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Monitoring of Khulans and Goitered Gazelles in the Mongolian Gobi – Potential and Limitations of Ground Based Line Transects

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Abstract: Central Asian remote rangelands are home to several charismatic, rare and far ranging ungulates which are increasingly becoming under pressure from human encroachment. Population monitoring is challenging due to the vast expanse of the species ranges, tight budgets and limited availability of suitable fixed winged-aircraft. Consequently, many current population estimates are based on pragmatically designed ground-bound transect surveys. Although, ample literature exists on how to design surveys in an ideal world, little effort has been made to demonstrate the potential and limitations of a time-series of ground-bound transect surveys under real world constrains.

Since 2003 we have been monitoring the two sympatric steppe ungulates, Asiatic wild ass ("khulan", *Equus hemionus*) and goitered gazelles ("gazelle", *Gazella gutturosa*), in the Great Gobi B Strictly Protected Area in south-western Mongolia using ground-bound line transects. Both species showed clear species-specific seasonal variation in group sizes which seem related to birthing and mating periods. Data on annual recruitment were impeded by the long flight distances and the difficulty to reliably identify and count young of the year. Distribution of khulans and gazelles showed clear species-specific seasonal patterns and highlighted the importance of two oasis complexes. Population estimates of 33 surveys covering 10,383 km² were highly variable even between consecutive surveys and had huge 95% confidence intervals (khulan: range: 1,707 to 45,040, gazelles: range: 2,564 to 10,766) making them unsuitable to obtain robust baseline population estimates.

Although our individual surveys were poor measures of population abundance, they provided important data on group sizes and species distribution and are presently used for Bayesian hierarchical trend modelling and species specific habitat suitability analysis. The ground surveys are relatively inexpensive as compared to aerial surveys and thus can be conducted at short temporal intervals, engaging park staff and researchers with local people thereby helping mutual understanding, information transfer, and detection of illegal activities.

Keywords: Asiatic wild ass, Distance sampling, *Equus hemionus*, *Gazelle subgutturosa*, Goitered gazelle, Mongolia, Monitoring.

INTRODUCTION

Central Asian remote rangelands are home to several charismatic, rare and far ranging ungulates which are increasingly becoming under pressure from human encroachment (Schaller 1998, Robinson and Milner-Gulland 2003, Mallon and Zhigang 2009, Batsaikhan *et al.* 2014). Reliably monitoring species is a challenge due to the vast expense of the species ranges, tight budgets, and limited availability of suitable fixed winged-aircrafts (Singh and Milner-Gulland 2011). Consequently, many current population estimates are based on pragmatically designed ground-bound transect surveys which in turn often provide the main source of information for species assessments, including the IUCN Red List assessment (Rodrigues *et al.* 2006). Although, ample literature exists on how to design strip and line transects surveys in an ideal world (*e.g.* Buckland *et al.* 2001, Sutherland 2006, Thomas *et al.* 2010) and how difficult it is to implement these prerequisites (*e.g.* Harris 1996), little effort has been made to document their potential and limitations under real world constrains using repeated surveys over multiple years.

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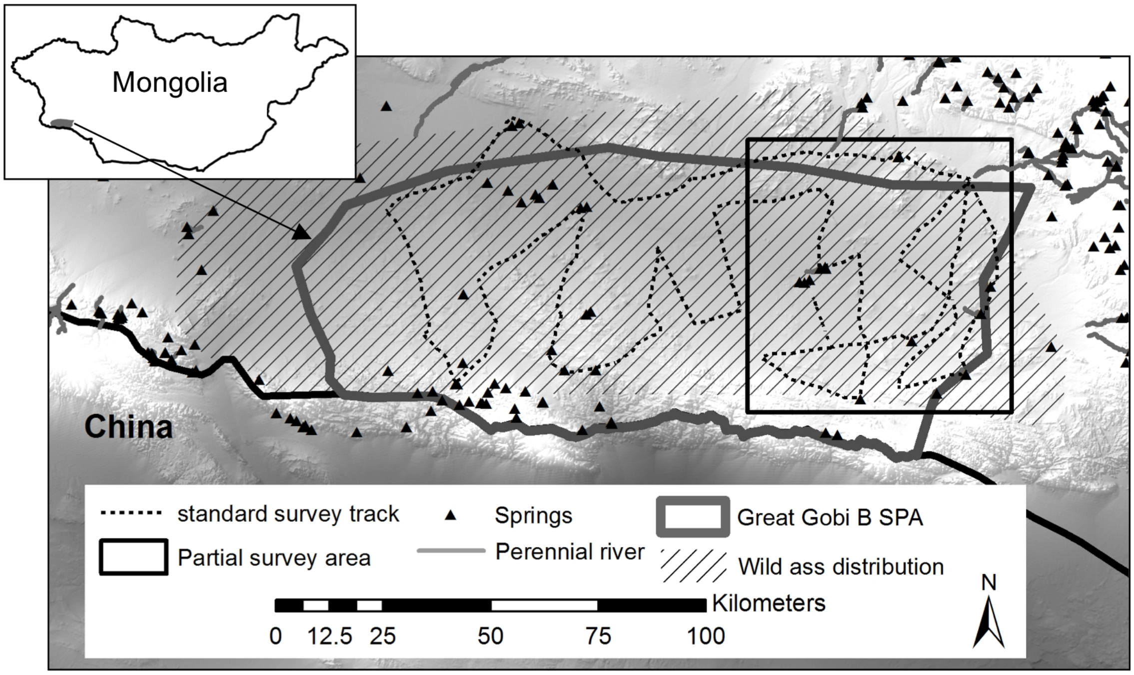

Fig. (1). Survey area for khulans and goitered gazelles in the 9,000 km² Great Gobi B Strictly Protected Area in south-western Mongolia. Location of two key oasis complexes: 1=Chonin us, 2=Takhi us.

The Mongolian Gobi is a vast stretch of arid land that provides an important refuge for several endangered large steppe ungulates. Mongolia's change to a free market economy resulted in dramatic socioeconomic changes, also affecting the Gobi regions. Infrastructure developments, particularly associated with mining, threaten to fragment and destroy habitat (Mallon and Jiang 2009, Kaczensky *et al.* 2011a, Batsaikhan *et al.* 2014). Overstocking with livestock results in competition for and degradation of pastures (Fernandez-Gimenez 1999, Sheehy *et al.* 2010, Berger *et al.* 2013). The huge demand for wildlife products in adjacent China, the increasing gap between rich and poor, and the deterioration of old values and norms resulted in high levels of illegal hunting (Pratt *et al.*, 2004; Wingard & Zahler 2006). At the same time, climate change scenarios predict a raise in temperature and an increase in the occurrence of extreme weather events (IPPC 2007). Monitoring wildlife populations is increasingly becoming a priority, particularly for threatened species and in protected areas.

Two ungulate species can be found throughout the plains of the vast Gobi region of southern Mongolia, the *endangered* Asiatic wild ass (*Equus hemionus*; "khulan" in Mongolian; Moehlman *et al.* 2008) and the *vulnerable* goitered gazelle (*Gazella subgutturosa;* Mallon 2008). Past population estimates of khulans and goitered gazelles in Mongolia arose from attempted total counts that lacked statistical rigor (Zhirnov and Ilyinsky 1986, Lhagvasuren *et al.* 1999, Amgalan 2000, Feh *et al.* 2001, Lhagvasuren 2007), while those implying statistical methods were plagued by low precision (Reading *et al.* 2001, B. Lkhagvasuren and S. Strindberg, unpubl. data). A recent large scale aerial survey (Norton-Griffiths *et al.* 2013) suggested that several past ground-bound transect surveys likely both widely under- and overestimated the actual population size.

In 2003, we started monitoring goitered gazelles and khulans in the Great Gobi B Strictly Protected Area (SPA) in the south-western Gobi using ground based line transects. Our aims were to explore the potential of line transect surveys to: 1) identify group size and recruitment dynamics, 2) document seasonal patterns in species distribution, and 3) obtain baseline population estimates. We discuss our findings in the light of large-scale conservation in remote areas.

Study Area

The Dzungarian Gobi in south-western Mongolia is surrounded by high mountains on three sides. This natural geographic isolation is further enhanced by the border fence separating Mongolia from China along its southern and western edge. Almost the entire eastern and central part of the Dzungarian Gobi falls into the 9,000 km² Great Gobi B Strictly Protected Area (SPA; Fig. **1**).

Elevations within the Great Gobi B SPA range from 1,000 to 2,840 m. Climate is continental with an average annual temperature around 1.0°C and temperature extremes varying from -43°C in winter to +35°C in summer (Appendix 1). Average annual rainfall is 96 mm with a peak during summer. Average snow cover lasts 97 days. Rain- and snowfall can be highly variable from year to year in space and time and the area is generally considered to follow non-equilibrium dynamics (Fernandez-Gimenez and Allen-Diaz 1999).

The landscape of the Great Gobi B SPA is dominated by plains in the east and rolling hills in the west. Open water (rivers & springs) is unevenly distributed with almost no water in the central or western part of the park. Desert areas are widely dominated by Chenopodiaceae, such as

Haloxylon ammodendron and *Anabasis brevifolia*. The steppe areas are dominated by Asteraceae, such as *Artemisia* and *Ajania*, and Poaceae like *Stipa* and *Ptilagrostis* (von Wehrden *et al.* 2006).

The park is used by ~100 families with ~60,000 livestock, predominantly in winter and during spring and fall migration (Kaczensky *et al.* 2007a). In summer, human presence in the park is almost negligible. No paved roads exist and dirt tracks are not maintained. In winter, access and mobility within the park are often limited by snow cover. Poaching occurs, but based on the small number of wild ungulate carcasses encountered, seems to be of minor importance compared to other Gobi areas (Kaczensky *et al.* 2006). Nevertheless, khulans and gazelles are very wary and generally start to run when they spot a vehicle.

Study Species

The wild ungulate community of the steppe areas in the Great Gobi B SPA consists of goitered gazelle (hereafter called "gazelle"), khulan, and a small population of reintroduced Przewalski's horse (*Equus ferus przewalskii*). The khulan population of the Dzungarian Gobi constitutes a rather closed population and is restricted to 11,983 km² in and immediately around the Great Gobi B SPA but excluding the high mountains (Kaczensky *et al.* 2011a; Fig. **1**).

Khulans in the Dzungarian Gobi have non-exclusive annual home ranges in the magnitude of 4500 to 7000 km² (Kaczensky *et al.* 2008, Kaczensky *et al.* 2011a,b, Kaczensky unpubl. data). They seem to show little preference for any particular plant community type, but avoid steep slopes and need regular access to open water (Kaczensky *et al.* 2008, Kaczensky *et al.* 2010). Like other arid adapted equids, khulans seem to live in fission-fusion groups, with the only stable unit being females and their foals (Sundaresan *et al.* 2007, Kaczensky *et al.* 2008). Females give birth in mid-June to a single foal and come into estrous 1-2 weeks post-partum. Females are polyestrous with estrous recurring every 21-25 days until conception or the end of the breeding season (Asa 2011, Schook *et al.* 2013). Consequently, peak mating period is the end of June, but stretches well into July (Kaczensky unpubl. data).

Gazelles have been little studied in Mongolia, but likely also range over large areas. Gazelles visit water points, but seem less water dependent than khulans (Heptner *et al.* 1988, Nandintsetseg *et al.* in prep.). No studies have been conducted looking at habitat preferences in Central Asia, but in adjacent Xinjiang province, China, *Stipa glareosa* was a major food item throughout the year, whereas in autumn and winter *Haloxylon ammodendron* becomes quite important (Xu *et al.* 2012). Goitered gazelles usually occur in small groups, although it is possible to find larger aggregations (Heptner *et al.* 1988, Qiao *et al.* 2011, Blank *et al.* 2012). Fawns, often twins, are born end of May/begin of June. Rutting season is from mid-October through mid-December, during which time dominant males defend small territories (Blank 1998, Qiao *et al.* 2011, Xia *et al.* 2014).

METHODS

Line Transect Surveys

Between April 2003 and October 2010 we conducted 71 line transect surveys for khulans and gazelles. Thirty-five surveys just covered the eastern part of the Great Gobi B SPA (*partial park* survey), while 36 surveys covered the entire protected area (*all park* survey; Fig. **1**, Appendix **2**). Surveys were generally attempted once a month, but adverse weather conditions or technical problems on several occasions made surveys impossible or resulted in missing data.

Our surveys followed a distance sampling approach (Thomas *et al.* 2010) using a Russian UAZ 4x4 jeep. A survey team consisted of 4 people (driver, data recorder, 2 spotters with compasses) recruited from park rangers and the Great Gobi B SPA administration staff. Maximum speed was 40 km/hour and observers were seated ~1.20m off the ground.

For each gazelle or khulan sighting the team took a GPS fix of their own position and a compass bearing towards the location where an animal group was first detected. Observers recorded group size, composition (distinguishing when possible between adults and young of the year), and the main behaviour (laying, standing, walking or running) of the animals. Species did not occur in mixed groups and groups were generally easily distinguishable as several animals standing or running in close proximity. Initial observer distance had to be estimated because flight distances were large and conventional rangefinders are incapable of measuring distances beyond 700m. The survey team regularly calibrated their distance estimates using people placed at known intervals of 100, 500, 1000, 2000, 3000 and 5000m. After each survey, date, time and the GPS coordinates were downloaded from the GPS unit to calculate animal location and perpendicular distances to the transect line.

The Gobi ecosystem is very sensitive and vehicles leave long lasting scars in the vegetation. Consequently, we refrained from using a random or systematic survey design, but rather made largely use of the existing dirt track system. The standard *all park* survey consisted of 43 transect lines varying in length between 1.5 km and 32 km and summing up to a total effort of 762 km. The *partial park* survey consisted of 21 transect lines with a total effort of 350 km. However, in reaction to track conditions and in order to exploit alternative routes, transect lines did slightly differ among surveys. Individual transects were defined when the track changed direction or when marked changes in the topography occurred. Transect lines ran though all plant community types, except the high mountain communities unused by the steppe ungulates (Fig. **1**, Appendix **3**).

Past and recent telemetry data of khulans in Great Gobi B SPA showed neither avoidance nor attraction of khulans to dirt roads in general or to our survey track in particular (Kaczensky *et al.*, 2008, P. Kaczensky unpubl. data). The steppe habitat of the Great Gobi B SPA consists of open landscape without any tree cover. Telemetry data suggests that khulans use the seven main plant communities more or less as they are available (Kaczensky *et al.*, 2008). However, no such data are available for gazelles.

Table 1. Khulans and goitered gazelles encountered on 71 line transect surveys in Great Gobi B SPA from 2003-2010.

Species	N groups	Group Size						N Individuals
		Mean	SD	Median	Mode	Min.	Max.	
Gazelle	3,778	5.83	7.85	3	1	1	111	22,029
Khulan	2,197	32.50	108.91	5	1	1	2,110	71,405

Data Analysis

Annual Group Size Variation

Since we did not find significant differences in log-transformed group sizes of gazelles (Mann-Whitney U-test, $P = 0.260$) and khulans ($P = 0.975$) between *partial* and *all park* surveys we pooled data from all 71 surveys. To test for significant non-linear effects of the respective month on log-transformed group sizes for khulans and gazelles we used generalized additive models (GAM; Hastie and Tibshirani 1990) using program R 2.10.1 (R Development Core Team 2009). We assessed whether there were random effects of the respective sampling year by comparing nested models using a likelihood ratio test (LRT). To this end, we fitted a fixed effects model by generalized least squares (GLS) and a mixed effects model (GLMM) containing sampling year as random intercept (package nlme) following Zuur *et al.* (2009). All models were estimated with restricted maximum likelihood (REML). Non-linearity, if revealed in the GAM, was considered by including month as appropriate x^{th} order polynomial based on model selection with the lowest AIC (Johnson and Omland 2004). We calculated the *p*-values based on the likelihood ratio using the correction provided by Verbeke and Molenberghs (2000; in Zuur *et al.* 2009) for comparing models without random effects versus models with random intercept.

Seasonal Spatial Distribution

We analysed the seasonal spatial distribution of khulans and gazelles for the 33 *all park* surveys using the "Euclidian allocation" of area to the survey transects and "ordinary kriging (interpolation technique in which the surrounding measured values are weighted to derive a predicted value for an unmeasured location)" function in ArcMap 9.3 (ESRI, Environmental Systems Research Institute, Inc., Redlands, California, USA) based on mean densities over all surveys during this season. We defined the four seasons: spring (March-May), summer (June-August), fall (September-November), and winter (December-February) based on average annual weather conditions (Appendix **1**).

Abundance Estimates

We calculated abundance estimates using program DISTANCE 6.0.2 (Research Unit for Wildlife Population Assessment, University of St. Andrews, UK; http://www.ruwpa.st-and.ac.uk/distance/) only for the 33 *all park* surveys, but included sighting distances of the first 24 *partial park* surveys for calculation of the probability detection function. We used the conventional distance sampling option with 500m bins up to a maximum distance of 3000m. We used a half normal cosine probability detection function based on all 57 surveys available in distance format. We used post-stratification for stratum (in our case the individual survey) to get separate cluster size and density estimates by stratum. We tested for a size bias in the detection g(x) of different sizes of groups (clusters) of animals. When the size bias regression was significant at $P = 0.15$ then we used the regression ln(cluster size) against the estimated g(x), else the mean cluster size.

We calculated our survey area based on a square around the outer edges of the 3,000 m buffer around our standard survey track. The resulting survey area was 10,383 km² for the *all park* survey, thus covering 86% of the total distribution area of khulans in the Dzungarian Gobi, but 14% more area than the 9,000 km² Great Gobi B SPA (Fig. **1**).

RESULTS

Annual Group Size Variation

We encountered 2,197 groups of khulans and 3,778 groups of gazelles (Table **1**). Group sizes showed significant non-linear effects throughout the year (month; GAM, df=1, $F_{khulan} = 45.8$, $F_{gazelle} = 153.7$, $p < 0.001$). The khulan data were best described by including month as quadratic term in the GLMM and gazelle data were best described by a 5^{th} order polynomial resulting in a bimodal group size distribution throughout the year. The respective sampling year had significant effects for khulans (LRT, df = 1, loglikelihood ratio = 6.96, $p = 0.0042$) and gazelles (LRT, df = 1, loglikelihood ratio = 50.0, $p < 0.0001$). Khulans had the smallest group sizes in June and July, whereas gazelles showed a bimodal pattern with a low in June and an additional drop in December (Fig. **2**).

We encountered very large groups of khulans (>500) 16 times: 13 in summer, 2 in fall and 1 in spring. The largest group numbered 2,110 individuals. Large groups of gazelles (>50) were observed 12 times: 5 in spring and 2 each in fall and winter. The largest group numbered 111 individuals (Appendix **4**).

The majority of gazelles (71%) and khulans (57%) were observed running (Appendix **5**). Due to the large flight distances and the swift flight response of the majority of khulans and gazelles, it was not possible to reliably determine group composition. When reasonably close, a reliable distinction between young of the year and adults was only possible until October. Young of the year for both gazelle and

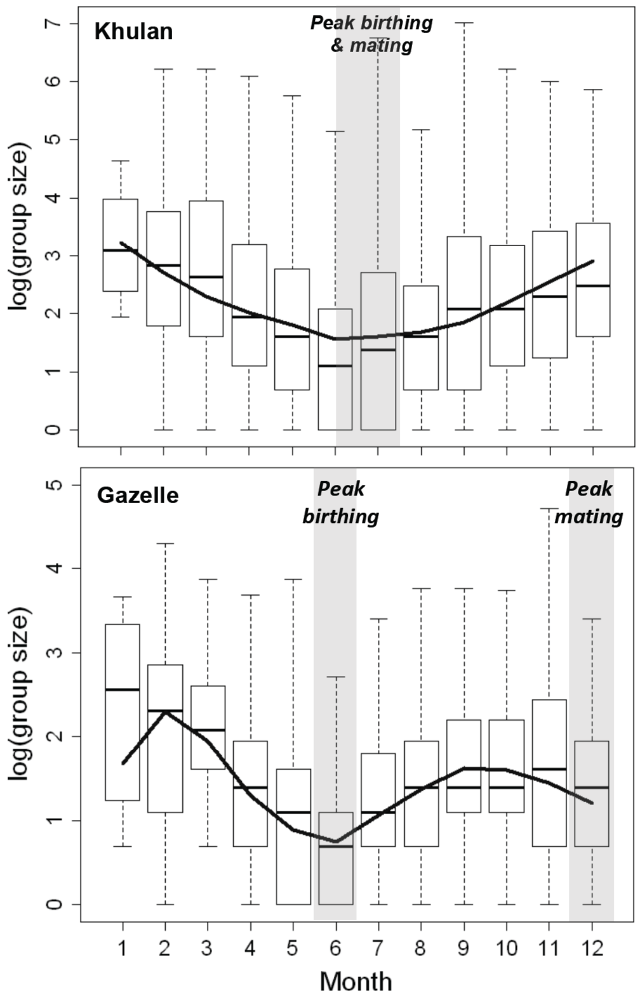

Fig. (2). Boxplots showing the median group sizes (logarithmic scale) of khulan and goitered gazelle groups by month. The trend lines show group sizes based on the values derived from the GLMMs.

khulan were first observed in June. Young of the year in groups containing foals or fawns averaged 21% in khulans and 34% in gazelles (Appendix **6**).

Seasonal Spatial Distribution

Both species showed a clear seasonal pattern in their longitudinal, but not in their latitudinal distribution. Khulans were more likely seen in the western part in spring, the central and eastern part in summer and the central parts in fall and winter. Gazelles were more likely seen in the western part of the park in fall and winter and in the eastern part of the park in spring and summer (Fig. **3**, Appendix **7**).

Abundance Estimates

The probability detection functions for khulan and gazelle observations were rather steep, with an effective strip width (ESW) of 673 m for khulans and 468 m for gazelles (Appendix **8**). Population estimates for khulans ranged from 1,707 to 45,040 animals; had huge 95% confidence intervals and an average percentage coefficient of variance (%CV) of 50. Population estimates for gazelles were less variable, but still ranged from 2,564 to 10,766 animals, with large 95% confidence intervals and an average %CV of 29 (Fig. **4**, Appendix **2**). Population estimates varied hugely even between consecutive surveys and often in a magnitude well beyond recruitment potential. There seemed to be no obvious trend in population estimates over time.

DISCUSSION

Annual Group Size Variation

Long term changes in group sizes, dynamics or distribution can be important indices of population status and will also influence abundance estimates (McConville *et al.* 2009). So far we have no indication of any linear trend of group size dynamics over the last eight years (S. Kramer-Schadt unpubl. analysis). Furthermore, khulan group size pattern is very much in line of observations from 1992-1996 (Feh *et al.* 2001). However, the effect of changes in overall density on group size distribution may also be a rather small (Blank *et al.* 2012) or complicated by variable effects on the two sexes (Vander Wal *et al.* 2013) and should not be used in isolation as an indicator of population trends. Maximum group sizes may provide some additional clues and at least for khulans can provide minimum population numbers, e.g. in summer 2009 at least 2,110 khulans were present in the Great Gobi B SPA.

Both species showed clear seasonal variation in group sizes in relation to their birthing and mating season. The pattern for gazelles was largely in accordance with data from other parts of Central Asia (Heptner *et al.* 1988, Qiao *et al.*, 2011, Blank *et al.* 2012). For khulans little data on group size distribution had previously been available. Being post-partum estrous, birthing and mating season in khulans is closely connected and peaks from mid-June to mid-July. Contrary to gazelles, khulan mares with young foals seemed to congregate with other mares with foals (Kaczensky own obs.). Nevertheless, group sizes were smallest in June/July, which may be due to subadult and barren females only forming small groups and a large portion of khulan stallions holding temporary territories (Kaczensky *et al.* in prep., Sundaresan *et al.* 2007). However, summer was also the time when large aggregations of khulans were most likely encountered.

The segregation of females with and without foals makes measuring annual reproductive success challenging as counts of a few herds may be highly skewed, depending on what groups are encountered (e.g. Enkhbileg *et al.* 2007, Tsendjav and Purevsuren 2007). The large flight distances in the Great Gobi B SPA make spotting and counting young of the year a real challenge and rangers were often unable to determine if and how many young of the year were present; consequently we were not able to calculate annual foal or fawn rates. The proportion of young of the year within identifiable reproductive groups may be an indicator of annual reproductive success in gazelles as one can expect more twins to be born and surviving in good years, but this assumption needs further investigation. Our monitoring data suggests annual fluctuations,

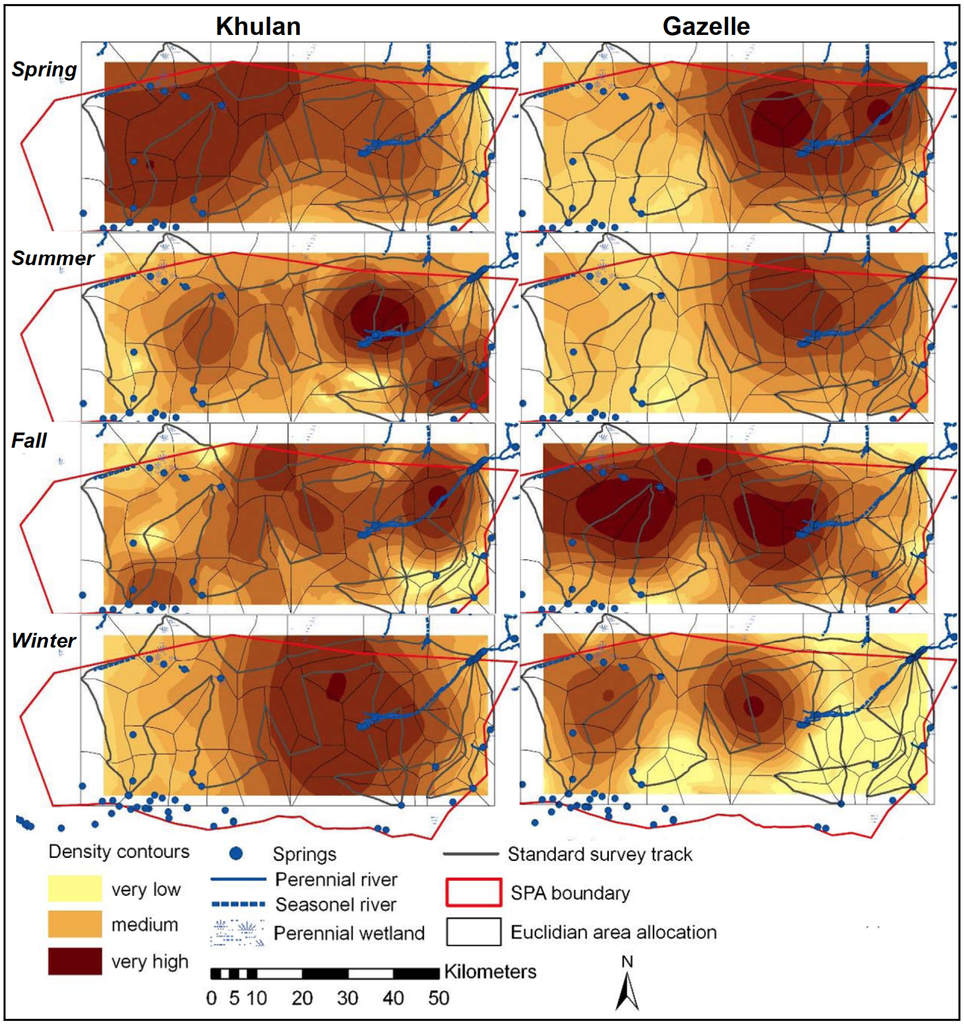

Fig. (3). Seasonal distribution of khulans and goitered gazelles based on Euclidian allocation to the survey transects and ordinary krigging of mean densities over all surveys during each season (2004 to 2010: spring = 7, summer = 12, fall = 8, winter = 6).

but no overall trend. For khulans which can only produce one foal and where mares with foals join peers, the foal rates within reproductive groups appears to be a questionable indicator of relative annual reproductive success.

Seasonal Spatial Distribution

The most important data for park management and wildlife conservation came from the seasonal distribution data. The data clearly showed that both gazelles and khulans seasonally shift range use. The data also highlighted the importance of the two oasis complexes *Takhi us* in the east and *Chonin us* in the north-central part of the SPA for steppe ungulate conservation. Since both areas are also important Przewalski's horse habitat, ranger emergency stations have been erected in 2011 and the two oasis complexes have become focal areas for ranger patrols to discourage illegal hunting, illegal collection of *Haloxylon ammodendron* for fire wood, and illegal placer mining. In the past, conservation work was mostly focused on the reintroduction of the Przewalski's horse in the north-eastern corner of the SPA (Kaczensky *et al.* 2007a,b). The introduction of the *all park* surveys guaranteed the regular presence of the rangers throughout the park. This did not only allow for a better understanding of wildlife and livestock distribution, but also of human activities in the Great Gobi B SPA. Regular and direct contacts with local herders and military posts throughout the park have helped mutual understanding, information transfer, and more rapid detection of illegal activities.

Abundance Estimates

Ground bound abundance estimates are challenging in the vast expanse of the study area. We violated three of the distance assumptions: random placement of the survey track, no movement of the animals prior to detection, and precise measurements of distances (Thomas *et al.* 2010).We had hoped to overcome some of the limitations through repeated surveys and by studying habitat- and space use in khulans (Kaczensky *et al.* 2008, 2011a). However, rather than narrowing down annual population estimates, our repeated surveys highlighted the low precision and poor accuracy of our population estimates. Results like these are difficult to publish, but we feel that it is actually extremely important to document and communicate such real world results to managers and conservationists. Most ground-bound surveys, particularly in remote regions of Central Asia where ungulate populations occur at low densities over large ranges, violate

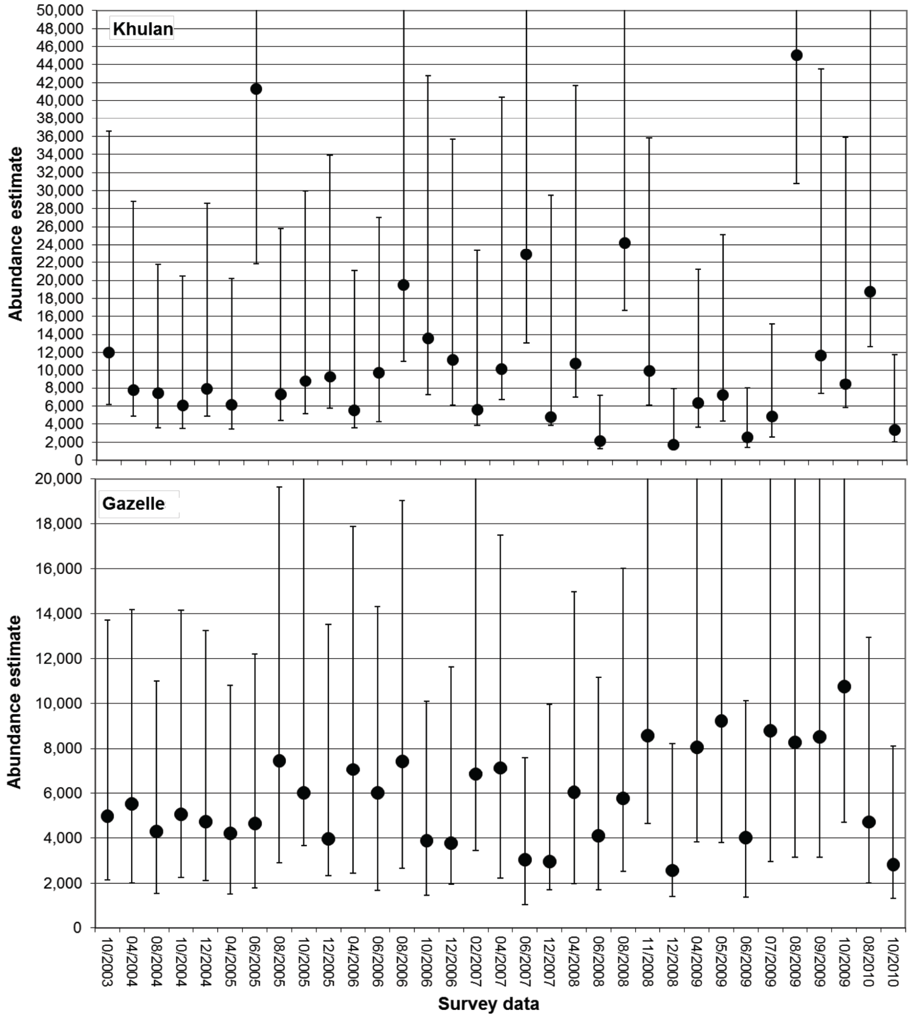

Fig. (4). Abundance estimates for khulans and goitered gazelles based on 33 all park surveys with 95% CI.

at least some of the line transect requirements. However, ground-bound line transects are often the only available option (e.g. Bårdsen *et al.* 2006) and these population estimates are widely used for population assessments, particularly when they seem "reasonable" or when two repeated surveys come up with similar numbers. However, our time series data shows that this can be highly subjective and potentially wrong.

The low precision of our estimates results from the low population density, the clumped distribution and the high variability in group sizes, especially in khulans. Single surveys, conducted at annual or multi-annual intervals would have a very low probability of reliably detecting a population change (Durant *et al.* 2011). However, what was more disturbing, and would have remained undetected with just a single survey, was the poor accuracy of our estimates. The large fluctuations in population estimates between consecutive surveys and surveys within the same year of the more or less closed khulan population (Kaczensky *et al.* 2011a) are clearly artefacts and even for the lesser studied gazelles seem unlikely to be based on real abundance changes. The variation in the point estimates were so huge, that calculating pooled estimates did not seem appropriate, as we are obviously dealing with some type of unaccounted for error.

Getting to the nature of this error is far from simple as observations per survey were rather small but potential influencing factors were numerous. We believe that non-random placement of the survey track was a minor problem as radio-tracking data suggests random use of habitat types at least for khulans (Kaczensky *et al.* 2008, P. Kaczensky unpubl. data). However, movement of the animals prior to detection frequently occurred as the majority of khulans and gazelles were detected running. Even when the animals were detected the moment the flight behaviour was initiated, the long observer distances made it impossible to use range finders, necessitating visual distance estimates. The long flight distances also forced observers to look far ahead of the transect line, which likely explains the heaping around zero ("guarding the line"; see Appendix **8**). The heaping around zero results in inflated population estimates if using the actual perpendicular distances. We correct for this effect by grouping distances in rather wide bins of 500m. However, if and how to bin the data results in widely differing population estimates and introduces another factor of uncertainty. Furthermore, survey team composition, season, weather condition, time of the day, and travel speed also varied in changing combinations within and among surveys.

The occurrence of very large groups in khulans is also problematic. A large group reduces the overall number of khulan groups, thus resulting in low and/or uneven encounter rates and increases variability in group sizes. Both variables negatively affect precision. Accuracy can also be affected, as missing a large group will likely result in underestimating the population. On the other end of the spectrum population estimates will likely be inflated when members of a large herd are encountered more than once (e.g. the group is counted twice, the group splits up and a subgroup is counted again, the group disintegrates and spreads out while the survey is ongoing).

Given the abovementioned constrains, we initiated a simultaneous count point in 2010, which produced rather robust estimates of 5,671 (95% CI = 3,611–8,907) wild asses and 5,909 (95% CI = 3762–9279) gazelles (Kaczensky *et al.* 2012, Ransom *et al.* 2012). The advantage of the simultaneous point count over the ground transects was that once the survey teams were stationed at their elevated vantage points, there was little further disturbance even allowing for multiple repeats. Consequently, only a small minority of animals was running and thus could be counted more precisely, from a better angle and with an inexpensive range finder (Ransom 2011). Furthermore, the point survey simultaneously covered half the study area, minimizing the risk of double counts. The down side of the point count is that the logistical effort and overall costs are much higher than for the ground transects (Kaczensky *et al.* 2012).

Future Prospects

To account for imperfect detections, line transect sampling has recently been coupled with Bayesian hierarchical modelling for analysing trends in animal abundance (Kéry *et al.* 2009, Moore and Barlow 2011). Since this approach allows including data uncertainty at all levels, it may be a useful tool to explore our data for trend analysis in khulan and gazelle abundance (Heckmann *et al.* in prep.). Furthermore, distribution data can be linked to habitat variables to develop habitat suitability models which in turn will help predict gazelle and khulan presence as well as identify seasonally important habitat features (Nandintsetseg *et al.* in prep.).

Although our individual surveys were poor measures of population abundance, they provided important baseline data on group sizes and species distribution and have potential for further analysis. The ground surveys are relatively inexpensive and thus can be conducted at short temporal intervals, allowing park staff and researchers to qualitatively assess environmental conditions throughout the SPA and engage with local people. We thus strongly recommend to continue the line transect surveys and back them up with point counts at 3-5 year intervals.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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Appendix 1. Average monthly temperatures based on hourly measurements (HOBO temperature logger, Hoskin Scientific Limited, Vancouver, Canada) at Takhin Tal research station at the NE edge of the Great Gobi B SPA in south-western Mongolia.

Season	Month	2003/4	2004/5	2005/6	2006/7	2007/8	2008/9	2009/10	2010/11	Mean
Spring	3		-11	-4	-7	-6	-1	-6	-14	-7
	4	14	6	5	3	6	4	8	-3	5
	5	10	12	11	10	12	13	11	9	11
Summer	6	19	17	16	17	17	19	15	18	17
	7	17	20	20	19	20	20	19	20	19
	8	15	16	17	18	17	18	16	17	17
Fall	9	11	9	11	11	12	11	11	12	11
	10	2	1	2	3	0	3	3	3	2
	11	-12	-10	-9	-5	-6	-9	-13	-8	-9
Winter	12	-19	-15	-18	-17	-14	-19	-21	-20	-18
	1	na	-18	-21	-20	-18	-21	-18	-23	-19
	2	na	-16	-21	-16	-12	-15	-18	-14	-16
Annual max.		31	35	32	35	33	32	31	34	
Annual min.		-37	-37	-44	-36	-33	-38	-41	-42	
Annual mean		na	1	1	1	3	2	1	0	

Appendix 2. Line transect surveys for khulans and goitered gazelles in Great Gobi B SPA in *south-western* Mongolia between 2003-2010. [grey = all park surveys].

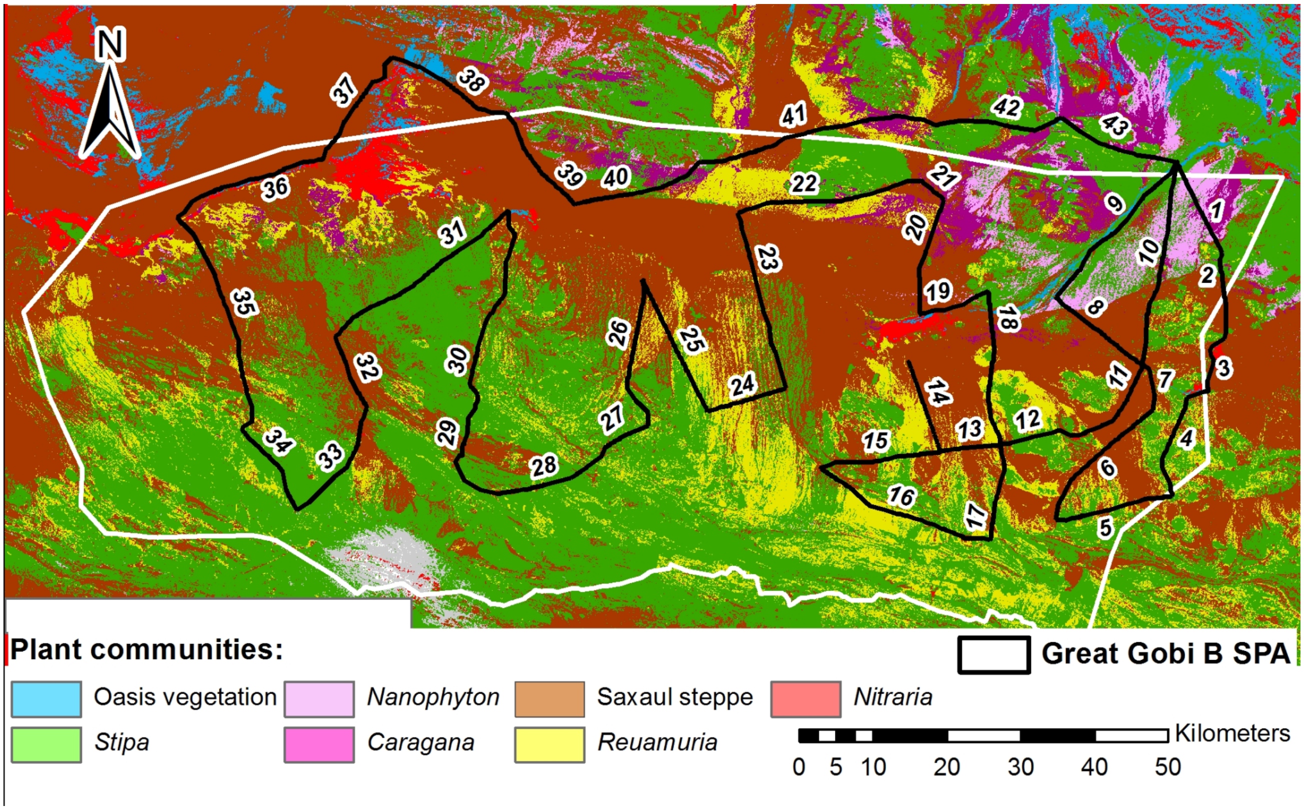
#	Date		Total effort (in km)	Groups encountered		Total number seen		DISTANCE estimate khulan					DISTANCE estimate gazelle					Comments
	from	to		khulan	gazelle	khulan	gazelle	N	%CV	df	95% CI		N	%CV	df	95% CI		
1	30.04.2003	01.05.2003	406	23	80	220	508	1,492	69.17	31.46	417	5,337	4,946	23.58	37.35	3087	7923	
2	26.05.2003	27.05.2003	343	10	78	31	246	205	42.13	27.87	89	469	2,981	28.46	33.6	1690	5257	
3	31.05.2003	01.06.2003	381	30	60	130	172	571	51.21	31.76	214	1,526	1,501	28.96	33.11	843	2674	
4	01.07.2003	02.07.2003	382	87	75	2693	287	6,992	36.06	68.58	3,481	14,047	2,670	19.1	43.07	1823	3911	
5	06.07.2003	08.07.2003	343	55	39	3299	239	10,284	46.74	73.23	4,241	24,938	2,037	25.86	40.21	1218	3406	
6	05.08.2003	06.08.2003	373	40	48	995	270	7,368	52.39	57.39	2,749	19,750	3,010	25.34	32.17	1811	5003	
7	06.09.2003	08.09.2003	382	10	29	65	195	297	65.48	16.78	84	1,047	1,846	38.56	29.71	863	3951	
8	06.10.2003	07.10.2003	388	9	9	289	41	1,025	95.78	11.37	175	6,012	440	50.86	28.86	165	1173	
9	20.10.2003	24.10.2003	692	49	60	1081	400	12,020	37.11	79.65	5,881	24,567	4,982	28.67	60.59	2840	8739	
10	24.03.2004	25.03.2004	357	1	11	1	145	8	101.11	21.04	1	46	1,690	59.04	30.61	554	5158	
11	15.04.2004	18.04.2004	996	40	88	2109	539	7,780	53.06	74.83	2,884	20,987	5,529	22.92	92.43	3528	8666	
12	16.05.2004	17.05.2004	357	48	90	520	305	4,165	52.05	28.12	1,528	11,353	2,817	23.1	28.48	1767	4493	
13	07.06.2004	08.06.2004	382	47	58	823	168	4,699	42.46	61.23	2,082	10,607	1,264	20.59	39.87	838	1909	
14	05.07.2004	06.07.2004	382	31	65	898	293	6,806	57.16	48.93	2,338	19,812	2,514	26.55	40.09	1483	4260	
15	08.08.2004	12.08.2004	731	70	78	909	327	7,419	34.32	97.8	3,826	14,388	4,290	22.61	61.78	2745	6703	
16	05.09.2004	07.09.2004	422	53	43	2230	265	15,103	51.51	74.52	5,745	39,701	2,613	26.17	37.14	1551	4401	
17	15.10.2004	20.10.2004	715	37	67	1668	463	6,080	45.47	70.44	2,561	14,434	5,065	29.95	58.09	2817	9106	
18	12.11.2004	16.11.2004	386	8	2	132	5	990	75.8	14.4	234	4,183	54	73.89	22.54	14	211	
19	10.12.2004	14.12.2004	772	22	67	797	329	7,913	50.71	49.01	3,026	20,692	4,731	29.97	50.74	2625	8524	
20	19.03.2005	21.03.2005	395	19	9	2132	174	15,642	59.54	35.5	5,116	47,827	1,394	14.72	24.24	236	8227	
21	27.04.2005	30.04.2005	754	38	88	598	430	6,120	43.8	79.75	2,659	14,087	4,217	22.63	65.88	2699	6588	
22	20.05.2005	21.05.2005	426	29	40	306	113	1,857	40.46	52.86	850	4,055	1,104	21.88	64.96	717	1701	
23	09.06.2005	13.06.2005	701	126	101	3754	296	41,320	39.56	162.99	19,459	87,740	4,652	24.85	108.67	2864	7556	
24	25.07.2005	27.07.2005	382	25	44	286	228	2,168	42.11	43.47	960	4,896	2,484	31.59	39.11	1332	4635	
25	20.08.2005	24.08.2005	806	54	78	765	542	7,325	49.16	93.06	2,908	18,450	7,460	24.97	73.51	4569	12178	
26	22.09.2005	23.09.2005	349	3	11	3	95	25	53.33	21.14	9	70	1,133	50.17	30.26	431	2982	
27	17.10.2005	20.10.2005	818	42	40	1077	443	8,808	46.3	80.8	3,665	21,168	6,010	49.79	52.98	2338	15444	

Appendix **2**. contd…

#	Date		Total effort (in km)	Groups encountered		Total number seen		DISTANCE estimate khulan					DISTANCE estimate gazelle					Comments
	from	to		khulan	gazelle	khulan	gazelle	N	%CV	df	95% CI		N	%CV	df	95% CI		
28	21.11.2005	23.11.2005	349	16		852		7,060	61.97	31.99	2,210	22,549	0					
29	19.12.2005	23.12.2005	628	14	45	752	225	9,251	50.96	31.44	3,474	24,632	3,979	45.52	38.99	1654	9571	
30	03.01.2006	05.01.2006	357	3		113		916	82.45	21.81	206	4,081	0					
31	20.03.2006	22.03.2006	367	6	32	426	495	3,363	65.92	18.69	955	11,842	5,617	40.02	32.33	2563	12313	
32	26.04.2006	29.04.2006	733	35	117	626	548	5,555	55.05	61.16	1,986	15,542	7,062	21.5	56.52	4614	10809	
33	16.05.2006	17.05.2006	357	2	50	4	223	32	85.1	7.17	6	184	2,598	28.48	32.55	1471	4586	
34	16.06.2006	18.06.2006	734	173	182	1567	479	9,722	29.35	58.16	5,469	17,283	6,001	16.44	57.43	4327	8320	
35	17.07.2006	21.07.2006	395	43	46	2967	177	21,756	45.41	51.94	9,124	51,875	1,638	28.02	27.79	932	2877	
36	12.08.2006	14.08.2006	755	60	99	1909	506	19,526	43.55	99.72	8,541	44,639	7,440	22.57	68.2	4769	11607	
37	27.09.2006	28.09.2006	356	15	27	614	152	4,994	58.63	26.13	1,634	15,261	1,777	38.42	45.43	842	3751	
38	22.10.2006	27.10.2006	741	41	54	1305	259	13,593	39.78	68.5	6,326	29,205	3,878	24.06	68.27	2416	6225	
39	28.11.2006	29.11.2006	~350	4	23	29	178											only group size & sighting distance
40	25.12.2006	28.12.2006	741	24	47	1072	252	11,167	40.64	48.33	5,089	24,504	3,773	38.02	73.21	1814	7848	
41	28.01.2007	30.01.2007	~350	8	3	312	65											only group size & sighting distance
42	23.02.2007	26.02.2007	824	22	24	636	509	5,581	62.92	51.26	1,751	17,791	6,856	36.02	63.06	3411	13779	
43	23.02.2007	25.02.2007	~350	15	35	163	307											only group size & sighting distance
44	22.04.2007	25.04.2007	749	27	90	984	573	10,145	58.99	66.05	3,407	30,207	7,130	18.99	88.09	4906	10365	
45	15.05.2007	16.05.2007	~350	8	44	110	227											only group size & sighting distance
46	17.06.2007	21.06.2007	830	53	97	2466	394	22,926	44.55	95.74	9,851	53,354	3,041	20.49	65.51	2028	4559	
47	16.07.2007	18.07.2007	~350	30	30	1057	130											only group size & sighting distance
48	14.08.2007	16.08.2007	~762	82	70	706	367											only group size & sighting distance - *track lost*
49	28.10.2007	31.10.2007	~762	19	12	265	137											only group size & sighting distance - *track lost*
50	27.11.2007	28.11.2007	~350	3	5	32	34											only group size & sighting distance

Appendix **2**. contd…

#	Date		Total effort (in km)	Groups encountered		Total number seen		DISTANCE estimate khulan					DISTANCE estimate gazelle					Comments
	from	to		khulan	gazelle	khulan	gazelle	N	%CV	df	95% CI		N	%CV	df	95% CI		
51	24.12.2007	27.12.2007	724	8	33	445	193	4,743	88.9	12.86	911	24,709	2,957	44.93	46.47	1248	7009	
52	26.01.2008	28.01.2008	~350	1	5	10	66											only group size & sighting distance - *track lost*
53	17.02.2008	19.02.2008	~762	19	24	1620	176											only group size & sighting distance - *all GPS data lost*
54	28.03.2008	29.03.2008	~350	8	36	158	378											only group size & sighting distance
55	16.04.2008	18.04.2008	749	18	77	1046	485	10,777	56.21	48.62	3,759	30,896	6,034	20.03	88.9	4069	8949	
56	24.05.2008	25.05.2008	~350	22	56	823	285											only group size & sighting distance
57	12.06.2008	13.06.2008	718	27	71	408	266	2,112	46.1	51.75	875	5,097	4,110	27.71	96.01	2395	7052	
58	19.07.2008	20.07.2008	~350	10	45	42	284											only group size & sighting distance
59	15.08.2008	18.08.2008	714	39	66	4096	426	24,193	63.78	65.6	7,534	77,687	5,757	29.46	55.21	3229	10264	
60	08.09.2008	09.09.2008	~350	16	38	3222	533											only group size & sighting distance
61	24.11.2008	26.11.2008	746	15	46	964	576	9,979	49.76	38.73	3,853	25,844	8,571	40.75	73.92	3925	18714	
62	05.12.2008	07.12.2008	610	11	26	311	141	1,707	68.44	20.19	469	6,214	2,564	40.71	41.61	1163	5652	
63	23.04.2009	25.04.2009	711	32	65	586	516	6,361	44.53	70.1	2,724	14,856	8,051	33.23	73.05	4224	15346	
64	13.05.2009	15.05.2009	744	34	89	697	673	7,235	47.66	65.51	2,932	17,857	9,235	27.03	67.48	5436	15691	
65	11.06.2009	13.06.2009	663	33	69	898	240	2,537	40.26	61.99	1,169	5,506	4,017	21.15	65.3	2645	6100	
66	27.07.2009	30.07.2009	735	27	133	463	694	4,850	39.33	62.64	2,273	10,350	8,798	20.68	59.02	5842	13249	
67	06.08.2009	08.08.2009	784	33	86	4577	682	45,040	61.9	42.22	14,272	142,140	8,264	24.18	54.79	5125	13326	
68	11.09.2009	14.09.2009	703	28	75	1063	539	11,675	53.15	46.43	4,279	31,854	8,509	23.48	65.04	5357	13517	
69	20.10.2009	23.10.2009	566	24	50	622	549	8,486	63.45	44.96	2,630	27,383	10,766	29.29	53.87	6056	19138	
70	12.08.2010	14.08.2010	750	56	65	1819	319	18,716	61.01	74.77	6,103	57,396	4,718	28.31	48.61	2700	8244	
71	28.10.2010	31.10.2010	882	27	33	757	253	3,316	49.12	53.77	1,306	8,424	2,825	32.21	68.56	1509	5287	
All	30.04.2003	31.10.2010	~39,672	2,197	3,778	71,405	22,029											



Appendix 3. Standard all park survey track consisting of 43 transects covering a total of 762 km.

Appendix 4. Percentage of main behaviour of the khulans and goitered gazelles observed during 71 line transect surveys in Great Gobi B SPA from 2003-2010.

Species	Main Behaviour of Animal / Group of Animals			
	Laying	Standing	Walking	Running
Gazelle	13	10	5	71
Khulan	22	16	5	57

Appendix 5. Proportion of young of the year in groups containing foals or fawns in Great Gobi B SPA from 2003-2010.

Year	Month	Adults		Foals/Fawns		% of Foals / Fawns		N Groups	
		Gazelle	Khulan	Gazelle	Khulan	Gazelle	Khulan	Gazelle	Khulan
2003	6	NA	NA	NA	NA	NA	NA	NA	NA
	7	184	2,226	81	643	0.31	0.22	42	26
	8	96	255	35	39	0.27	0.13	15	8
	9	38	31	13	8	0.25	0.21	9	3
	10	72	503	40	132	0.36	0.21	16	20
All 2003		*390*	*3015*	*169*	*822*	*0.30*	*0.21*	*82*	*57*

Appendix **5**. Contd…

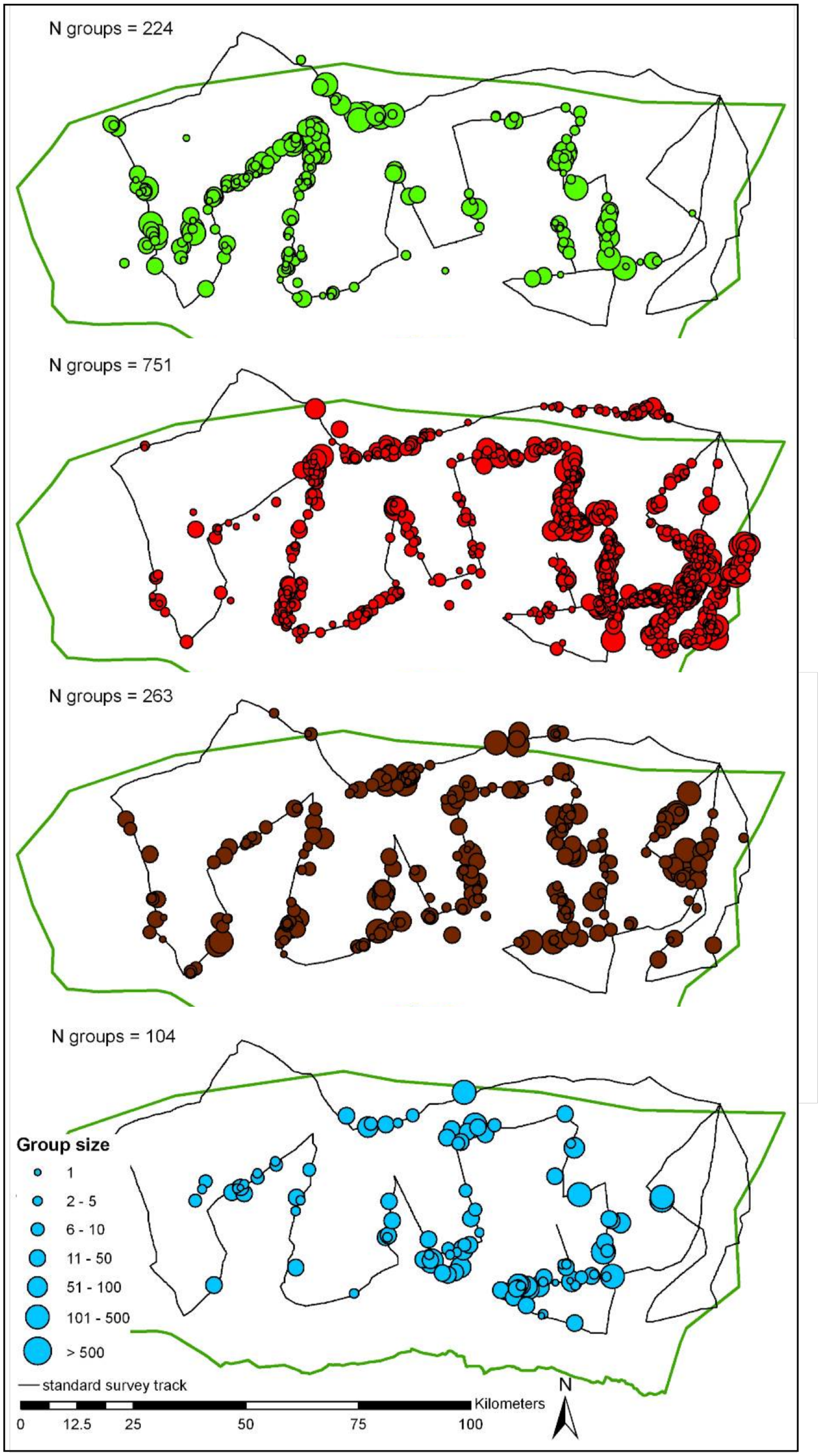
Year	Month	Adults		Foals/Fawns		% of Foals / Fawns		N Groups	
		Gazelle	Khulan	Gazelle	Khulan	Gazelle	Khulan	Gazelle	Khulan
2004	6	2	112	1	6	0.33	0.05	1	5
	7	99	14	61	7	0.38	0.33	28	4
	8	110	296	82	108	0.43	0.27	36	15
	9	31	927	16	321	0.34	0.26	9	11
	10	242	246	108	56	0.31	0.19	37	15
All 2004		*482*	*1483*	*267*	*492*	*0.36*	*0.25*	*110*	*45*
2005	6	---	642	---	56	---	0.08	0	6
	7	91	125	46	50	0.34	0.29	18	11
	8	164	283	56	50	0.25	0.15	24	13
	9	33	---	18	---	---	---	7	0
	10	96	30	30	9	0.24	0.23	5	4
All 2005		*384*	*438*	*150*	*109*	*0.28*	*0.20*	*54*	*28*
2006	6	30	307	16	22	0.35	0.07	10	9
	7	57	1,382	54	383	0.49	0.22	26	19
	8	191	228	133	96	0.41	0.30	54	12
	9	11	43	8	22	0.42	0.34	5	4
	10	75	340	51	125	0.40	0.27	27	14
All 2006		*334*	*1993*	*246*	*626*	*0.42*	*0.24*	*112*	*49*
2007	6	112	2,142	42	234	0.27	0.10	18	21
	7	58	43	35	8	0.38	0.16	13	3
	8	164	133	81	35	0.33	0.21	39	15
	9	NA	NA	NA	NA	NA	NA	NA	NA
	10	70	192	10	37	0.13	0.16	4	9
All 2007		*292*	*368*	*126*	*80*	*0.30*	*0.18*	*56*	*27*
2008	6	51	20	5	3	0.09	0.13	3	3
	7	24	---	6	---	---	---	3	0
	8	79	1,278	31	260	0.28	0.17	17	5
	9	160	2,523	53	643	0.25	0.20	6	11
	10	NA	NA	NA	NA	NA	NA	NA	NA
All 2008		*263*	*3801*	*90*	*903*	*0.25*	*0.19*	*26*	*16*

Appendix **5**. Contd…

Year	Month	Adults		Foals/Fawns		% of Foals / Fawns		N Groups	
		Gazelle	Khulan	Gazelle	Khulan	Gazelle	Khulan	Gazelle	Khulan
2009	6	11	546	8	211	0.42	0.28	4	5
	7	268	121	173	33	0.39	0.21	65	3
	8	192	31	150	15	0.44	0.33	55	6
	9	225	733	90	173	0.29	0.19	32	7
	10	136	466	79	85	0.37	0.15	9	12
All 2009		*821*	*1351*	*492*	*306*	*0.37*	*0.18*	*161*	*28*
2010	6	NA	NA	NA	NA	NA	NA	NA	NA
	7	NA	NA	NA	NA	NA	NA	NA	NA
	8	99	115	63	22	0.39	0.16	32	5
	9	NA	NA	NA	NA	NA	NA	NA	NA
	10	21	98	10	21	0.32	0.18	6	4
All 2010		*120*	*213*	*73*	*43*	*0.38*	*0.17*	*38*	*9*
All years		3086	12662	1613	3381	0.34	0.21	639	259

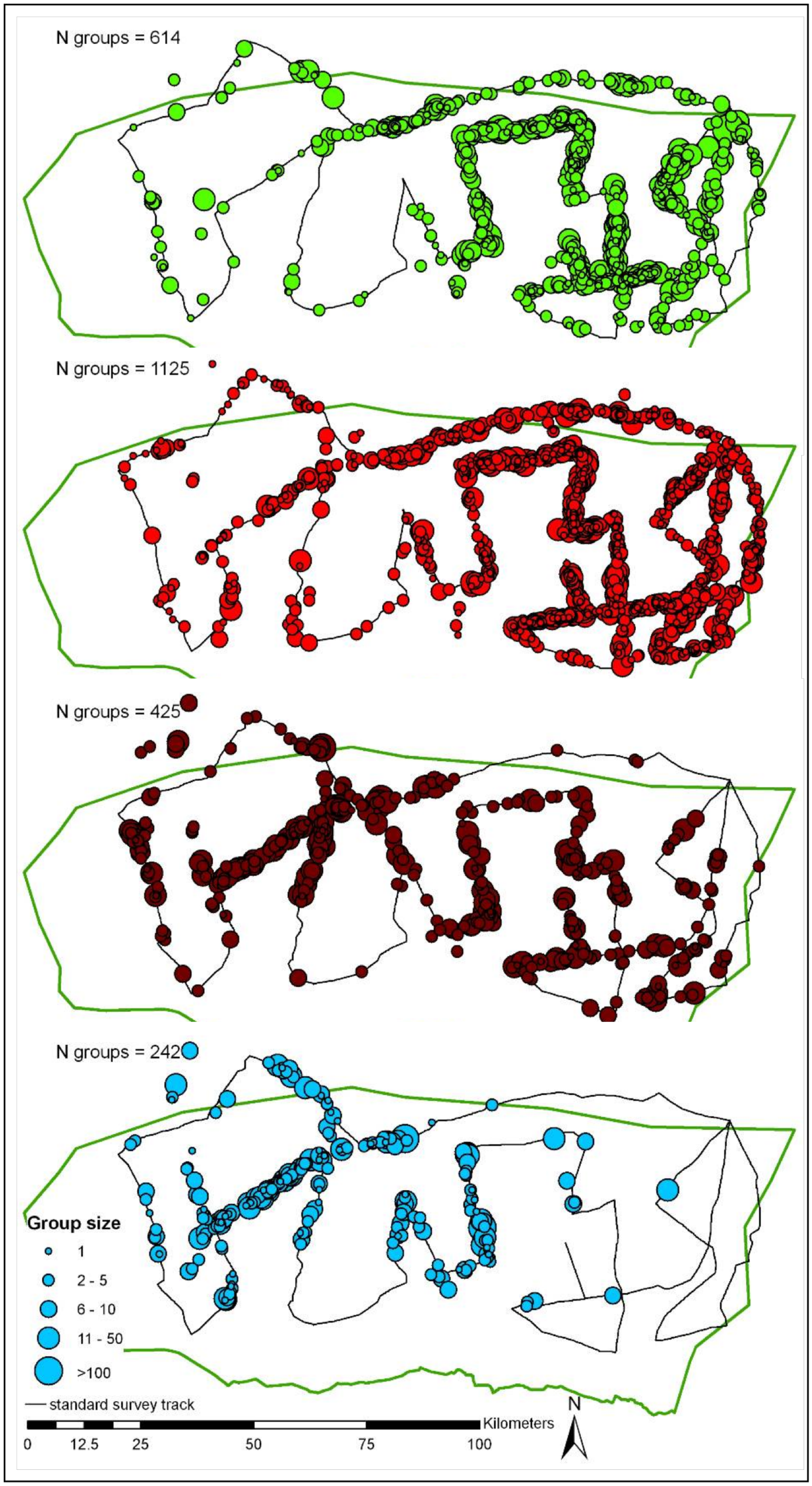
Appendix 6. Observations of very large groups of khulans and large groups of gazelles in Great Gobi B SPA from 2003-2010.

Khulan			Gazelle		
Date	Season	Group size	Date	Season	Group Size
01.07.2003	summer	850	25.03.2004	spring	60
06.07.2003	summer	802	19.10.2004	fall	64
08.07.2003	summer	735	22.03.2006	spring	78
18.04.2004	spring	634	23.02.2007	winter	73
07.09.2004	fall	900	24.02.2007	winter	73
16.10.2004	fall	600	23.04.2007	spring	100
11.06.2005	summer	650	26.11.2008	fall	111
11.06.2005	summer	1,000	26.11.2008	fall	75
19.06.2007	summer	600	26.11.2008	fall	62
15.08.2008	summer	1,200	24.04.2009	spring	81
15.08.2008	summer	1,200	14.05.2009	spring	66
11.06.2009	summer	700	23.10.2009	fall	60
07.08.2009	summer	2,110			
07.08.2009	summer	1,500			
07.08.2009	summer	800			
13.08.2010	summer	1,000			



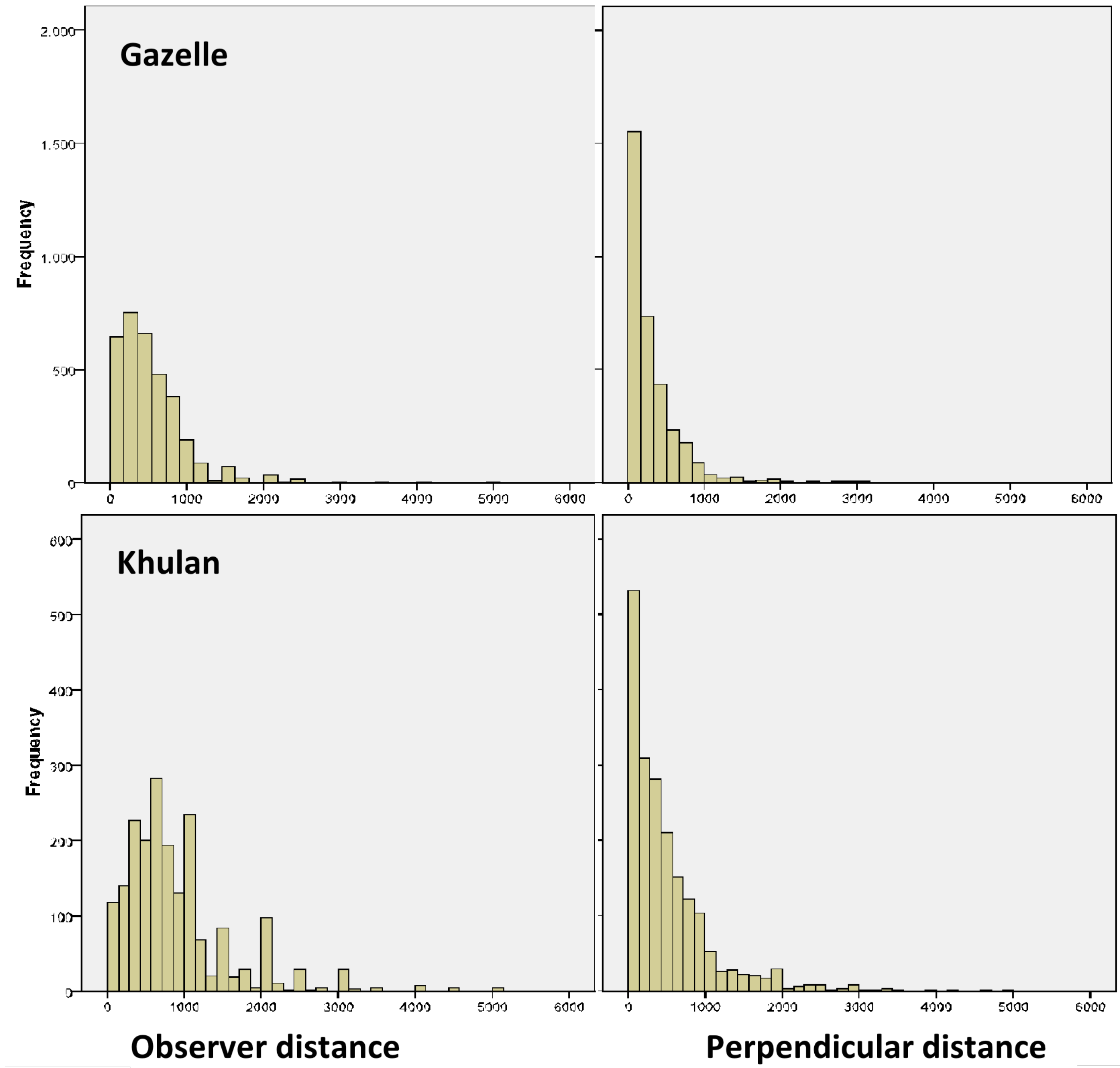
A) Seasonal distribution of all wild ass observations in Great Gobi B SPA from 2003-2010.

Appendix **7**. contd…



B) *Seasonal distribution of all gazelle observations in Great Gobi B SPA from 2003-2010.*

Appendix 7:



Appendix 8. Observer and perpendicular distances in goitered gazelles and khulans in Great Gobi B SPA from 2003-2010.

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