did not change (pure intervals).

To check whether the distances covered among the behavioural categories differed we calculated an ANOVA using the log-transformed distances for data normalization. For a first visual assessment of cut points we plotted the percentage of correctly / incorrectly classified intervals against the distance between successive GPS fixes. Subsequently we applied Fisher's discriminate analysis to model best cut points (LEYER & WESCHE 2007; fig. 3).

All statistical analysis was done in SPSS 14.0 (Statistical Package for the Social Sciences; SPSS Inc., Chicago, Illinois, USA). GPS positions were visualized and total ranges calculated in ArcView 3.1. (ESRI, Environmental Systems Research Institute, Inc., Redlands, California, USA).

4. Results

Collar performance

The four stationary collars that dropped off the Asiatic wild asses had an average distance between successive fixes of 10 m, with 90 % being within 23 m of the previous fix (table 1). Thus, two locations less than 23m apart can be assumed to be identical and suggest an immobile animal.

The GPS SOB collar attached to *Erhes* collected and stored 3,436 correct GPS fixes between 15 July and 20 August 2008. Only 44 fixes were missing or taken at the wrong interval resulting in a success rate of 99 %. During the monitoring period *Erhes* roamed over an area of 40.6 km² (100 % minimum convex polygon) in and around the adaptation enclosure (fig. 4). Adding up all successive locations, *Erhes* covered a total distance of 484 km during the 37 days he was wearing the GPS SOB collar. On average he moved 141 m (SD = 207 m; range 0-2,286 m) between successive locations.

Table 1: Distances between successive GPS fixes of four stationary collars at 15 minutes intervals

distances (m) between GPS fixes at 15 m intervals					
collar Id	N GPS locations	mean	percentile		
			50 %	90 %	95 %
30	322	10	5	24	35
38	309	9	6	22	30
39	69	14	5	24	123
42	301	10	7	23	31
all	1001	10	6	23	33

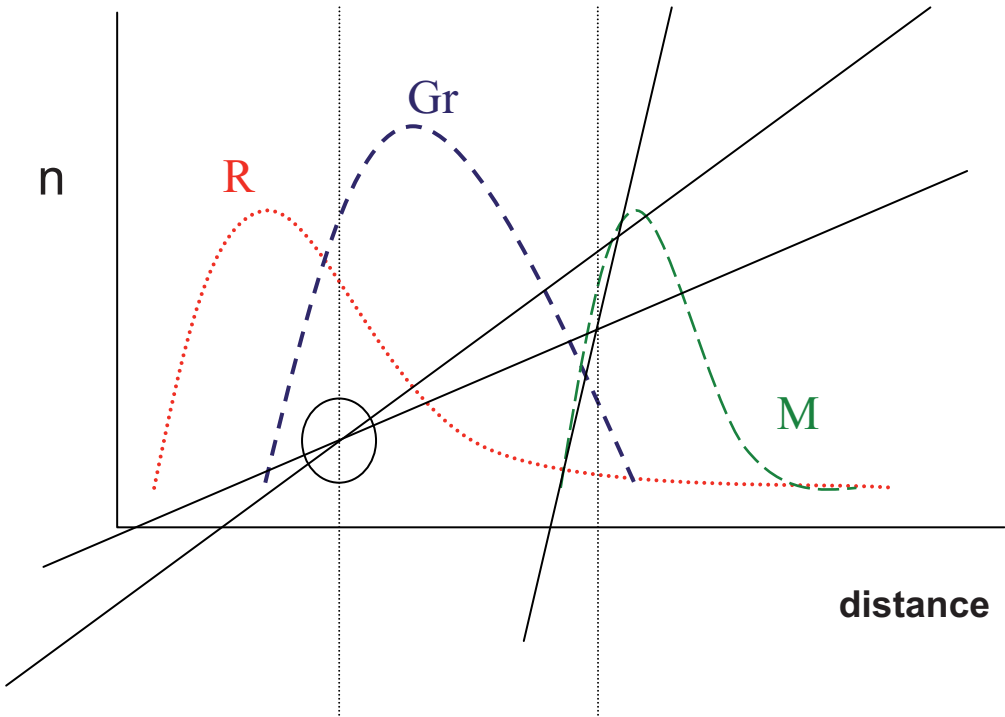


Fig. 3: Showcase for defining the exact thresholds with Fisher's discriminate analysis. The number (n) of activity intervals within a certain distance are illustrated as curves. The variables of the straight lines running through the curves are defined by the classification function coefficients. The cut points are marked by the two circles.

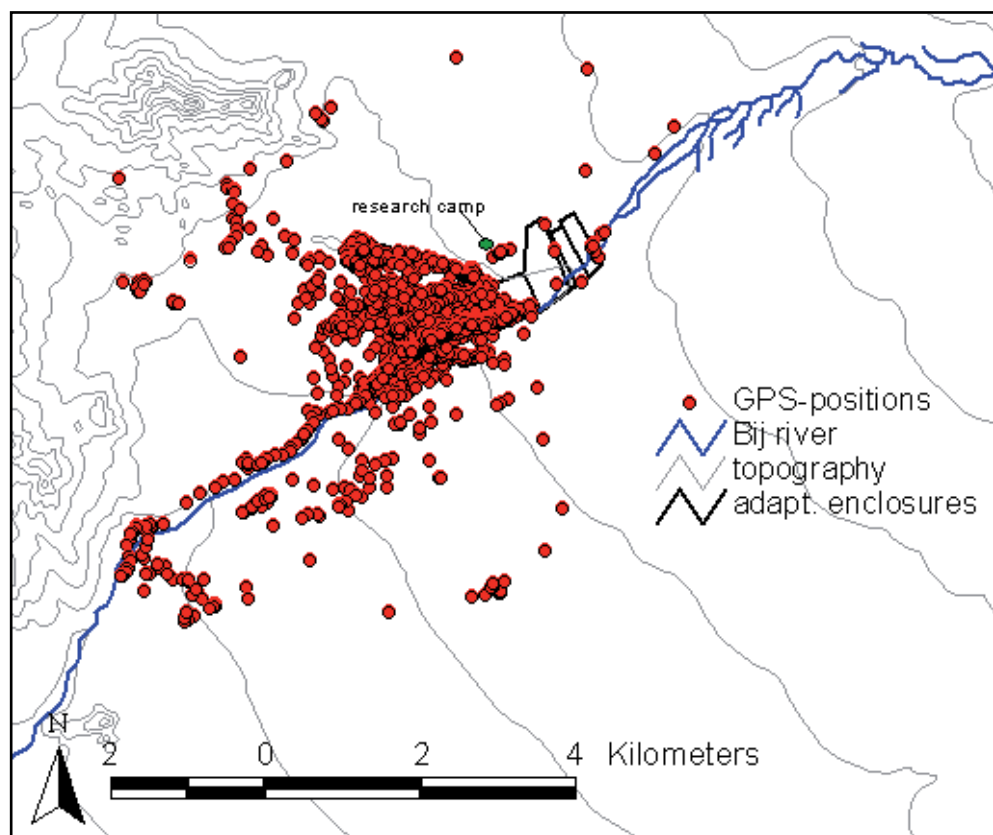


Fig. 4: Study area with GPS positions of Przewalski's horse Erhes from 15.07.-20.08.2009.

During the 6,393 minutes of continuous behavioural monitoring *Erhes* spent 13 % *Moving*, 44 % *Grazing*, 34 % *Resting* and 9 % involved in *Other* behaviour. Average duration of the main behaviour categories was 20 min (range: 1-118 min; *Moving* mean: 8 min, range: 1-38 min; *Grazing* mean: 32 min, range: 1-115 min; *Resting* mean: 23 min, range 1-118 min). About 3 % of the main behaviours lasted for less than 5 min and about 20 % for less than 15 min (less than 5 min: *Moving* 11 %; *Grazing* < 1 %; *Resting* 2 %; less than 15 min: *Moving* 80 % , *Grazing* 8 % , *Resting* 12 %).

3,425 GPS fixes were taken 15 min apart of which 409 GPS fixes were taken parallel to the direct observations. Of these 409 parallel intervals 210 (51 %) showed only one behaviour and were used for discriminating behaviour based on distances between successive fixes (N intervals: *Moving* = 6, *Grazing* = 111, *Resting* = 93).

The distribution of differences travelled differed significantly among the three behavioural categories (*Resting* - mean: 39 m range: 1-691 m, *Grazing* - mean: 112 m, range: 3-930 m, *Moving*: mean: 759 m, range: 535-973 m; ANOVA, $P < 0.0001$). Visual inspection of the data suggested that the three behavioural categories can be separated quite well by classifying all intervals with distances < 35 m as *Resting*, between 35 m to 570 m as *Grazing* and > 570 m as *Moving* (fig. 5).

Fisher's discriminate analysis supported the visual assessment and delineated the 1. cut point at 31.2 m and the 2. cut point at 509.6m with an expected overall fit of 84 % (77.4 % for *Resting*, 76.6 % for *Grazing* and 100 % for *Moving*). However, using these cut points on the entire behavioural dataset would result in a behavioural classification which deviates rather strongly from the observed behaviour (table 2).

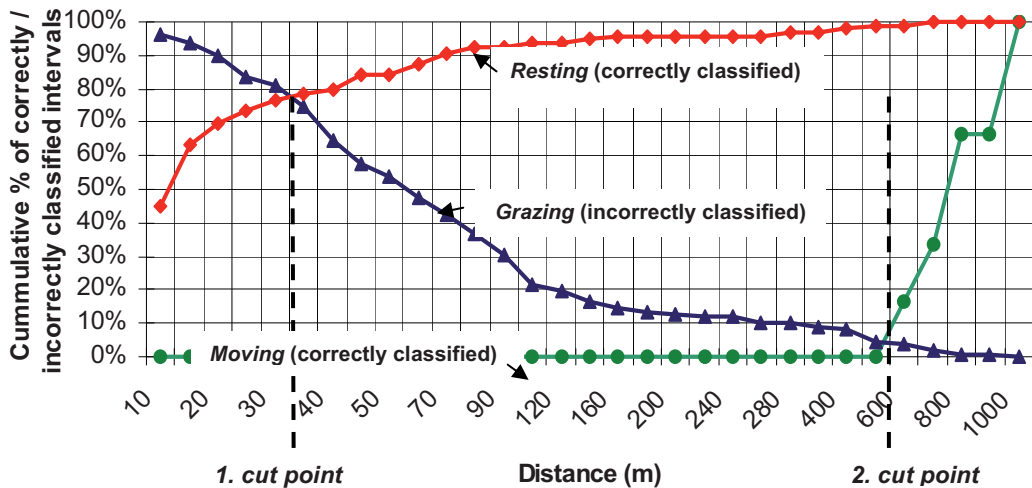


Fig. 5: First visual assessment of suitable cut points to differentiate between the three main behavioural categories.

Table 2: Different time budget estimations based on different classification methods

Behavioural categories	Behavioural classification (%) based on		
	continuous observations in minutes	grouped in 15min intervals	classification based on cut points
Resting	34	23	28
Grazing	44	28	62
Moving	13	1	10
Other / Mixed	9	48	NA*

* Not applicable because mixed behaviour cannot be identified

5. Discussion

Wild equids in the Gobi environment are ideally suited for the use of GPS technology. The large size of the animal allows attaching rather large GPS units which allow a lot of battery power and consequently can collect locations either over a long time period or at short intervals. In addition, wild equids avoid steep terrain (KACZENSKY et al. 2008) and live in an environment with scarce vegetation that rarely reaches belly height – thus GPS performance is neither affected by topography (CAIN et al. 2005) nor canopy closure (SAGER-FRADKIN et al. 2007). Accordingly precision and success rate of our collar was high.

Unfortunately our data clearly shows that from distances covered between successive GPS fixes alone the behaviour of the Przewalski's horse *Erhes* could not be reliably classified. Although pure intervals could be fairly reliably separated based on the distances covered between successive fixes, almost half the dataset consisted of mixed intervals. Fifteen minute intervals are too long to just catch one behavioural category. However, a reduction in the interval between successive GPS fixes also reduces the possible distance covered by the animals which

in turn will make it more difficult to distinguish between real movements and pseudo-movements created by GPS location inaccuracy (PEPIN et al. 2004).

However, reducing GPS sampling intervals to 5min and combining it with information collected from a data logger registering head position and/or movements will likely improve the ability to differentiate between *Resting*, *Grazing*, *Moving* and *Other* behaviour as has been shown for cattle by UNGAR et al. (2005). We had originally planned to use activity and head position data for behavioural discrimination, but unfortunately the data logger failed. Although our present approach was not particularly successful, we believe that using GPS data in combination with activity sensor and additionally including the geometry of locations (e.g. degree of clustering, turning angle) holds great potential for inferring main behavioural categories. In addition, high resolution GPS data in combination with GIS can provide useful information on specific behaviours like the timing and frequency of drinking (KACZENSKY et al. 2010, this volume).

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Cattle and Wild asses in competition for water resources in the South Gobi, photos: M. STUBBE.