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First Experience with a Camera Collar in a Free-Ranging Przewalski's Horse Group in the Mongolian Gobi

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Abstract

Remote sensing and satellite telemetry have allowed to greatly expanding the understanding of how species use various landscapes, even in remote settings. However, remotely collecting data also harbours the risk of losing "touch with the ground". We explore the possibility of the additional insight cameras integrated in GPS-satellite collars can provide for the behaviour and ecology of free-ranging Przewalski's horse in the remote Great Gobi B Strictly Protected Area in southeastern Mongolia. Over a 91-day period, the camera collected 1,080 images. 62% of the images showed Przewalski's horses and provided insights into behaviour and grouping patterns and can supplement indirect measures of behaviour from acceleration sensors. Other images provided first information on insect harassment and show the potential of images for ground-truthing environmental conditions, e.g. the occurrence of rainfall. The potential for camera collars as an additional tool to study large-bodied ungulates in remote ecosystems seems really promising, although this relatively new technology seems still prone to technical failures.

Key words: Animal-borne camera system, Mongolia, *Equus ferus przewalskii*, behaviour, social organisation, Gobi Desert, ground truthing, nomadic movements, Przewalski's horse, remote data collection

1. Introduction

Remote sensing and satellite telemetry have allowed us to greatly expand our understanding of how species use various the landscapes, even in remote settings (KAYS et al. 2015). Remote data collection does allow for regular sampling schedules and is not compromised by factors such as adverse weather conditions, daylight hours, or observer fatigue. However, remotely collecting data also harbours the risk of losing "touch with the ground" and many analyses focus on correlations or patterns, often with little understanding of the species or ecosystem by those running the analysis. On the other hand, direct observations in remote settings and of highly mobile species are particularly challenging and results may be biased due to economic, logistical, and environmental constrains.

The use of remote cameras has become increasingly popular to detect and count species, and to record their behaviour (CARAVAGGI et al. 2017). Camera traps mounted at fixed locations in the habitat can capture the behaviour of many individuals passing this location, but cameras attached to individual animals ("camera collars") can provide continuous insight into an individual's behaviour and its interaction with conspecifics, other species, and the environment (MOLL et al. 2007; THOMPSON et al. 2012). Possible applications of data collected are still in their infancy, but the potential of camera collars to add to our understanding of habitat and space use, especially of rare species in remote ecosystems, seems tremendous.

In the Great Gobi B Strictly Protected Area (SPA) in southwestern Mongolia, Przewalski's horses have been reintroduced since 1992 (KACZENSKY et al. 2017; KING et al. 2015). Behavioural observations of free-ranging Przewalski's horses in the Gobi have been challenging due to their large ranges (being 10-times larger than in the more productive mountain steppe habitat in Hustai National Park), the remoteness of the study area, and the harsh climate (KACZENSKY et al. 2008b; KING 2002; SOURIS et al. 2007). The overall aim of this study was to explore the potential of camera collars as an additional tool for studying Przewalski's horse behaviour and ecology in the Mongolian Gobi.

2. Materials and Methods

2.1. Study area

The study area covers roughly 900 km^2, located at the south-eastern corner of the 9,000 km^2 Great Gobi B SPA in the Gobi-Altai province of south-western Mongolia (KACZENSKY et al. 2004). The area is characterized by plains, small mountain ranges, and the Bij river valley (fig. 1). Elevations range from 1500 m in the Bij river valley to just over 1900 m on the higher peaks.

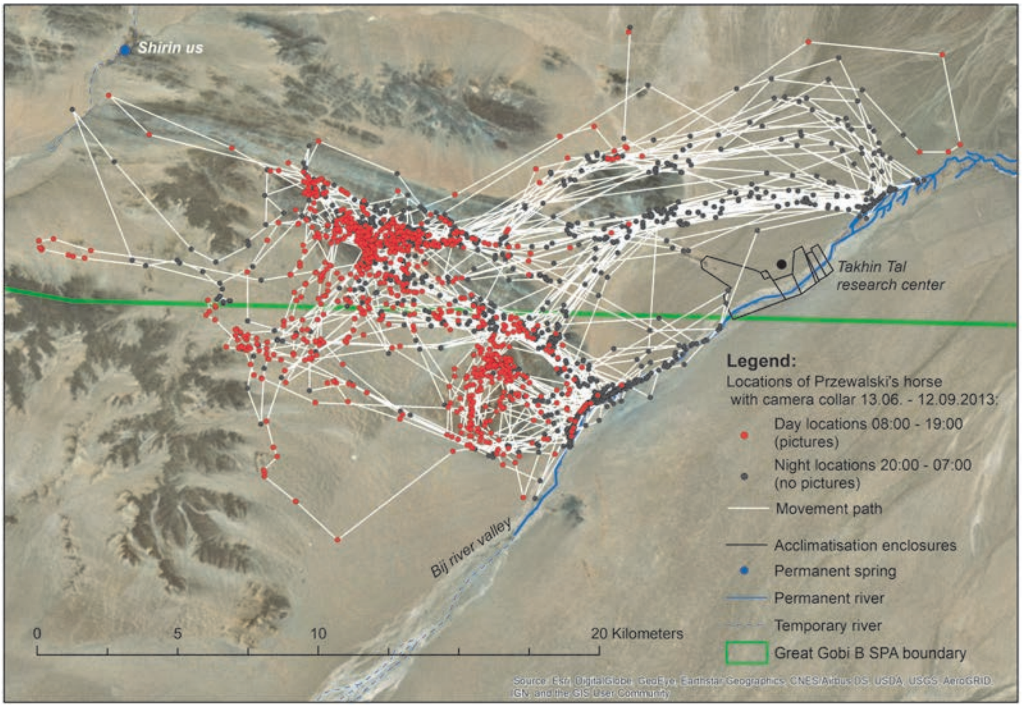

Fig. 1: Study area with hourly GPS locations of the Przewalski's horse mare Boroo from capture on 13 June 2013 until the premature end of the camera recording on 12 September 2013. The total area covered during this 92-day period by Boroo was 385 km^2 (100% Minimum Convex Polygon).

The vegetation is dominated by *Stipa*-communities, interspaced with *Caragan*-and *Nanophyton*-communities, and a small portion of *Haloxylon*-communities (von WEHRDEN et al. 2006). The climate is strongly continental with monthly temperatures averaging +18 °C in summer (June–August) and -18°C in winter (December–February), with extremes ranging from +35 to -43 °C. Average rainfall is 100 mm with a distinct peak in summer.

Other large mammalian wildlife in the study area include Asiatic wild ass (khulan; *Equus hemionus*), goitered gazelles (*Gazella subgutturosa*), ibex (*Capra sibirica*), and grey wolf (*Canis lupus*). Whereas ibex are largely constrained to mountainous terrain, which is rarely used by the Przewalski's horses, the other large mammals roam widely (KACZENSKY et al. 2008a; KACZENSKY et al. 2008b).

Semi-nomadic herders and their livestock leave the protected area in summer for mountain pastures in the Altai mountain range. Livestock, with the exception of some domestic camels, is absent from the protected area during summer from mid-June until mid-September (KACZENSKY et al. 2006; KACZENSKY et al. 2017).

2.2. Animal capture and collar details

In June 2013, was equipped a female Przewalski's horse, mare "Boroo" (Studbook #5372) with a GPS-satellite collar with an integrated camera (GPS PLUS-4 Collar, Vectronic Aerospace, Germany). To our knowledge, this is the first ever camera collar deployed on a free-ranging wild equid. Test deployment on a domestic horse showed that with a forward-facing camera, most images were obscured by the horse's long lower jaw (also see: https://arcg.is/1jP4L1). Hence, we chose a side-facing camera and adapted the housing to provide the best fit for the anatomy of equids; the final collar weight was 1.8 kg (~1% of the body mass).

The collar additionally featured an integrated internal temperature sensor and a two-axis acceleration sensor (to record overall activity status) and was programmed to collect: 1) hourly GPS positions over 24 hours, 2) hourly photographs during the daytime hours between 8:00 and 19:00, and 3) temperature and acceleration data averaged over 5-minute sampling intervals. GPS locations were transmitted at 10-hour intervals via the Iridium satellite system, whereas photographs, temperature, and acceleration data were stored on-board of the collar. An external drop-off mechanism (CR2a, Telonics, USA) was pre-programmed to release the collar after 10.5 months to allow collar retrieval without the need to re-capture the Przewalski's horse.

Boroo originated from Doebritzer Heide, Germany and arrived together with three other mares at Takhin Tal research station in July 2012. In spring 2013, Takhin Tal born stallion *Erkhes* jumped the fence of the acclimatization enclosure and claimed the mares, subsequently forming the small *Erkhes* harem of five. *Boroo* was collared on 13 June 2013, a few days post-release from the adaptation enclosure at the north-eastern corner of the Great Gobi B Strictly Protected Area (SPA); for details on capture procedures see WALZER (2014), WALZER et al. (2007). *Erkhes* harem also included mare "Tsagaanaa" (Studbook #5341, who was equipped with a regular GPS-satellite collar without camera), mare "Bulgan" (Studbook #4942), and mare "Alag" (Studbook #5719).

2.3. Analysis

Image database

Boroo's camera collar collected hourly GPS positions and temperature and activity data over the entire 10.5 months deployment time. However, the battery of the camera unit failed prematurely on 12 September 2013. Over the 91-day operation time, the camera collected 1,080 out of the 1,093 expected images (99 % success rate). Of these images, only two provided no information because they were black. Of the remaining 1,078 images available for image analysis, 212 (20 %) had some blurry spots, 91 (8 %) had the sunshine into the lens, and 50 (5 %) had mud spots, blurring or obstructing a part of the image.

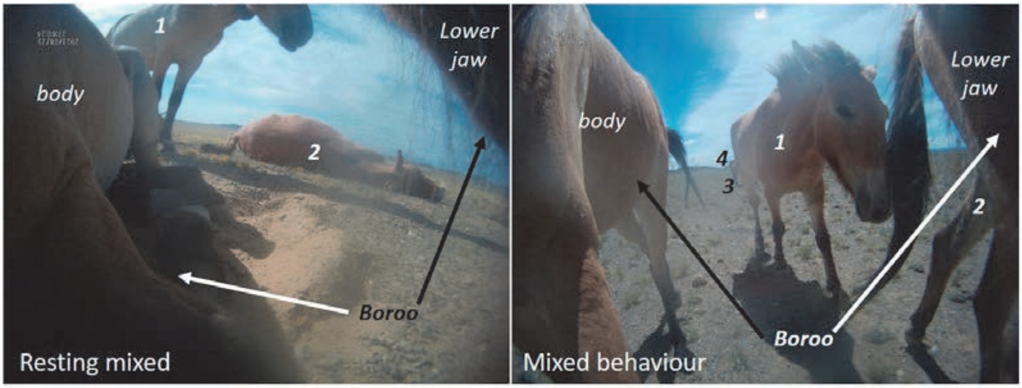

Fig. 2: Counting Przewalski's horses visible in images but avoiding selfies of Boroo when looking sharply back. Left image: The GPS-satellite collar of the second mare Tsaganaa is clearly visible. Przewalski's horse 1 is standing, Przewalski's horse 2 laying down and the image was coded as showing Resting mixed. Right image: Przewalski's horses 1 and 2 are coded as Walking and 3 and 4 as Standing and the image was coded as showing Mixed behaviour.

Images were hand-coded by SG following a coding scheme aimed at counting the numbers of Przewalski's horses visible in the images, whether the stallion could be identified, whether *Tsagaanaa* with the regular GPS-satellite collar was visible, the behaviour of the Przewalski's horses visible in the images, presence of other wildlife, humans, livestock, or insects, and weather condition.

We counted Przewalski's horses visible in the images, excluding selfies of *Boroo* (e.g. when she turned her head sideways; fig. 2). We did not attempt to recognize individual horses but marked down when *Tsagaanaa* with the regular GPS-satellite collar was visible, or when one of the horses could be clearly identified as a stallion based on genitals.

We classified the main behavioural categories of the other Przewalski's horses in an image into: *All lying down*, *Resting mixed* (horses seen lying down and standing), *Standing close*, *Standing*, *Grazing*, *Walking*, *Mixed* (when an equal number of the animals seem was involved in different behaviours), and *Other* (fig. 2 & 3).

Fig. 3: Main behavioural categories of Przewalski's horses seen in the camera collar images.

Image tilt & activity sensor data to classify behaviour

The sideways orientation of the camera resulted in a tilted horizon of the image ("horizon tilt") when *Boroo* lifted or lowered her head, and the horizon was close to horizontal when she was standing. As the head position varies with different behaviours, we predicted that the horizon tilt could possibly be used as a proxy for behavioural categories – especially feeding or drinking, which requires the head to be down - and we measured the horizon tilt in each image using the open source software *ImageJ* (https://imagej.net/ImageJ). Low tilt values represent a near straight neck, negative tilt values a lowered head, and positive tilt values a lifted head.

Climate data

We coded weather conditions in the images as one of the following categories: *Clear*, *Cloudy*, and *Raining*. We obtained collar temperature from the 5-minute activity readings and calculated daily averages. For comparison we obtained hourly temperature and rain events from a temperature datalogger and rain gauge (Hobo, Onset Computer Corporation, Inc., MA, USA) at Takhin Tal research center (fig. 1).

3. Results

3.1. Number of Przewalski's visible in the images

Przewalski's horses were visible in 671 (62 %) of the 1,076 images available for coding, with 44 (6.6 %) showing 4, 184 (27.4 %) showing 3, 194 (28.9 %) showing 2, and 249 (37.1 %) showing 1 Przewalski's horses. The average number seen per day was 1.26 (SD = 0.42, range = 0.58-2.33, median = 1.27), the maximum number ranged between 2 and 4 (fig. 4). The average number of Przewalski's horses seen appeared somewhat higher in July, but the time series was rather short.

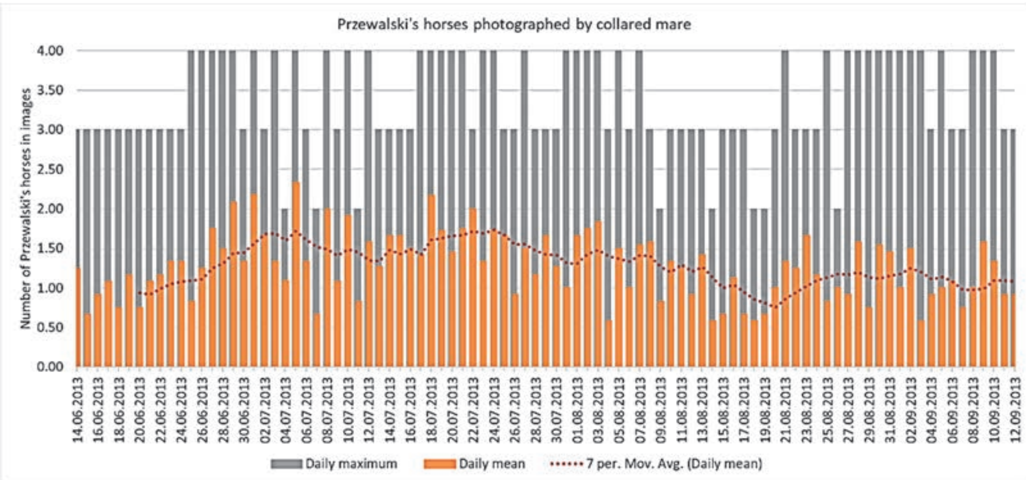

Fig. 4: Przewalski's horses visible in 671 camera collar images.

In 190 (28 % of all images with Przewalski's horses) images the mare *Tsaganaa* with the regular GPS-satellite collar was visible; an additional 14 images showed her right back side with the brand 5341. In 176 of those images the orientation of the collar was clearly visible, showing a correct collar orientation in 139 images and a rotated collar orientation (battery pack on top, GPS antenna under the neck) in 37 (21 %) images. The stallion *Erkhes* was identifiable in 107 (15.9 %) images. Only one image showed the brand 4943 of mare *Bulgan*; mare *Alag* did not have a brand.

3.2. Przewalski’s horse behaviour

Przewalski’s horse behaviour could be coded in 670 of the 671 images with Przewalski’s horses. Most images showed Przewalski’s horses standing close or grazing (fig. 5). *Other* behaviour was extremely rare, with only two images showing Przewalski’s horses running, 1 drinking, and 1 defecating. Images showing all Przewalski’s *Lying down*, *Resting mixed*, or *Standing close* strongly suggest overall resting behaviour and these categories accounted for 47.3 % of all images.

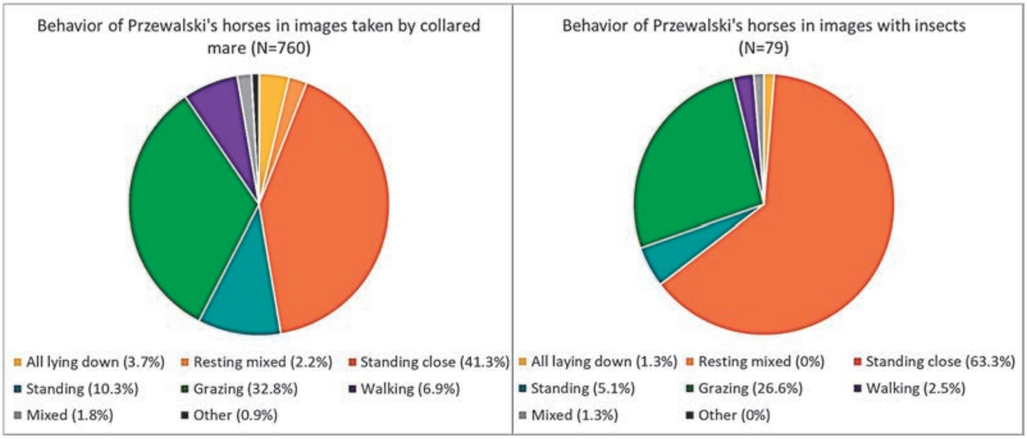

Fig. 5: Main group behaviour of Przewalski’s horses seen in 670 camera collar images. Left: All images with Przewalski’s horses. Right: Only images in which also insects are seen.

3.3. Presence of other wildlife, humans, livestock or insects

No images showed any other wildlife and no images showed humans or livestock.

A total of 145 (13.4 %) images from 57 days (or 63 % of the 91 camera days) showed insects buzzing around or sitting on the Przewalski’s horses. Insects seem more frequent in June and July, after which their occurrence decreased (fig. 6).

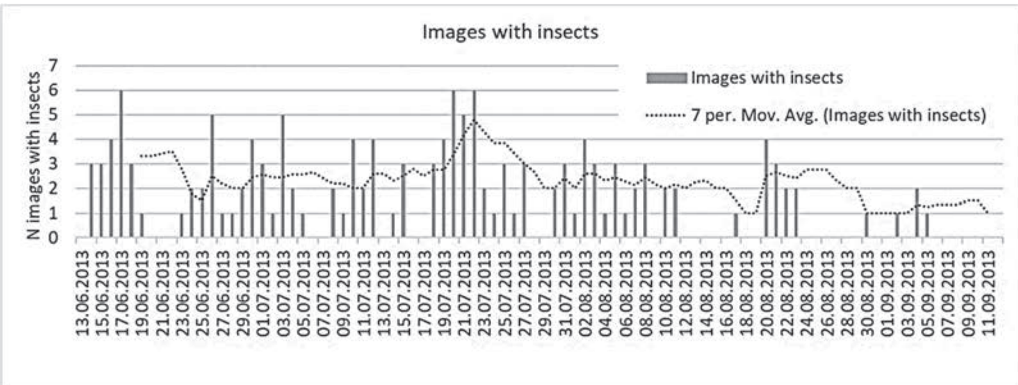

Fig. 6: Number of images with insects.

However, seeing insects and let alone counting them is rather hard and subjective and hence the number of images with insects is likely only a rather crude index of insect harassment (fig. 7).

Fig. 7: Two examples of insects visible in camera collar images.

3.3. Image tilt and sensor values

Behavioural synchronization in a Przewalski's horse harem tends to be high and so we examined if horizon tilt and activity sensor values are suitable to differentiate between different main behavioural categories in the Przewalski's horse harem. Horizon tilt seemed a suitable way to differentiate *Grazing* from the remainder of the main behavioural categories but suggests that differentiation among the other categories is hardly possible. The acceleration data looks promising for differentiating between inactive and active behaviours, but also shows a large overlap from one main behavioural category to the next (fig. 8).

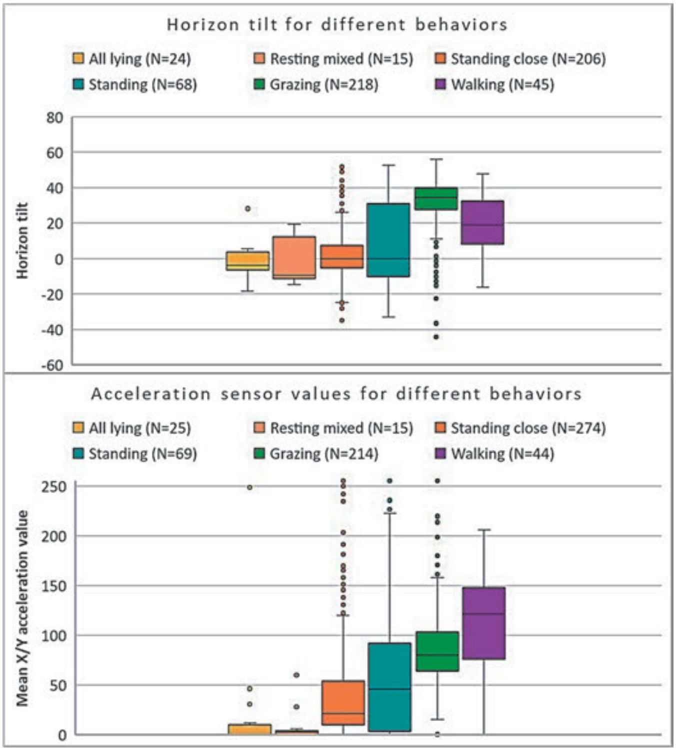

Fig. 8: Values for horizon tilt and activity of images showing Przewalski's horse behaviour.

The box indicates the median, 25 % and 75 % quartiles and whiskers are the largest values that are not outliers, while circles mark outliers.

Acceleration sensor data over the entire 10.5-month period was highest immediately after the release, reaching a low in March, but increasing again in April. Diurnal activity pattern showed relatively high average activity levels throughout day and night, but with slight activity peaks around dawn and dusk (fig. 9).

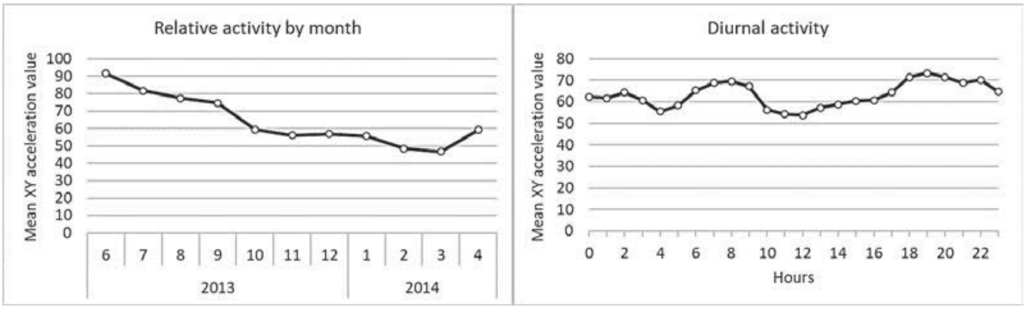

Fig. 9: Relative activity levels based on the two-axis acceleration sensor over the entire 10.5-month monitoring period.

3.4. Climate

The weather conditions could be coded from 1,061 (98.4 %) images. In the remaining images, close-ups of Przewalski's horses covered the frame. About half of the images had clear sky (48.0 %) and the other half showed clouds or an overcast sky (50.2 %), with the reminder showing rain (1.8 %). Rain was directly obvious on 6 days (e.g. depicting wet Przewalski's horses or water on the lens, see fig. 3 middle left) of the 14 rain days recorded by the rain gauge at the Takhin Tal research station during the 91-day period the camera of the camera collar was working.

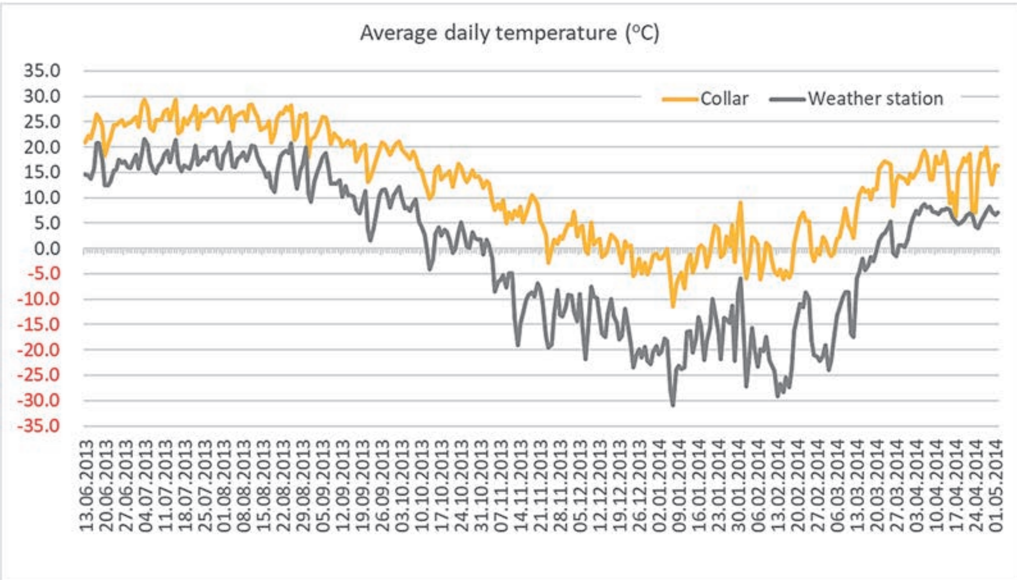

Fig. 10: Average daily temperature measured by a sensor in the camera collar and the local weather station at Takhin Tal research camp.

For the 8 days we failed to record rain in the images, we re-visited the images and for all 8 days found at least one images with indirect evidence of a recent rain event (e.g. wet smears on the lens and/or rain clouds).

Collar temperature over the entire 10.5-month period showed that average daily collar temperature was 12.6 °C (SD = 4.7, range = 0.5-25.5, median = 11.8) higher that the ambient temperature measured by a nearby weather station (fig. 10). The absolute difference was lowest when it was hot (8.3 °C in July 2013 when the average monthly temperature was 17.7 °C) and highest when it was cold (19.3 °C in February 2014 when the average monthly temperature was -20 °C).

4. Discussion

The overall aim of this analysis was to explore the potential camera collars have as an additional tool for studying Przewalski's horse behaviour and ecology. Because analysis was restricted to one animal in a newly released harem over only a 91-day period, the results were kept descriptive as they do not allow drawing wider conclusions about the Przewalski's horse population in Great Gobi B SPA.

Grouping

The average number of Przewalski's horses counted in the 12 images per day shows that, with a camera facing in only one direction, the chances to photograph all members of a group are likely small. However, the chance to have at least 1 image per day with all other 4 Prewalski's horses was >40%. This suggests that some combination of mean, maximum, or medium number of animals seen will likely provide a suitable index to document grouping patterns in Przewalski's horses and other large ungulates.

For *Erkhes* harem, the images confirmed that in summer, different Przewalski's horse harems rarely meet in Great Gobi B SPA. Unfortunately, the collar stopped working in mid-September. In winter, *Erkhes* group expanded their range and shared the habitat with multiple other Przewalski's horse harems (OG and NA pers. obs.) and the images could have helped to document the frequency of meetings and resulting group sizes. Such data is otherwise difficult to obtain as it would require all or most Przewalski's harem groups to be collared, or very frequent trips by the rangers (currently groups are checked roughly once a week) which are time consuming and expensive.

Behaviour

The images of other Przewalski's horses provided a large pool of instantaneous scan samples (Altmann 1974) over the daytime hours without the need to have an observer accompany the group (Souris et al. 2007). This reduced monitoring costs, is possible year-round, and does not risk influencing behaviour or displace the group; the latter is particularly relevant for groups, which mainly consist of animals born in the Gobi rather than animals transported from zoos (which tend to be warier of people; OG, NA, and PK pers. obs.).

The images can also be expected to provide the day of birth of foals and could possibly help to document injuries or predation. In *Erkhes* harem, the images helped to document collar fit and collar orientation on the other mare with a satellite collar. For the Przewalski's harems in the western part of Great Gobi B SPA a few camera collars may help to narrow down when, where and potentially even why so many foals disappear in this region.

Interaction with other species

The images did not document any interaction with other wildlife, local herders or livestock. At least the latter comes as little surprise, as local herders and their livestock are all but absent from the park between mid-June until mid-September (Kaczensky et al. 2006). The absence of images of other wildlife may have been due in part to the relatively small area the Przewalski's horses initially utilized and the short operation time of the camera collar for only 91 days. Khulan presence throughout the summer, for example tends to be focused around the larger water points to the south and west of the area *Erkhes* harem used from June to September (Kaczensky et al. 2008b; Nandintsetseg et al. 2016).

The images did however provide an unexpected insight into interaction with insects, which were visible in many images especially in June and July. These images also happen to fall in the time with a period when the average number of Przewalski's horses seen was somewhat higher. During periods of fly harassment, domestic and Przewalski's horses are often seen to standing close and rubbing their heads and nosed on each other (OG, NA, PK pers. obs.). Thus there appears some potential to document insect harassment with images, which in turn may explain changes in behaviour (Górecka and Jezierski 2007; King and Gurnell 2010; Rutberg 1987).

Ground-truthing

The camera collar images also show the potential to ground-truth ecological conditions at the location of the collared animal. However, documenting rain for example is not quite as straightforward as we thought as rain events are hard to see and require indirect cues (e.g. water or smears on the lens or "rain clouds"), potentially making this assessment prone to subjectivity. But other environmental conditions, e.g. snow cover, can be expected to be unequivocal to code.

Images may also give clues about the use of certain key habitats or key resources. We had hoped to document the use of winter hay provided to recently released Przewalski's horse harems like *Erkhes* harem*;* unfortunately we could not test this due to the premature failure of the camera.

Sensor data

The GPS-satellite collar additionally featured a temperature and an acceleration sensor. The temperature sensor seems a good proxy for the temperature experience by the animal, especially if there is no local weather station in the vicinity. However, the difference between the collar temperature and the weather station data shows that the body heat of the Przewalski's horse resulted in significantly higher values, with the difference getting larger as the ambient temperatures get colder. Hence, without a larger samples size and species specific corrections, collar temperatures should only be used as an index, but not as a true representation of daily ambient temperatures.

The acceleration sensor also showed some promise to categorize overall activity as periods of high activity coincide with periods of high displacement (Gantulga et al. 2017). Behavioural synchrony in Przewalski's horse harems tends to be high (Boyd and Bandi 2002; Souris et al. 2007). Hence the main behaviour of the other Przewalski's horses seen in the images likely also represents the behaviour of the collared individual. Although the two-axis acceleration sensor did well to distinguish between active and passive behaviour, overlap between main behaviours was large. The image tilt, on the other hand, did a good job in identifying grazing behaviour, but performed poorly to separate between active and passive behaviour. Hence a 3-axis acceleration sensor, which measures the tilt of the head can be expected to greatly improve the ability for differentiate main behaviours. The image dataset showing Przewalski's horse behaviour could then be used to train automatic classification algorithms for the 3-axis acceleration sensor data (Brown et al. 2013; Kröschel et al. 2017).

Conclusions

A great deal of potential for the use of camera collars on Przewalski's horses and other large ungulates in remote ecosystems like the Mongolian Gobi ist to see. Currently the biggest constraint for implementing camera collars in monitoring and research is in our opinion the small number of devices that have been used so far. Our own experiences with four camera collars deployed on wild equids suggest that the technical challenges associated with a camera on a wild animal have not yet been eliminated (e.g. these cameras are exposed to the full forces of the environments 24/7 must withstand abusive behaviour like being kicked).

Out of the four collars, we deployed, only one on a free-ranging khulan was a full success (Table 1 – third collar; also see Khaliun 2018). In the other three cases problems occurred, in the first collar (this study) the camera stopped after 91 days due to a drained battery (technical problem).

In the second collar the lens was permanently covered by mud after 5 months due to the Przewalski's horse going into shallow, muddy water on a daily basis (environmental challenge), and in the fourth collar the image database was largely destroyed and the time stamp lost due to a corrupted memory card (technical problem).

Basically, at this point in the development, any study planning to implement camera collars should: 1) invest quite heavily into initial testing, ideally with individuals under semi-wild conditions, which closely match the environmental conditions in the wild and 2) should expect a significant portion of devices to fail.

Table 1: Camera collar performance of four camera collars tested on wild equids

Species	N	Location	Deployment time		N images		Success	Collar performance
			from	to	expected	retrieved	rate %	
Przewalski's horse	1	Mongolian Gobi	13.06.2013	01.05.2014	3,864	1,080	28	Camera unit stopped after 91 days due to drained battery
Przewalski's horse	1	Pentezug semi-reserve in Hortobágy National Park	01.10.2014	15.06.2015	7,100*	6,390	90	Lens permanently covered with mud after ca. 5 months due wetlands
Khulan	1	Mongolian Gobi	16.10.2015	16.10.2016	8,788	8,719	99	Worked as expected without any problems
Kulan	1	Central Steppe of Kazakhstan	23.10.2017	20.10.2018	8,688	825	9	Image loss due to a corrupted memory which also erased all image time stamps

*programmed with four different camera schedules, with image intervals varying between 15min to 1 hour, and daily operation time between 8 to 12 hours

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