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Mongolian Marmot Crisis: Status of the Siberian Marmot in the Eastern Steppe

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Abstract

Siberian marmots (*Marmota sibirica*) are important members of the Mongolian steppe ecosystem and local human economy. Recent declines in marmot numbers have forced the Mongolian government to ban marmot hunting for at least two years. The main objectives for this study were to develop a baseline understanding of current marmot distribution and density in the Eastern Steppe of Mongolia (Dornod, Sukhbaatar, and Khentii aimags). We conducted line transects across the Eastern Steppe during pup emergence from June through July 2005. These distance sampling surveys detected active and inactive marmot colonies ("burrow clusters"), marmots, and other wildlife (primarily carnivores, ungulates and raptors) along our transects; we used the program DISTANCE to estimate densities. Our density estimates, and particularly our population estimates, indicate a much more severe decline than noted in other published studies. We discuss our findings on raptors, wild ungulates and mammalian carnivores in the context of other published and anecdotal information.

Key words: distance sampling, keystone, marmot, *Marmota sibirica*, Mongolia, steppe

Introduction

Marmots are an important member of the Mongolian steppe ecosystem and are likely a 'keystone species' (Kotliar et al., 1999; Smith & Foggin, 1999; Lai & Smith, 2003) — a species whose impact on its community is disproportionately large relative to abundance (Paine, 1969; Power *et al*., 1996). Marmots perform a variety of functions, and, in this sense, are considered 'ecosystem engineers' (Wright & Jones, 2006): i) marmot burrowing brings soil to the surface, recycling nutrients and aerating soil; ii) burrows provide shelter for many native species, such as hedgehogs, rodents, foxes, Pallas cats, and even birds (Adiya, 2000; Zahler *et al*., 2004); iii) marmot selective feeding habits affect diversity and composition of vegetation; and (iv) marmots are an important food source for raptors and carnivorous mammals (Schaller, 1998). Marmots are also important to the Mongolian culture as a traditional source of protein, medicine, skin and fur (Wingard & Zahler, 2006). Economically, marmots play an important role with the annual fur trade exceeding 1.2 million skins on average since the late 1800s. However, due to a recent potentially dramatic decline in marmot abundance (for example, see Reading *et al*., 1998; Wingard & Zahler, 2006), a 2-year hunting ban was placed on marmots throughout Mongolia (2005 and 2006). Marmots have been experiencing significant declines across Mongolia, according to Adiya (2000), roughly a 75% decline in the last 60 years.

In an attempt to assist the Mongolian Government in managing this critically important resource and member of the steppe ecosystem, we conducted a survey in the Eastern Steppe in summer 2005 to establish a baseline estimate of the marmot population. In addition, because marmots are considered a keystone species, we noted other wildlife such as raptors, wild ungulates and mammalian carnivores. Taxa were chosen due to the high relative probability of detection and expected association between marmots and raptors/carnivores. We used distance sampling to estimate wildlife density and examined the relationship of marmot detections to wildlife presence.

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Methods

Surveys were conducted from 10 June to 31 July, 2005 in the 250,000 km^2 Eastern Steppe study area that includes the three eastern Mongolian aimags of Khentii, Dornod and Sukhbaatar. Line transects were randomly placed 50 km apart oriented north and south, and we started our north-south transects at a random location. Road surveys were conducted to achieve coverage when topography prevented the completion of line transects.

Line transects

Distance sampling along line transects was conducted to sample active and inactive burrow clusters, marmots and other wildlife. During additional road surveys, locations of marmots, ungulates, raptors and mammalian carnivores were recorded, but burrow clusters (active and inactive colonies) were not. Line transects were conducted from a jeep driven <40 km/h with observers (and a driver). A Geographical Positioning System (GPS) unit mounted on the dashboard was used to stay on each transect.

Two to three observers (right-front and left-back or right-front and left-back and right-back) scanned primarily within 150 m of the vehicle for burrows and marmots and then scanned to the horizon for marmots, ungulates, raptors and carnivores. Observers rotated once every moving hour. One observer was also a data recorder to ensure that no animal was counted twice.

When a detection (marmot, ungulate, carnivore, or raptor) was made, the vehicle was stopped. Radial distance and angle from our position to the observation, location, time, type of species, number of individuals, habitat, and behavior were recorded for each detection. A rangefinder and, on some occasions, visual estimates were used to determine distance. A compass was used on most occasions to obtain a radial angle. For ungulate detections, we disregarded subsequent observations when they were observed soon (<0.5 h) after medium to large groups (>50 individuals) had been detected or if the ungulate(s) was traveling in our direction.

Burrow clusters (our sampling unit) were defined as a group of burrows >10.2 to 30.5 cm in diameter that were within 15.2 m of one another. When a burrow or burrow cluster was detected, if the burrow was within the target size class, the observer took measurements on that burrow or burrow cluster. The burrow cluster size (area) was measured (m^2), and location data was collected from the center point. For each burrow cluster, we measured burrow number, burrow size class, and the presence of digging, tracks (consistent in size and shape with marmot), marmot scat (old or fresh), debris (in entrance), alarm call, latrine, and other animal sign (types and amount). If during one moving hour no burrows were detected, we stopped and two observers conducted 150 m walking transects perpendicular to the north-south transect in order to verify that we were not missing any burrows within our target size class. Methods and findings are presented in a separate paper (Townsend, this volume). We filled out habitat and weather logs every hour while on transect and noted significant changes in weather in our daily transect log.

Distance Analysis

The software program DISTANCE (v. 5.0; Thomas *et al*., 2005) was used to analyze the data collected from the line transect survey in order to estimate densities of active and inactive burrow clusters, marmots, ungulates, carnivores, and raptors. Data preparation and analysis followed published guidelines (Buckland *et al*., 2001).

Density estimates of clustered objects (Ds) and individuals (D) were estimated using the equations and, respectively (Buckland *et al*., 2001): Where n is the number of objects detected, L is the total length of the line, is the estimated probability detection function of the perpendicular distances evaluated at zero, is the estimated expected cluster size, and is the estimated density of clusters and individuals, respectively (objects km^2).

Final model selection was based on the lowest AIC (Akaike's Information Criterion) value (Burnham & Anderson, 1998). Goodness of fit (X^2) was used to assess the quality of distance data and the general shape of the detection function. We right truncated the width of the maximum sighting distance (w) at least 5% in order to improve model fit.

Distance sampling methods assume that line transects are located randomly with respect to the distributions of the units of observation that all objects are detected on the line, no movement prior to detection and accurate measurements of distances to the observations.

In our analysis for marmots, raptors, and carnivores, we used data from "road transects"(roads = dirt tracks) (e.g., these include transects 1 and 12, Figure 1) and for ungulates, this includes data from transect 1. Using distance data from road transects is thought to violate the first assumption that line transects are distributed randomly (unless one can show that presence of roads does not affect distribution of target animals). The presence of roads may affect the randomness of this distribution (animals may avoid or be attracted to roads or in some way otherwise be affected in distribution).

Estimating population using burrow cluster densities. We use estimates of percentage occurrence of clan types in a marmot population (Suntsov, 1981) to calculate a population estimate using active burrow cluster estimate for Dornod and Sukhbaatar aimags. We multiply the percentage occurrence of clan type by our total number of active burrow clusters and then add up the resulting marmot numbers.

Pairwise comparisons

In order to examine the relationship between marmot, carnivore, raptor and ungulate detections km^2 for 12 transects, we used the Pearson Product Moment correlation for all pairwise comparisons (SigmaStat for Windows v. 1.0, 1992 - 1994). Additionally, we ran all pairwise correlations between burrow clusters (active and inactive), marmots, ungulates, carnivores and raptors for transects 2 through 11. We expected increased marmot and burrow detections to correlate positively with raptor and carnivore detections. In addition, we expected the presence of burrows correlated positively with carnivore detections.

RESULTS

We completed 12 transects (3,148 km), 10 transects were oriented north-south (2 through 11; 1,966 km), and two were conducted from roads [1 and 12; 1,182 km (Table 1, Figure 1)]. Transect 1 was conducted in the most eastern part of the Dornod Aimag in the Numrug Special Protected Area, and transect 12 was conducted in the Khentii Aimag, north of the Kherlen River. As we moved from east to west, our transects were >50 km apart in order to complete the survey within our survey window. Marmot observations peaked at 9:00 and 15:00 and dropped off considerably in the middle of the day (Figure 2).

Table 1. Location, transect number, length and type of transect in the Eastern Steppe (Khenti, Sukhbaatar, and Dornod aimags), Mongolia 2005.

Location (Aimag)	Transect #	Length (km)	Type
Dornod	*1*	*812.9*	*Road*
Dornod	2	43.4	N-S Transect
Dornod	3	84.1	N-S Transect
Dornod	4	153.4	N-S Transect/Road
Dornod/Sukhbaatar	5	276.0	N-S Transect
Dornod/Sukhbaatar	6	344.2	N-S Transect
Dornod/Sukhbaatar	7	386.7	N-S Transect
Dornod/Sukhbaatar	8	300.1	N-S Transect
Sukhbaatar	9	244.4	N-S Transect
Sukhbaatar	10	69.9	N-S Transect
Sukhbaatar/Khenti	11	63.6	N-S Transect
Khenti	*12*	*369.7*	*Road*
Total		**3148.4**	

Distance Analysis

Marmot Density and Number. Analysis was based on exact distances, and detections >400 m from transects were excluded based on model fitting. Hazard rate cosine had the lowest delta AIC value of three models run (uniform cosine and hazard rate cosine). Distance calculated the estimate of density of marmots and cluster of marmots (Table 3).

We detected marmots 68 times with a total of 130 marmots observed. All transects were included, as distance from the transect line was recorded in every instance. The density estimate

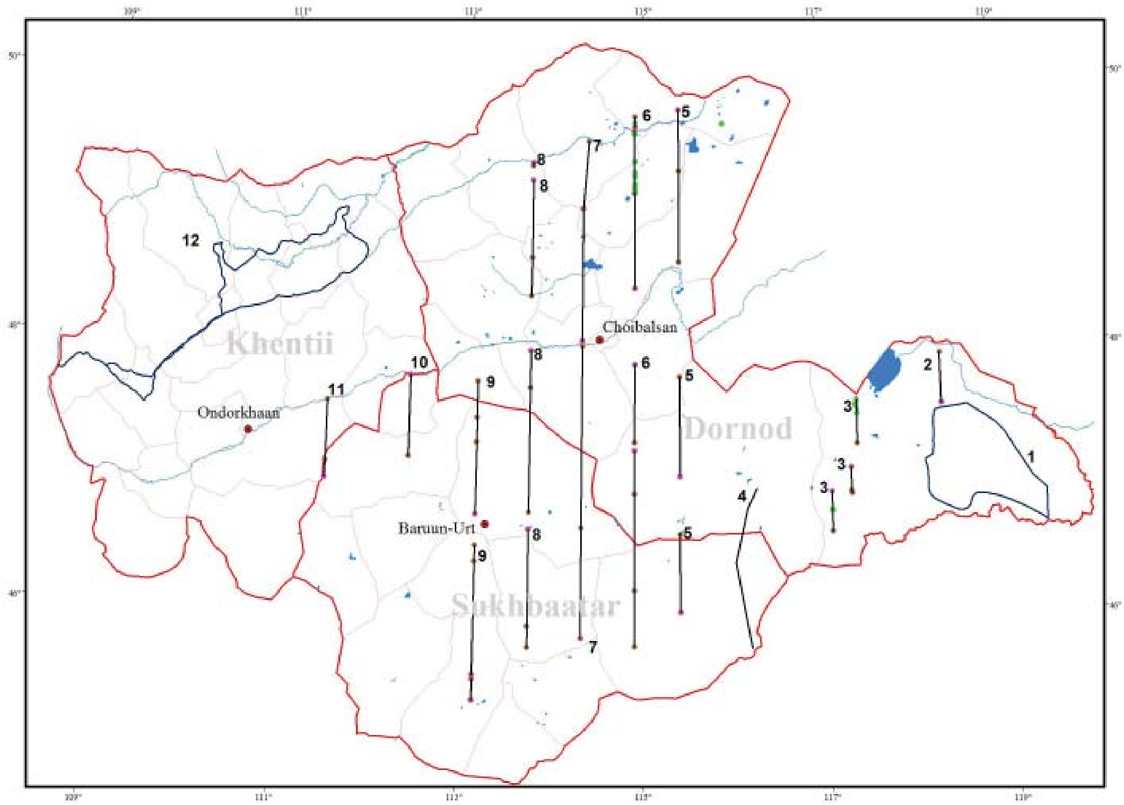

Figure 1. Transects 1 through 12 driven in the Eastern Steppe (Khentii, Dornod and Sukhbaatar aimags), Mongolia in June and July 2005 to detect marmots, marmot burrow clusters, wild ungulates, carnivores and raptors.

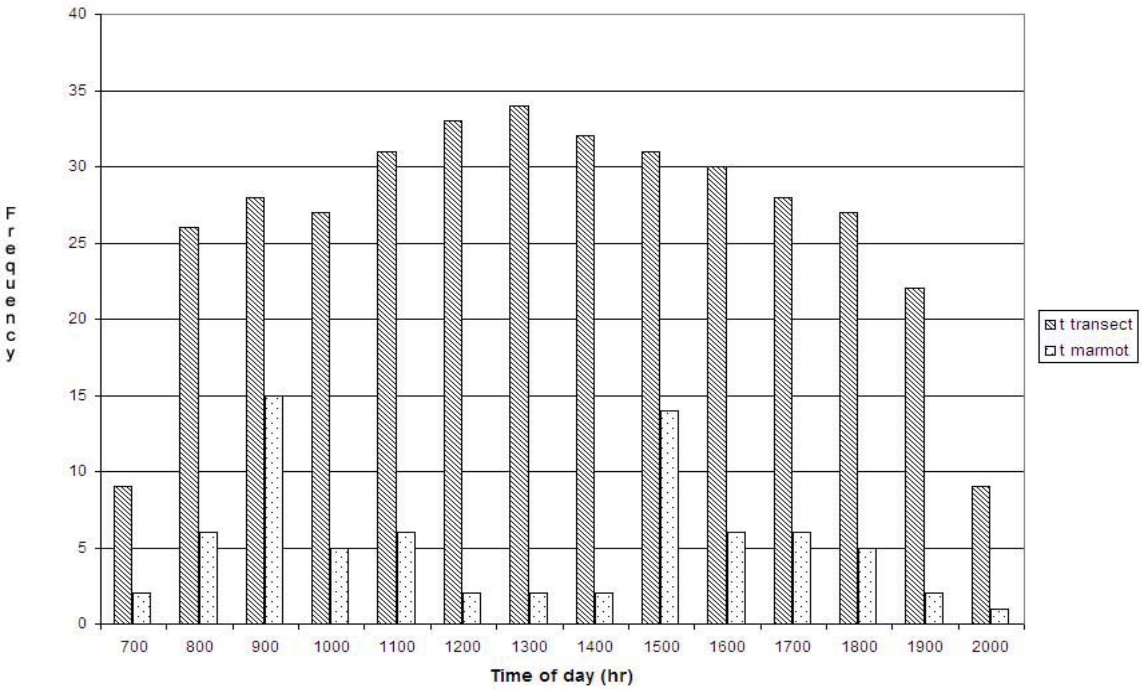

Figure 2. Frequency distribution of time of day when transects were driven (hatched) and time of day for marmot detections (spotted), Eastern Steppe, Mongolia (June – July 2005).

for marmots was 0.123 (± 0.0435) km^2 or 33,982 (±12,050) marmots for all three aimags (277,225 km^2; Tables 2 and 3).

Ungulate Density and Number

Analysis was based on exact distances, and detections >600 m from transects were excluded based on model fitting. Half-normal cosine had the lowest AIC value of three models run (uniform cosine and hazard rate cosine). Distance calculated the estimate of density of ungulate clusters and ungulates.

We detected ungulates 138 times with a total of 7,192 individuals on 11 transects. The majority was Mongolian gazelle (*Procapra gutturosa*) with the exception of a few roe deer (*Capreolus pygargus*, n = 4) detected on Road Transect 1 (Numrug Specially Protected Area); all were included in our analysis. We analyzed data from Dornod and Sukhbaatar aimags (195,225 sq km^2; Table 2). Our density estimate for ungulates was 6.39 (± 2.31) km^2 or 1,247,300 individuals (± 451,290; Table 3).

Carnivore Density

The species we encountered included red fox (*Vulpes vulpes*), corsac fox (*Vulpes corsac*), steppe ferret (*Mustela eversmanni*), wolf (*Canis lupus*),

Table 2. The sample size (N), transect number, transect length, transect width, and study area (size) used for distance analysis of burrow clusters, marmots, wild ungulates, carnivores and raptors.

Target	*# obs (N)*	*Transects Number*	*Transect l (km)*	*Transect w (m)*	*Area (km^2)*
Inactive burrow clusters	1811	2-11	1965.50	150 (300)	195,225
Active burrow clusters	95	2-11	1965.10	150 (300)	195,225
Marmots $\hat{D}$ ($\hat{D}_s$)	130 (68)	1-12	3148.43	400 (800)	277,225
Ungulates $\hat{D}$ ($\hat{D}_s$)	7,181 (138)	1-11	2335.00	600 (1200)	195,225
Carnivores $\hat{D}$ ($\hat{D}_s$)	14 (12)	1-12	3148.09	400 (800)	277,225
Raptors – Dornod	40	1 - 4	650.65	500 (1000)	123,500
Raptors – Sukhbaatar	38	9 -11	377.81	500 (1000)	82,000
Raptors - Khentii	136	12	812.9	500 (1000)	82,000

Table 3. Density estimates (± standard error), coefficient of variation (CV), confidence interval (95% CI), population estimates ±standard error [N(± SE)], coefficient of variation (CV) and confidence interval (95 % CI) for burrow clusters (active and inactive), marmots, ungulates, carnivores, and raptors for the study area.

Target	*Density km^2*	*CV*	*95% CI*	*N (±SE)*	*CV*	*95% CI*
Inactive burrow clusters	9.49	18.79	6.24 - 14.44	1,852,900	18.79	1,217,500-2,819,900
Active burrow clusters	0.423	25.7	0.245 - 0.729	82,597	25.7	47,935-142,320
Marmots ($\hat{D}$)	0.12258 (±0.0435)	35.46	0.05957 - 0.2522	33,982 (±12,050)	35.46	16,513 - 69,930
Marmots ($\hat{D}_s$)	0.0647	34.62	0.0318 - 0.1316	n/a	n/a	n/a
Ungulates ($\hat{D}$)	6.39 (±2.31)	36.18	3.16 - 12.91	1,247,300 (±451,290)	36.18	617,080 - 2,521,200
Ungulates ($\hat{D}_s$)	0.2573	24.33	0.1527 - 0.4339	n/a	n/a	n/a
Carnivores ($\hat{D}$)	0.1439 (±0.0709)	49.3	0.0531 - 0.3896	39,892 (±19,665)	49.3	14,734 - 108,000
Carnivores ($\hat{D}_s$)	0.13668	48.2	0.0511 - 0.3657	n/a	n/a	n/a
Raptors - Dornod	1.26 (±0.523)	41.92	0.540 - 2.958	156,060 (±65,411)	41.92	66,664 - 365,310
Raptors – Sukh.	2.49 (±1.234)	49.65	0.759 - 8.139	203,800 (±101,180)	49.65	62,239 - 667,370
Raptors - Khentii	4.85 (±0.879)	18.13	3.397 - 6.916	397,490 (±72,059)	18.13	278,580 - 567,140

and badger (*Meles meles*). Analysis was based on exact distances to observed carnivore, and detections >400 m from transects were excluded based on model fitting. Hazard-rate cosine had the lowest AIC value of three models run (uniform cosine and hazard rate cosine). DISTANCE calculated the density estimate for carnivores, and clusters of carnivores.

We detected carnivores 12 times, or 14 individuals, on 12 transects. This very low sample size in a relatively large study area resulted in the large coefficient of variation. The density estimate for carnivores was 0.14 (±0.071) km^2 or 38,892 individuals (±19,665; 49.3% CV) for the three aimags (277,225 km^2 study area, Tables 2 and 3).

Raptor Density and Number

Analysis was based on exact distances, and detections >500 m from transects were excluded based on model fitting. Hazard rate cosine had the lowest delta AIC value of three models run (uniform cosine and hazard rate cosine), and the results presented are based on this model.

Raptors were observed on 311 instances, including a total of 412 individuals. Several transects were dropped from the analysis due to inconsistencies in methods of recording radial angle and distance (only for raptors). Of the 311 observations, 214 were used for the DISTANCE analysis. The results were stratified into Dornod Aimag (transects 1 through 4), Sukhbaatar (transects 9 through 11) and Khentii (N of the Khurlen River, transect 12). Density estimates ranged from 1.26 (± 0.523) km2 in Dornod to 4.85 (± 0.879) km^2 in Khentii (Table 3). Abundance estimates for each region were 156,060 (±6 5,411) for Dornod, 203,800 (± 101,180) for Sukhbaatar, and 397,490 individuals (± 72,059) for Khentii (Table 3).

Active and inactive burrow clusters. We had sufficient information for 1,906 burrow clusters to use DISTANCE to analyze our data; of these, 1,811 were inactive, and 95 were active (Table 2). For the study area, Dornod and Sukhbaatar aimags (195,225 km^2), densities of inactive burrow clusters (9.49 per km^2) exceeded that of active burrow clusters (0.423 per km^2; Table 3); this resulted estimates of 1,852,900 inactive burrow clusters and 82,597 active burrow clusters (Table 3).

Burrow cluster data were stratified for analysis (active and inactive). Parameter estimation specification included encounter rate by stratum, detection probability by stratum and estimated by stratum, density by stratum, and pooled estimates unweighted stratum estimates. Analysis was based on exact distances, and detections >150 m from transects were excluded based on model fitting. Estimated detection probability for inactive colonies was 0.0206 [coefficient of variation (CV) = 2.04, degrees of freedom (df) = 1809, 95% confidence interval (CI) = 0.01979 to 0.02144]. Estimated detection probability for inactive colonies was 0.0175 (CV = 11.11, df = 93, 95% CI = 0.0141 to 0.0218).

We used the estimated number of active burrow clusters (82,597) to calculate a marmot population estimate (462,130; Table 4).

Correlation of detection rates: Ungulates, Raptors, Carnivores, Marmots and Burrow Clusters. Raptor detections increased with ungulate density ($r = 0.7204$, $N = 10$, $p = 0.018$). Other correlations were not significant [raptor x carnivore ($r = 0.0234$, $N = 12$, $p = 0.9423$), raptor x marmot ($r = 0.5451$, $N = 12$, $p = 0.0668$), carnivore x marmot ($r = -0.257$, $N = 12$, $p = 0.420$), carnivore x ungulate ($r = -0.310$, $N = 12$, $p = 0.326$), ungulate x marmot ($r = 0.459$, $N = 10$, $p = 0.182$)]. There were no significant correlations between burrow clusters per km (all, active, and inactive) and marmot, carnivore, ungulate and raptor detections. There was a weak correlation (non-significant, $p \geq 0.05$) between carnivore detections and inactive burrow clusters ($r = 0.6155$, $N = 10$, $p = 0.0582$).

Discussion

Comparisons to other density estimates

Batbold *et al*. (2000) determined that in 1990 total occupied habitat (for marmots) in Mongolia was 252,038.79 km^2 with the Eastern Steppe representing 23.2% of that habitat (83,745.49 km^2 in total; Dornod Aimag represents 32,745 km^2 [13%], Sukhbaatar Aimag 19,497 km^2 [7.7%], Khentii Aimag 31,500 km^2 [12.4%]). Furthermore, according to Batbold *et al*. (2000), the Eastern Steppe in 1990 supported 26.9% of the population (estimated at 6,230,772 marmots; Dornod and Sukhbaatar aimags 66.9% [4,169,145 marmots], and Khentii Aimag 33.1% [2,061,627 marmots]). Our population estimate is much lower than what might be expected, even with increased hunting pressure. If our findings reflect similar changes in the remaining portions of Mongolia, the marmot population is in real crisis. Batbold *et al.*'s (2000) density estimates were greater than our density estimates by several orders of magnitude (starting at 50 and up to 450 marmots per km^2), which may in part be an artifact of different assessment methods. Our density estimate for marmots was 0.123 ± 0.044 km^2, also astonishingly low in comparison.

From a study in Tuva, Suntsov (1981) determined the percentage occurrence of different clan types in a marmot population, and we assumed our activity measures for burrow clusters reflected a similar distribution of clan types. This approach gave us an additional way to estimate total marmot numbers for Dornod and Sukhbaatar aimags; the resulting estimate (462,130 marmots) represents 11.1% of the 1990 estimates, still significantly lower than what might be expected.

Our density estimates for other wildlife, in particular carnivores, should be used with caution. Our overall low detection rate for carnivores reduces the power of our findings; however, the rarity of carnivores is also cause for alarm. Wolves are considered widespread in the Eastern Steppe; however, our findings indicate rarity. Corsac fox were detected most, and we observed corsac fox with young on several occasions while observing active marmot colonies.

Our ungulate density estimates are somewhat low but consistent with findings by Olson *et al*. (2005), which were 11.5 ± 3.2 km^2. Their estimates were the result of 2 spring and 2 autumn surveys conducted in 2000 to 2002 in parts of Dornod and Sukhbaatar aimags (80,000 km^2 study area) within our study area.

Raptors were sighted throughout our study area. Areas with apparent pika and/or vole activity likely affected distribution and density of raptors. Therefore, the presence of these other prey would affect potential associations with marmots. Additionally, in areas where Mongolian gazelles were calving, we saw large groups of black vultures (>10 individuals) and eagles (steppe and golden). Indeed, raptors and ungulate detections were significantly correlated. This association may indicate the role of primary production in the occurrence of both taxa, and ungulates may provide a significant contribution to some raptors' diet.

Our pairwise correlations did not reveal any strong associations between marmot presence and burrow clusters with other wildlife; there was a weak correlation between raptors and marmots and a weak correlation between carnivores and inactive burrow clusters. Both of these associations are consistent with our expectations that marmots are important in the ecosystem both for their role as prey and provider of burrows. Continuing to study this role is important because of the resulting indirect effects and the potential overall degradation of the ecosystem that could result from the significantly decreased marmot density and distribution.

The type of sampling we developed for this survey is repeatable and generates density estimates that are rigorous and quantitative (Buckland *et al*., 2001). The advantage of conducting this baseline survey in the first year of the marmot hunting ban may serve (if repeated on an annual basis) to gauge its success (or failure). We believe developing good baseline distribution and abundance data on important steppe wildlife species can serve as a sound basis for conservation decisions in the region.

Our research suggests there has been a recent and dramatic decline in the Eastern Steppe marmot population. Enforcement of hunting bans and other regulatory laws affecting marmots, allowing limited traditional hunting during certain times of year, and developing local support for and investment in the conservation of marmots are clearly important in the conservation of marmots in the Eastern Steppe. Results from this and future annual surveys could inform the most effective way to promote the recovery and the continued healthy persistence of marmots in the Eastern Steppe.

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Хураангуй

Монгол тарвага (*Marmota sibirica*)-ны сүүлийн жилүүдэд тоо толгой ихээхэн буурсан тул тус улсын засгийн газар тарвага агналтын 2 жилийн хугацаагаар хориглох шийдвэр гаргасан билээ. Бид Дорнод Монголын тал хээрийн бүс нутагт 2005 оны 06 ба 07 дугаар сарууддад шугаман трансектийн аргаар судалгааг хийж, тэдгээрийн нягтшилыг тодорхойлоход DISTANCE программыг ашиглав. Тарваганы популяци, нягтшилын үнэлгээрээр уг зүйлийн тоо толгойн хэмжээ бусад судалгааны мэдээтэй харьцуулбал эрс буурсан нь тогтоогдов. Түүнчлэн бид махчин шувууд, зэлэг туруутан болон махчин амьтдын талаархи мэдээллийг хэвлэлийн бусад мэдээ баримттай харьцуулан авч үзэв.

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