

Status and distribution of khulan (*Equus hemionus*) in Mongolia

Richard P. Reading¹*, Henry M. Mix², Badamjaviin Lhagvasuren³, Claudia Feh⁴, David P. Kane¹, S. Dulamtseren¹ and Sumyain Enkhbold⁵

¹ Denver Zoological Foundation and University of Denver, 2900 East 23rd Avenue, Denver, CO 80205, U.S.A.

² Naturschutz International, Schulzenweg 1, 15345 Möllensee, Germany

³ Mongolian Academy of Sciences, Institute of Biology, Ulaanbaatar – 51, Mongolia

⁴ Station Biologique de la Tour du Valat, Le Sambuc, 13200 Arles, France

⁵ Mongolian National University, Department of Zoology, Ulaanbaatar, Mongolia

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Abstract

The Asiatic wild ass *Equus hemionus*, or khulan, once ranged across much of Central Asia, but is now globally threatened. The largest free-ranging populations are now restricted to a 250-km wide area (range 100–400 km) across the Gobi Desert region of southern Mongolia. Over the last 23 years the population has moved further north and east into its former range. Surveys conducted in the 1970s and 1980s estimated that the Mongolian population contained fewer than 15 000 animals and was declining as a result of human exploitation and livestock competition. Aerial surveys (one in autumn 1994, two in spring 1997) were flown as line transects over portions of the khulan's range in Mongolia and ground surveys (five in spring, summer, and autumn 1994–97) were conducted by vehicle and foot. Sample sizes and areas surveyed were larger than previous surveys, and our methods were often more systematic. Population size was estimated at 33 000–63 000 wild asses in Mongolia. Animal density ranged from 4.2 ± 1.3 to 19.1 ± 3.2 per 100 km². Mean group size ranged from four to 35 animals in the south-western Gobi, four to seven animals in the southern Gobi, and three to 18 in the south-eastern Gobi. Our data suggest that Mongolia is the most important stronghold for the conservation of *E. hemionus*. Conservation management continues to be challenging because intensive studies on khulan biology and ecology are just beginning. As a free-market economy continues to emerge in Mongolia, pressure from resource extraction interests and nomadic livestock herders to remove the khulan's protected status, permit harvesting and halt population growth and expansion, also makes implementation of research and conservation management programs more imperative.

Key words: Gobi, *Equus hemionus*, Khulan, Mongolia, wild ass

INTRODUCTION

Mongolia represents one of the last strongholds for Asian wild asses *Equus hemionus*, a wide ranging species that inhabits the Middle East (*E. h. onager*), Central Asia (*E. h. kulan*), parts of India (*E. h. khur*), and the Gobi Desert of China and Mongolia. Taxonomic status of the Gobi subspecies of wild ass, or khulan, remains unclear, with some authors referring to it as *E. h. luteus* (IUCN, 1996; Wang & Schaller, 1996) and others as *E. h. hemionus* (Shagdarsuren *et al.*, 1987; Reading, Sumya *et al.*, 1994; Shirevdamba *et al.*, 1997; Denzau & Denzau, 1999; Feh, Munkhtuya *et al.*, in press).

Asian wild asses in Mongolia are referred to as 'khulan' by Mongolians (not to be confused with the 'kulan' of the central Asian republics) and as 'dziggetai' by Russians. Khulan are listed as rare in the Mongolian Red Book (Shirevdamba *et al.*, 1997) and protected as rare animals under the Mongolian Hunting Law of 1995 (Wingard, 1996). A globally threatened species, *E. hemionus* is also included in appendix I of the Convention on the International Trade of Endangered Species of Flora and Fauna (CITES) and listed as 'vulnerable' by the World Conservation Union (IUCN, 1996). The *E. h. luteus* subspecies is listed as 'data deficient' in China and Mongolia (IUCN, 1996). Similarly, the IUCN's Equid Specialist Group records the khulan as 'insufficiently known' (Duncan, 1992).

*All correspondence to: R. P. Reading.
E-mail: zooresearch@denverzoo.org

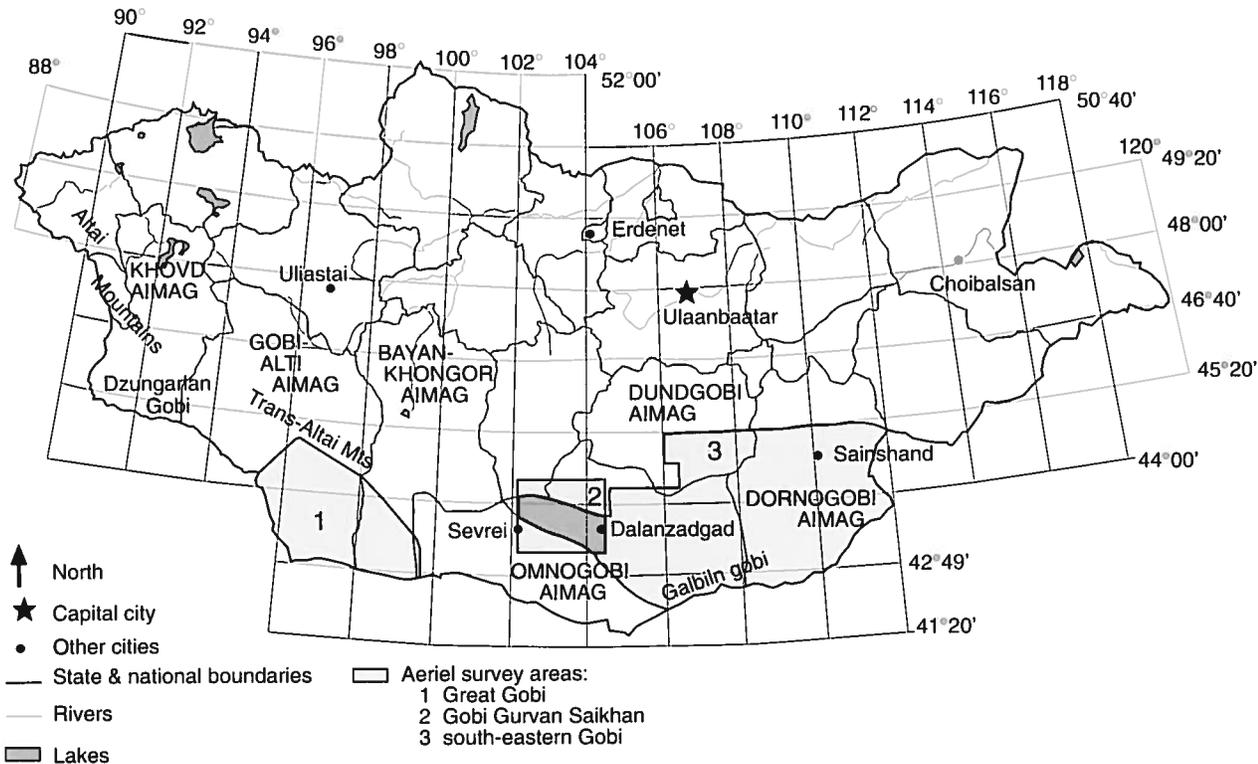


Fig. 1. Aerial survey areas for khulan *Equus hemionus* in Mongolia.

Status and distribution of khulan

Until the mid-1800s, khulan were distributed across most of Mongolia, small parts of Siberia and Manchuria, western Inner Mongolia, and northern Xinjiang (Harper, 1945). Reports from expeditions to the region in the late 1800s and early 1900s suggest that the khulan range was contracting, such that by 1938 wild asses could no longer be found in north-eastern Mongolia, where the holotype for the species was found (Harper, 1945). Andrews (1932) made expeditions to the Gobi in 1922 and 1925, reporting high densities near Lake Tsagaan Nuur (45°20'N, 101°30'E) and no sightings east of the Gurvan Saikhan Mountains (43°30'N, 104°E) (Fig. 1). Bannikov (1961) summarized the results of Russian expeditions for the same period and estimated that their range extended to 48°N and 108°E. He estimated a total population of 'tens of thousands' of khulan in the 1940s.

Today, khulan are distributed throughout the Gobi region of southern Mongolia. This area includes the southern portions of Khovd, Gobi-Altai, Bayankhongor, and Dundgobi *Aimags*, or provinces, as well as southern and eastern Omnogobi *Aimag* and southern and western Dornogobi *Aimag* (Figs 1 & 2). Relatively large numbers of khulan have been located in this desert and semi-desert region (Zhirnov & Ilyinsky, 1986; Mix, Reading & Lhagvasuren 1995, 1997; Wang & Schaller, 1996; Feh, Munkhtuya *et al.*, in press). Recent field research and surveys suggest that these populations may, however, be increasing and expanding further

northward into the semi-desert steppe zones, especially in the eastern portion of its range (Mix *et al.*, 1995). Khulan are rare in adjacent areas of China, especially Inner Mongolia, where the population is probably sustained only by migration from Mongolia (Wolfe, 1979; Gao & Gu, 1989; Wang & Schaller, 1996).

Most of the limited research on khulan has focused on behavioural ecology or systematics (Bannikov, 1971, 1975; Wolfe, 1979; Munkhsaikhan *et al.*, 1989; Feh, Boldsukh & Tourenq, 1994). Fewer assessments of khulan status and distribution have been conducted. Previous researchers estimated variable numbers of khulan in Mongolia (see Zhirnov & Ilyinsky, 1986), including 4000–15000 in the 1970s (Sokolov *et al.*, 1978; Shiirevdamba *et al.*, 1997) and 6000–15 000 in the 1980s (Bannikov, 1981; Zhirnov & Ilyinsky, 1986). These earlier estimates were based on surveys from relatively limited portions of the range of khulan in Mongolia. In particular, little to no research or surveys were conducted in the south-eastern Gobi, a particularly important portion of the range of the species.

Recently some surveys have been conducted to assess the current population size and distribution of khulan in Mongolia (Mix *et al.*, 1995, 1997; Reading, Mix, Lhagvasuren & Blumer, 1999; Reading, Amgalanbaatar & Lhagvasuren, 1999; Feh, Munkhtuya *et al.*, in press). From 1994 to 1997, three aerial surveys were conducted over *c.* two-thirds of the range of khulan. In addition, several ground surveys were performed for large ungulates in portions of Gobi-Altai, Bayankhongor, Omnogobi, Dundgobi, and Dornogobi *Aimags*.

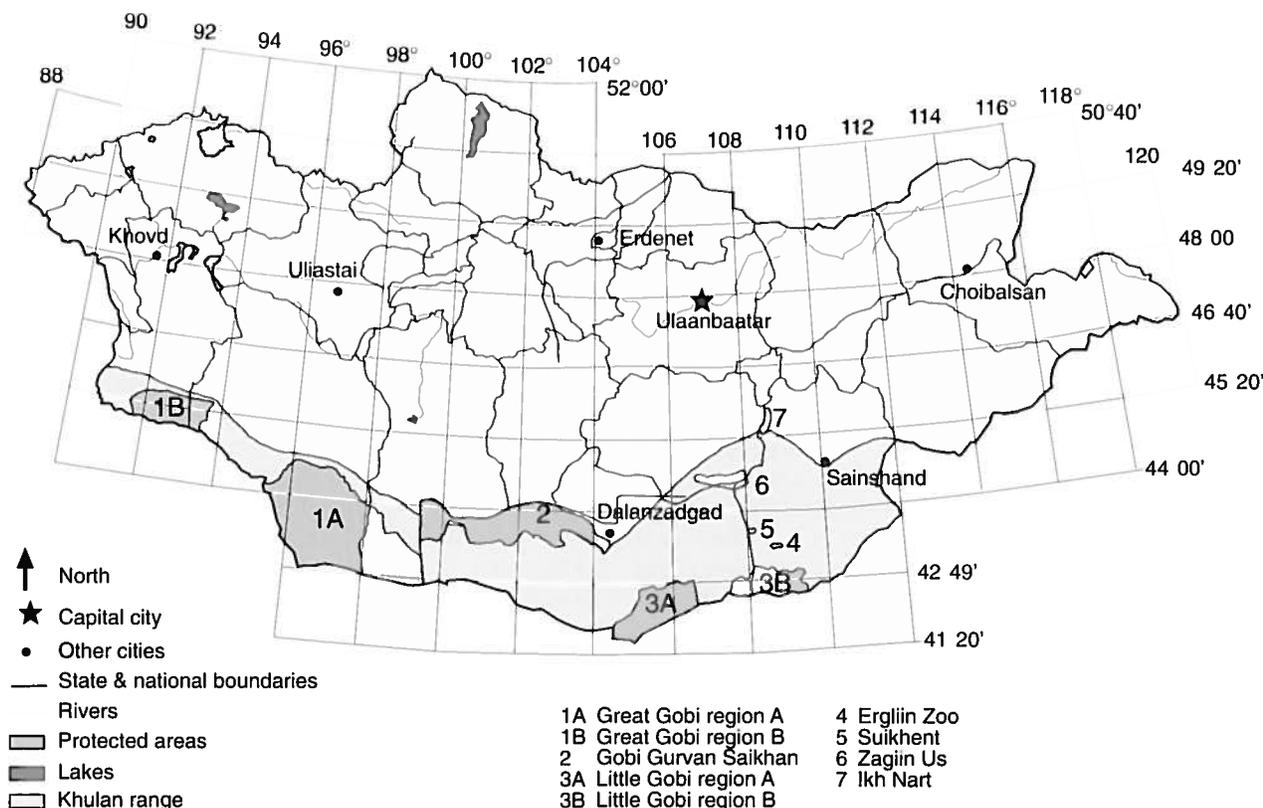


Fig. 2. Distribution of khulan *Equus hemionus* in Mongolia.

STUDY AREA

The study area included the portions of Khovd, Gobi-Altai, Bayankhongor, Dundgobi, Omnogobi, and Dornogobi *Aimags* and varies from true desert through semi-desert to Gobi-steppe (Zhirnov & Ilyinsky, 1986; Figs 1 & 2). The flora and fauna are representative of the arid regions of Central Asia. The region is characterized as a high upland (c. 1000 m) with dry streambeds and hummocks, rocky outcrops, and mountain massifs rising to >2000 m above the surrounding landscape. Springs and other water sources are rare. Climate is strongly continental and arid, characterized by cold winters (to -35°C), dry, windy springs (to 5 m/s), and relatively wet, hot summers (to 40°C). Precipitation in the Gobi is low, for example averaging 100 mm/year in Great Gobi region B, 127.2 mm/year in Omnogobi *Aimag* and 116.7 mm/year in Dornogobi *Aimag*.

Vegetation is sparse, especially in the southern regions, and generally increases northward. Fine-leaved grasses and onions dominate vegetation of the Gobi-steppe. Dominant plants include *Stipa klemenzi*, *S. gobica*, *Salsola passerina*, *Thymus gobica*, *Cleistogenes squarrosa*, *Ajania fructiculosa*, *Artemisia frigida*, and *A. rutifolia*. The semi-desert regions are characterized by semi-shrubs, shrubs, and some grasses, including *A. fructiculosa*, *S. gobica*, *S. glareosa*, *Caragana korshinskii*, *C. pygmaea*, *Scorzonera capito*, *Lagochilus ilicifolius*, *A. frigida*, and *Haloxydon ammodendron*. The true Gobi desert contains little vegetation. Semi-shrubs, shrubs,

and scrub vegetation dominate, including *Zygophyllum xanthoxylon*, *S. passerina*, *Anabasis brevifolia*, *Caragana leucophloea*, and *H. ammodendron*. Oases support the greatest density of vegetation in the region, and are dominated by *Phragmites communis*, *Juncus* spp. and *Achnatherum splendens*. For more detail see Zhirnov & Ilyinsky (1986).

METHODS

To assess the status of khulan throughout Mongolia recently collected data from a variety of sources were reviewed. We collected most of these data, some of which are published elsewhere (Mix *et al.*, 1995; Reading, Amgalanbaatar & Lhagvasuren, 1999; Reading, Mix, Lhagvasuren & Blumer, 1999; Feh, Munkhtuya *et al.*, in press). Other data are being presented here for the first time, and still other researchers collected additional data (Wang & Schaller, 1996).

We conducted 3 aerial surveys over portions of the khulan's range in Mongolia in 1994 and 1997. We followed the guidelines proposed by Burnham, Anderson & Laake (1980) for conducting line transect surveys as modified by Reading, Amgalanbaatar, Mix & Lhagvasuren (1997). Soviet AN-2 biplanes were flown in straight, parallel transects at c. 100 m above the ground. Navigation was conducted using a global positioning system (GPS), compass bearings, and landscape features. One national biologist was responsible for

assisting the 2 pilots in accurate navigation. To compensate for the relatively fast air speed (mean = 170 km/h), 2–4 observers were placed on either side of the plane. In addition, the navigating expert often located animals. One person took still and video camera photographs for later data correction. Data collected included species, group size, perpendicular distance from the transect line, time of the sighting, weather, observer, and the observer's location in the plane. Observers estimated perpendicular distances by using markings on the wings as guides. Sometimes animals moved before detection, possibly introducing a source of bias into our estimate (Burnham *et al.*, 1980).

Survey 1 was conducted using 2 planes from 22 to 25 and 27 October (Mix *et al.*, 1995). The survey included the south-eastern third of Dundgobi *Aimag*, the central and eastern parts of Omnogobi *Aimag*, and the southern three-fourths of Dornogobi *Aimag* (Fig. 1). Data were stratified by ecological zone and *Aimag*. Transects ran north to south and were separated by *c.* 40 km (although distance varied somewhat for logistic reasons, such as refuelling). We flew from 10:00–12:45 and then 14:00–16:30 on the first day using 2 aircraft, 09:20–12:00 on the second day using 1 aircraft, 09:45–12:00 and then 14:00–17:00 on the third day using 2 aircraft, 10:00–14:00 on the fourth day using 2 aircraft in the morning (1 plane until 11:30), and 09:00–11:45 on the fifth day using 2 aircraft.

Survey 2 was conducted using 1 plane from 2 to 6 March 1997 over region A of Great Gobi Strictly Protected Area (Reading, Mix, Lhagvasuren & Blumer, 1999; Fig. 1). Transects ran north to south and were separated by *c.* 15 km. We conducted surveys from 09:12 to 11:40 and 14:16–18:24 on 2 March, 08:49–11:21 and 13:39–15:39 on 3 March, 08:46–11:15 on 4 March, and 09:54–12:50 on 6 March.

Survey 3 was conducted using 1 plane from 12 to 15 March 1997 over Gobi Gurvan Saikhan National Park and the surrounding area (Reading, Amgalanbaatar & Lhagvasuren, 1999; Fig. 1). Transects ran east to west and were separated by *c.* 15 km. Unfortunately, strong winds forced the plane to deviate northward during a portion of the survey. As a result, 2 portions of the survey area were slightly under-sampled. Surveys were conducted from 09:00 to 10:45 on 12 March, 09:15–12:45 and 13:30–14:40 on 13 March, and 09:30–10:40 on 15 March.

Large mammal density, group density, and population size was estimated using the interactive computer program Distance (Burnham *et al.*, 1980). To obtain an estimate that accurately modelled the data, we were required to pool data into the following distance classes based on the distribution of sightings by distance for Survey 2: 0–100 m, 101–200 m, 201–500 m, 501–750 m, 751–1000 m, 1001–2500 m. We allowed the program to select among a variety of possible estimators, including half normal, negative exponential, hazard-rate, and uniform models based on minimum Akaike information criterion ($-2 \ln \text{likelihood} + 2m$, where m = the number of parameters). We selected estimators whose prob-

ability detection function model was not significantly different from the distribution of actual observations using a χ^2 goodness-of-fit test (Burnham *et al.*, 1980). The robustness of some of our density and population estimates was examined by excluding large portions of the survey area that did not have animal sightings (primarily in the north) and remodelling our data. Estimates using different survey areas and sampling effort varied by <0.5%. Results are presented as \pm standard error of the mean (se).

Ground surveys were conducted in: (1) Great Gobi region B of southern Gobi-Altai and Khovd *Aimags* each year from 1994 to 1996 (Feh, Munkhtuya *et al.*, in press); (2) Omnogobi, Dornogobi, and Dundgobi *Aimags* in August 1994; (3) Omnogobi *Aimag* in September and November 1995 (Reading, Amgalabaatar & Lhagvasuren, 1999); (4) Omnogobi *Aimag* in May and June 1996 (Reading, Amgalabaatar & Lhagvasuren, 1999); (5) Omnogobi, Dornogobi, and Dundgobi *Aimags* in October 1997. For the first ground survey, total counts were made by travelling 318 km on 2–3 consecutive days each study period (June 1994, October 1995, and October 1996), stopping at the same locations each study period, climbing hills, and scanning the surrounding terrain with a spotting scope. The selected locations permitted complete coverage of Great Gobi region B, and it was often possible to count khulan and recognize foals up to a distance of 10 km. All other ground surveys were made by traversing large areas by vehicle or on foot searching for khulan. Positive identification of all khulan was made using binoculars and a spotting scope and where possible adult-foal classification of all animals observed was recorded. For the second ground survey only, data were also collected on the distance of khulan groups from the survey line for a 450 km section of the 1004 km survey route, permitting population estimation using the Distance program.

The khulan's range in Mongolia was determined by plotting all sightings made by our Mongolian colleagues or by us during 1994–97. Sighting locations were recorded with a GPS or plotted on topographic maps. Interviews with local people were used to validate our findings. The probable distribution of khulan was plotted based on locations and geographic features that were considered barriers to dispersal (e.g. large mountain ranges). Because we could not be sure that khulan did not range beyond the distribution we plotted, our distribution should be viewed as conservative.

RESULTS

South-western Gobi: Great Gobi Strictly Protected Area and surrounding regions

The range of khulan in south-western Mongolia extends from region A of Great Gobi Strictly Protected Area across southern Mongolia to region B in the Dzungarian Gobi. Khulan in these areas are distributed south of the Altai and Trans-Altai Mountains (Fig. 2).

Table 1. Number of khulan *Equus hemionus*, groups, mean (\pm SE) group sizes, and animals/100 km observed in different regions of the Gobi Desert of Mongolia

Survey Type	Date	No. of animals	No. of groups	Mean group size \pm SE (median)	No. of khulan seen/100 km
Great Gobi's region A					
Air	Mar 1997	155	34	4.32 \pm 0.66 (3)	9.1
Great Gobi's region B					
Ground	Jun 1994	1397	74	19.53 \pm 11.68 (3)	4.5
Ground	Oct 1995	1486	47	33.94 \pm 8.72 (8)	5.0
Ground	Oct 1996	1506	43	35.02 \pm 14.17 (8)	4.7
Gobi Gurvan Saikhan					
Ground	Sep–Nov 1995	61	9	6.78 \pm 1.99 (4)	3.7
Ground	May–Jun 1996	18	4	4.50 \pm 1.19 (5.5)	1.2
Air	Mar 1997	35	5	7.00 \pm 2.49 (6)	3.4
South-eastern Gobi					
Ground	Aug 1994	287	84	3.41 \pm 0.64 (2)	28.6
Air	Oct 1994	2530	139	18.20 \pm 5.36 ^a (6)	55.6
Ground	Oct 1997	1744	125	13.95 \pm 1.86 (6)	122.1

^a Mean group size drops to 13.3 \pm 2.09 khulan/group if a single group of 700 animals is excluded.

Khulan are scattered throughout Great Gobi Strictly Protected Area and surrounding regions, but are densely distributed and slightly more numerous in region B and the north of region A.

During the aerial survey of Great Gobi's region A in winter 1997, 155 khulan were observed in 34 groups, for a mean group size of 4.3 \pm 0.7 khulan/group (Table 1). Group size ranged from one to 18 animals/group. Four of these groups were observed while flying to and from the survey area (north of the survey area) and were therefore not included during population size and density estimation. The estimated density of khulan in Great Gobi A was 4.2 \pm 1.3 animals/100 km² and 2.2 \pm 0.6 groups/100 km² (Table 2). The population estimate for that section of the park was therefore 1674 \pm 506 animals (95% confidence limit = 926–3025 khulan).

Ground surveys in Great Gobi's region B counted 1445 (74 groups), 1595 (47 groups), and 1506 (43 groups) khulan in 1994, 1995, and 1996, respectively (Table 1). Therefore, an average of 1515.3 \pm 43.6 khulan inhabited the 8810 km² of Great Gobi B in the mid-1990s, yielding a mean density of 17.2 \pm 0.5 animals/100 km² (Table 2). Mean group size varied from 19.53 \pm 11.68 to 35.02 \pm 14.17 animals (range one to 850 animals).

We estimate that between 3500 and 5000 khulan inhabit the desert and semi-desert areas of Mongolia west of, and including, Great Gobi A.

Southern Gobi: Gobi Gurvan Saikhan National Conservation Park and surrounding areas

Few khulan were sighted in the southern Gobi in and around Gobi Gurvan Saikhan National Conservation Park. We conducted two ground surveys and one aerial survey in this region. Nine groups (0.5 herd/100 km) with 61 animals (3.7 animals/100 km) were sighted during roadside count surveys in 1995 and 18 khulan

(1.2 animals/100 km) in four groups (0.3 groups/100 km) were sighted in 1996. During an aerial survey in winter 1997, 35 khulan were sighted in five groups. Mean khulan group size was 6.8 \pm 2 animals/group in 1995, 4.5 \pm 1.2 animals/group in 1996, and 7 \pm 2.5 animals/group in 1997 (Table 1). During all of these surveys, only two groups (six animals and one animal) were sighted within park boundaries, both in 1996, in the mouth of a valley in the north-central Zoolongiin Mountains. The remainder were sighted outside park boundaries in the desert–steppe area south of the Zoolongiin Mountains. According to local people, khulan use areas of the park near Sevrei during the summer.

The area south of Gobi Gurvan Saikhan Park to the Chinese border and west of the park to Great Gobi is the area least surveyed for large ungulates. We have flown and driven only a small portion of this region. These surveys, on the edges of the khulan range, suggest that khulan densities are relatively low in the southern Gobi, perhaps on the order of that found in Great Gobi A (~4 khulan/100 km²; Table 2). We therefore roughly extrapolated using these densities to estimate that 1000–2500 khulan inhabit the South Gobi from the eastern boundary of Gobi Gurvan Saikhan to the eastern boundary of Great Gobi. Khulan in this region range from the southern portion of Gobi Gurvan Saikhan to the Mongolian border with China (Fig. 2).

South-eastern Gobi

Our most rigorous and reliable population estimates for khulan come from the south-eastern Gobi where two ground surveys were conducted. In August 1994 we surveyed the Galbiin Gobi of southern Omnogobi and Dornogobi *Aimags*. This depression is an important khulan foaling area. During 1004 km of driving 287 animals, or 28.6 khulan/100 km, were observed in 84 groups. Mean group size was 3.4 \pm 0.6 (range = one to 47; Table 1). The Distance program was used to

Table 2. Khulan *Equus hemionus* population size and density estimates (\pm SE) in the Gobi Desert of Mongolia

Variable	Great Gobi A	Great Gobi B	South-eastern Gobi	
			Ground survey	Aerial survey
Year	1997	1994–96	1994	1994
Area surveyed (km ²)	39 865	8810	6000	209 000
Distance travelled (km)	1700	318	450	4552.5
Number of groups	32	43–74	61	139
Animal density/100 km ²	4.20 \pm 1.27	17.20 \pm 0.49	17.94 \pm 4.14	19.13 \pm 3.20
Group density/100 km ²	2.18 \pm 0.57	0.62 \pm 0.11	8.23 \pm 1.62	1.64 \pm 0.17
Population estimate	1674 \pm 506	1515 \pm 44	1076 \pm 248	39991 \pm 6697
Estimation method	Distance ^a	Total count	Distance ^a	Distance ^a
Model ^b	Negative exponential	N/A	Negative exponential	Hazard rate
Significance ^c	$P=0.92$	N/A	$P=0.66-0.79$	$P=0.15-0.23$

^a Survey data modelled using the Distance program to estimate densities and numbers (see Burnham *et al.*, 1980).

^b Sightings models selected by the Distance program included the hazard rate key model: $k(y) = 1 - \exp(-y/A(1))^{**} - A(2)$, where k = no. of samples, y = distance, and $A(i)$ = the i -th parameter in the estimated probability density function; and the negative exponential model: $k(y) = \exp(-y/A(1))$, where k , y , and $A(i)$ are as above.

^c Significance measurements are for χ^2 tests of actual data vs the Distance program's modelled curve. Better models have lower χ^2 values, and thus higher P -values (i.e. actual data and modelled curves are not significantly different). Ranges of P -values are provided for models that permitted data to be grouped into several different categories.

estimate khulan densities for the 450-km portion of the survey during which data were collected on the distance of khulan groups from the survey line ($n=61$ groups). Estimated densities were 17.9 \pm 4.1 khulan/100 km² and 8.2 \pm 1.6 groups/100 km² (Table 2). In October, 1997 we surveyed portions of the Borzongiin, Galbiin, Ooshiin, and Dolooddin regions of the Gobi, and adjacent areas to the north in Omnogobi, Dornogobi, and Dundgobi *Aimags*. We sighted 1744 khulan in 125 groups during 1428 km of survey work, or 122.1 khulan/100 km (Table 1). Mean group size was 13.9 \pm 1.9 (range one to 140; Table 1). The number of young were counted for 50 groups. These groups averaged 8.9 \pm 1.3 adults (444 total) and 2.4 \pm 0.3 young (118 total) per group, or 21.0% young. We were unable to distinguish between males and females for most animals sighted.

In August 1994, Wang & Schaller (1996) conducted a ground survey of large ungulates in Dundgobi, Omnogobi, and Dornogobi *Aimags* of the south-eastern Gobi. They sighted 1400 khulan (including one group of 400+ animals) during 2700 km of driving, or 51.9 khulan/100 km. The frequency of sighting drops to 37 khulan/100 km if the herd of 400 is excluded; a sighting frequency similar to that found during our first ground survey.

Ground survey results compare favourably with results from an aerial survey conducted in 1994. In autumn 1994, an aerial survey was made over the entire south-eastern Gobi (from east of Gobi Gurvan Saikhan National Conservation Park). During the aerial survey, 2530 khulan were seen in 139 groups during 4552.5 km of flying over 20.9 million ha. Mean group size was 18.20 \pm 5.36 khulan/group (range one to 700), although it drops to 13.26 \pm 2.09 khulan/group (range one to 200) if we exclude the large group of 700 (Table 1).

Khulan densities were estimated by modelling the aerial survey data, but without using the group of 700 khulan (which were added to the results of the model-

ling). We found 19.1 \pm 3.2 animals/100 km² and 1.6 \pm 0.2 groups/100 km² for the entire south-eastern Gobi (Table 2). Since most khulan were concentrated in the southern portion of their range, data were also examined for the southern 11.6 million km² of the survey area. As expected, densities were greater in the south: 30.6 \pm 5.7 animals/100 km² and 2.4 \pm 0.3 groups/100 km². Our population estimate for the south-eastern Gobi is therefore 39 991 \pm 6697 animals (95% CL = 28 867–55 402 khulan), with the majority (35 666 \pm 6627 khulan) in the southern half. Khulan in this region range from the eastern boundary of Dornogobi *Aimags* westward across the southern portion of Mongolia. Their distribution includes most of the area north of the Chinese border to a line running approximately south of Sainshand to just west-northwest of Sainshand to just south of Dalanzadgad (Fig. 2).

Overall

The overall estimate for Mongolia therefore includes: (1) 3500–5000 khulan in the south-western Gobi; (2) 1000–2500 khulan in the southern Gobi; (3) 28 867–55 402 khulan in the south-eastern Gobi, for a total of 33 367–62 902 animals in Mongolia. The species ranges across the southern one-quarter to one-fifth of the nation from Dornogobi *Aimags* to Khovd *Aimags*, an area that corresponds to the extent of the Gobi Desert in Mongolia. The south-eastern Gobi Desert (southern and western Dornogobi, southern Dundgobi, and south-eastern Omnogobi *Aimags*) seems to be the stronghold for khulan in Mongolia, although a healthy population also apparently inhabits Great Gobi B (Feh, Munkhtuya *et al.*, in press). Recent surveys suggest that the species may be expanding into its former range in this region of Mongolia (Schaller, 1994; Mix *et al.*, 1995; Feh, Munkhtuya *et al.*, in press).

Table 3. Population estimates for different geographically isolated population of Asian wild asses *Equus hemionus*

Country	Subspecies	Year	Population estimate	Source
India	<i>E. h. khur</i>	1993	750	Shah (1993)
Iran	<i>E. h. onager</i>	1997	500	B. Dareshori & L. Tatin (pers. comm.)
Turkmenistan	<i>E. h. kulan</i>	1995	5000	P. Duncan (pers. comm.)
Kazakhstan	<i>E. h. kulan</i>	1997	300	Salathé (pers. comm.)
Mongolia	<i>E. h. hemionus</i>	1974	15 000	Bannikov (1981)
		1976	~4000	Sokolov <i>et al.</i> (1978)
		1980	15 000	Bannikov (1981)
		1984	14 000	S. Dulamtseren (pers. comm.)
		1985	6000–7000	Zhirnov & Ilyinsky (1986)
		1994	10 000	A. Avirmed (pers. comm.)
		1990s	33 367–62 902	This study
China	<i>E. h. hemionus</i>	1996	250	Wang & Schaller (1996)

DISCUSSION

Status and distribution of khulan

Before the 1990s, there were few published surveys of khulan in Mongolia. Zhirnov & Ilyinsky (1986) conducted aerial surveys of Great Gobi in the early 1980s and estimated that 800 khulan inhabited Great Gobi Strictly Protected Area region A and another 1500 inhabited region B, but found high fluctuations of khulan numbers. Duncan (1992) suggested that 2500 khulan inhabited both regions A and B of Great Gobi. Unfortunately, methods and descriptive statistics from these earlier studies in the Great Gobi were lacking; however, if comparable with our results, they indicated that the khulan population in region B has remained remarkably stable at about 1500 animals, while the population in region A has been increasing from about 500 in the mid-1970s to 1674 ± 506 animals in the mid-1990s.

Zhirnov & Ilyinsky (1986) found mean densities of 0.8–5.1 khulan/100 km² and mean group sizes of 1.7–7.0 animals/group in the Great Gobi. Our numbers fell within those ranges; we found a density of 4.20 animals/100 km² and mean group size of 4.32 animals/group in region A of Great Gobi.

In the last few decades, khulan were reported as declining, being forced into more marginal habitats as a result of poaching and competition for forage and water (Zhirnov & Ilyinsky, 1986). Our data suggest that khulan populations have been expanding in recent years and that 33 367–62 902 khulan inhabit Mongolia; a population estimate much higher than estimates made over the past 25 years (Table 3). Bannikov suggested that about 15 000 khulan inhabited Mongolia in both 1974 and 1980 (Bannikov, 1981). Similarly, an unsystematic aerial survey in the mid-1980s yielded an estimate of 14 000 animals (S. Dulamtseren, pers. comm.; see also Shiirevdamba *et al.*, 1997). These estimates contrast with Sokolov *et al.* (1978), whose surveys in the mid-1970s led to a population estimate of 4000 or less, and with Zhirnov & Ilyinsky (1986), who estimated 6000–7000 khulan in Mongolia in the mid-1980s. Unfortunately, the methods used to determine these

estimates were not provided, making comparisons with our data difficult. If our numbers are correct, most or all of these earlier population estimates were probably too low, although some may have been correct if there has been a recent and substantial population increase. Mongolia harbours the world's largest population of Asian wild ass, of any subspecies, with numbers several times higher than that found in other countries (Table 3).

Our results are probably more reliable than previous estimates because they are based on a much larger sample size than previous studies, covering a far greater percentage of the territory occupied by khulan. In addition, our surveys of Great Gobi A (Reading, Mix, Lhagvasuren & Blumer, 1999), Great Gobi B (Feh, Munkhtuya *et al.*, in press), the southern Gobi (Reading, Amgalabaatar & Lhagvasuren, 1999), and the south-eastern Gobi (Mix *et al.*, 1995) were the only studies that systematically surveyed sample areas using standardized methods.

Conservation implications and recommendations

A substantially higher population of khulan was found than previously estimated, and all indications suggest that the population continues to grow and expand its range. As such, Mongolia represents an important stronghold for the conservation of the khulan subspecies, as well as Asian wild ass species in general. Several factors, however, threaten to change this situation. Increases in poaching, grazing pressure, and natural resources exploitation coupled with reduced law enforcement and major social changes (Valdez, Frisina & Buyandelger, 1995; Reading, Amgalanbaatar & Mix, 1998) could easily reverse what seems to be an increasing khulan population.

The expanding khulan population has resulted in an increase in the number of conflicts with local, nomadic herders who view khulan as competitors for livestock forage. One result has been increased pressure to remove the protected status from khulan, at least in some areas, and to permit recreational and even commercial harvests. In addition, poaching of khulan for

meat and hides seems to be increasing (Duncan, 1992). Greater competition between livestock and khulan may indeed be occurring (Shiirevdamba *et al.*, 1997), but it is unclear if this is a result of increased khulan numbers, expanding livestock herds (Mueller & Janzen, 1997), or both. We believe it is the latter. Finally, pressure to extract Mongolia's rich reserves of natural resources from khulan habitat is growing (Dondog, Lhagva & Hasbaatar, 1996), especially in the face of the recent, large-scale socio-political changes that have accompanied Mongolia's shift to democracy and a free market system (see UNDP, 1997). These factors and pressures are creating significant challenges to wildlife managers who have little money to address such issues. Given how little is really known about khulan biology and ecology in Mongolia, we recommend that managers proceed cautiously and only after additional research has been conducted to permit more informed, scientifically based management.

There have been few studies of khulan in Mongolia (Bannikov, 1971, 1975; Wolfe, 1979; Munkhsaikhan *et al.*, 1989; Feh, Boldsukh & Tourenq, 1994; Enkbold, 1997; Feh, Munkhtuya *et al.*, in press). Most of this research has focused on behavioural ecology or systematics, although some data were collected on khulan numbers and distribution during these and other studies (e.g. Zhirnov & Ilyinsky, 1986). Only recently have surveys been conducted to assess the current population size and distribution of khulan in Mongolia (Mix *et al.*, 1995, 1997; Wang & Schaller, 1996; Reading, Mix, Lhagvasuren & Blumer, 1999).

Several protected areas have been created within the khulan's range in Mongolia, and we found populations of animals in all of them (Johnstad, Reading & Wingard, 1996; MNE, 1996b; Shiirevdamba *et al.*, 1997; Fig. 2). The largest of these is the two-section, 53 117 km² Great Gobi Strictly Protected Area in the Dzungarian and south-western Gobi. Gobi Gurvan Saikhan National Conservation Park protects 21 717 km² in the South Gobi, but only a small portion of the park's area (in the south) includes khulan. Gobi Gurvan Saikhan should investigate the possibility of expanding its boundaries to the south to include important khulan habitat. Khulan habitat seems to be available, yet unused within the Park and studies should attempt to understand why this exists. Two new protected areas were created primarily for khulan conservation in 1996. Baga Gobi Strictly Protected Area covers 18 391 km² in a two-section reserve on the Chinese border in the south-eastern Gobi, and Zagiin Us Nature Reserve protects 2763 km² further north. Khulan also inhabit three smaller protected areas: Ergeliin Zoo Nature Reserve (609 km²), Ikh Nartiin Khad Nature Reserve (437 km²), and Suikhent Natural Monument (48 km²). Creation of these protected areas was an important first step, but now the hard work of initiating and implementing conservation management programmes begins. Effecting such programmes will require substantial commitment by the Mongolian government and assistance

from the international community (Reading, Johnstad *et al.*, 1999).

Although khulan are expanding their range in south-eastern Mongolia, the south-western population seems to be relatively stable. The reasons for the difference in population dynamics between the two regions are unknown, but deserve attention. Khulan inhabited the Great Lakes Basin in west-central Mongolia as recently as the 1950s (Bannikov, 1954), and conservationists might consider attempting to encourage re-establishment of a population in this area.

The khulan's range in southern Mongolia extends to the Chinese border (Fig. 2); however, only two small, fragmented khulan populations remain in China, one in the Junggar Basin of northern Xinjiang and the other in western Inner Mongolia (Zhang *et al.*, 1997). Wang & Schaller (1996) suggest that khulan, and several other species inhabiting the Gobi Desert, are sustained in China only by migration from Mongolia (e.g. Reading, Mix, Lhagvasuren & Blumer, 1999). For khulan, their suggestion is corroborated by our finding that the khulan population in Mongolia's south-eastern Gobi seems to be expanding.

Thousands of khulan inhabit large expanses of available habitat throughout the Mongolian Gobi. Although Mongolia's livestock and human populations are growing (Mueller & Janzen, 1997), both remain well below densities found throughout most of the rest of the Asian wild ass' range, providing conservationists with the opportunity to initiate proactive wild ass conservation in Mongolia.

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