

## Estimating Siberian marmot (*Marmota sibirica*) densities in the Eastern Steppe of Mongolia

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Siberian marmots (*Marmota sibirica*) have declined rapidly in Mongolia over the past 15 years; so much so, a countrywide hunting ban was instituted in 2005. In order to collect baseline data, we initially conducted transects in the Eastern Steppe in order to estimate marmot densities and distribution in 2005. We subsequently collected similar data over the next 2 years (2006 and 2007) and now present our findings and compare them across years and among aimags (administrative divisions in the Eastern Steppe). Overall, marmots and marmot burrow clusters increased in density in 2006 and 2007 compared to 2005. In addition, the percent active burrow clusters increased from year 2005 to 2006 and then stayed approximately the same from year 2006 to 2007. These findings bode well for the efficacy of the hunting ban toward efforts to recover marmot populations in the Eastern Steppe.

KEY WORDS: marmot, *Marmota sibirica*, distance sampling, Mongolia, steppe.

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## INTRODUCTION

Marmots generally occur in alpine and high altitude habitats but can occur in grasslands and have a worldwide holarctic distribution. They are, in some cases, considered potential bellwethers for climate change (INOUE et al. 2000). Of the 14 recognized species, eight are Old World species, and of these, *M. bobac* and *M. sibirica* occur in Steppe ecosystems (ARMITAGE 2000, 2003). The Siberian marmot (*M. sibirica*) occurs both in mountain steppe and steppe habitat at relatively low elevation grasslands (~ 600 to 1200 m). Relatively little is published about *M. sibirica* (although see ADIYA 2000), and virtually nothing is published on this species from studies completed in the steppe ecosystem.

The focus of this study is the Siberian marmot, which occurs in much of Mongolia (Fig. 1). Our study area is the 250,000 km<sup>2</sup> Eastern Steppe (Fig. 2). We expect that the marmot has an important role in this ecosystem and is likely a 'keystone species' (MILLS et al. 1993) — a species whose impact on its community is disproportionately large relative to abundance (PAINE 1969, POWER et al. 1996). *M. sibirica* appears to play a similar ecological role as the prairie dog (*Cynomys ludovicianus*) does in the western U.S. plains ecosystem (KOTLIAR et al. 1999, KOTLIAR 2000, SMITH & LOMOLINO 2004). The Mongolian steppe ecosystem is still relatively intact and supports a very low human population density of nomadic herders that have been living there for thousands of years. The marmots appear to have multiple functions: (1) provide burrows for meso-carnivores including the corsac fox (*Vulpes corsac*, MURDOCH et al. 2009), the red fox (*Vulpes vulpes*), and pallas cat (*Octolobus manul*) and an insectivore, the hedgehog, (2) as prey for raptors and wolves (*Canis lupus*) (SCHALLER 1998), (3) to aerate soil and alter vegetation composition (ADIYA 2000), and (4) to provide burrow mounds and burrows where numerous wild-life species have been observed. Because of these and perhaps other functions,

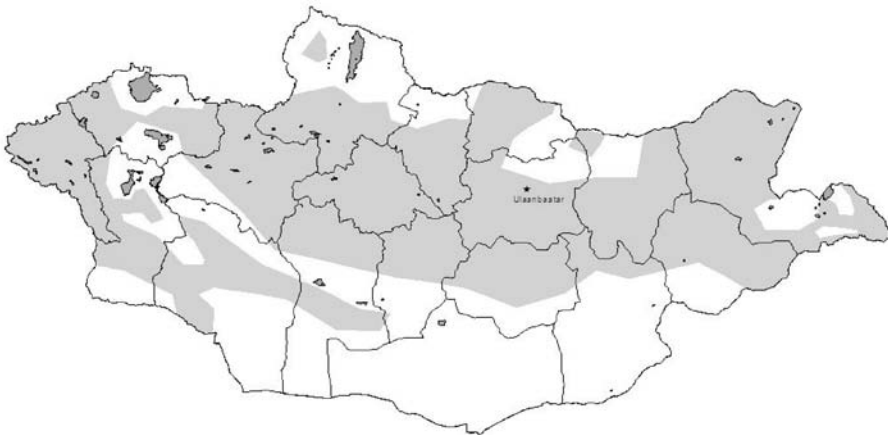


Fig. 1. — Distribution of the Siberian marmot in Mongolia (range = gray shading). Source: DULAMT SEREN (1970).

their recent decline may have negative consequences for health and integrity of the Eastern Steppe ecosystem.

In response to the notable decline, the Mongolian Government banned marmot hunting throughout the country from 2005 to 2008. Our objective for this study was to quickly and reliably assess baseline density estimates and distribution of marmots in the Eastern Steppe at the start of the hunting ban. We published our findings for 2005 (TOWNSEND & ZAHLER 2006), which confirmed a catastrophic decline; in this paper, we present our findings for years 2005-2007.

We conducted line transects using distance sampling to estimate densities (BUCKLAND et al. 2001) during and just after marmot pup emergence (June and July). We then calculated baseline density estimates for marmots and their burrows. For conservation purposes, understanding marmot densities and changes in density and distribution in the Eastern Steppe is critical in understanding its current status and how efforts toward recovering this species are performing. We present our results and compare density estimates by year and region.

## METHODS

### *Study area*

Surveys were conducted in the 250,000 km<sup>2</sup> Eastern Steppe study area that includes the three eastern Mongolian aimags of Khentii, Dornod and Sukhbaatar (Fig. 2). The area is characterized by open steppe ranging in elevation from approximately 600 to 1200 m in elevation.

### *Survey effort*

In 2005, transects were randomly placed 50 km apart oriented north and south, and, in all years, we started our north-south transects at a random location. In 2006 and 2007, we used a lay-out of 10 km (later changed to 20 km) north south transects placed 75 km apart (east-west) using the design component of Distance software (BUCKLAND et al. 2001). In 2005 and 2006, road surveys were conducted when topography prevented the completion of line transects. Roads were little more than dirt tracks and, at times, barely passable. Transect length for burrow clusters was shorter than for other taxa. We calculated the study area for each year as a 50 km buffer around transects; if the transect ended due to an impassable topographic feature or habitat, the buffer ended at that point.

### *Line transects*

We recorded detections of individual marmots and burrow clusters on our transects; we estimated densities using analytic software DISTANCE (THOMAS et al. 2005).

Our survey methods have been published elsewhere (TOWNSEND 2006, TOWNSEND & ZAHLER 2006); an abbreviated version is included here. Two to three observers scanned within 150 m of the vehicle driven < 40 km/hr for burrows and marmots and

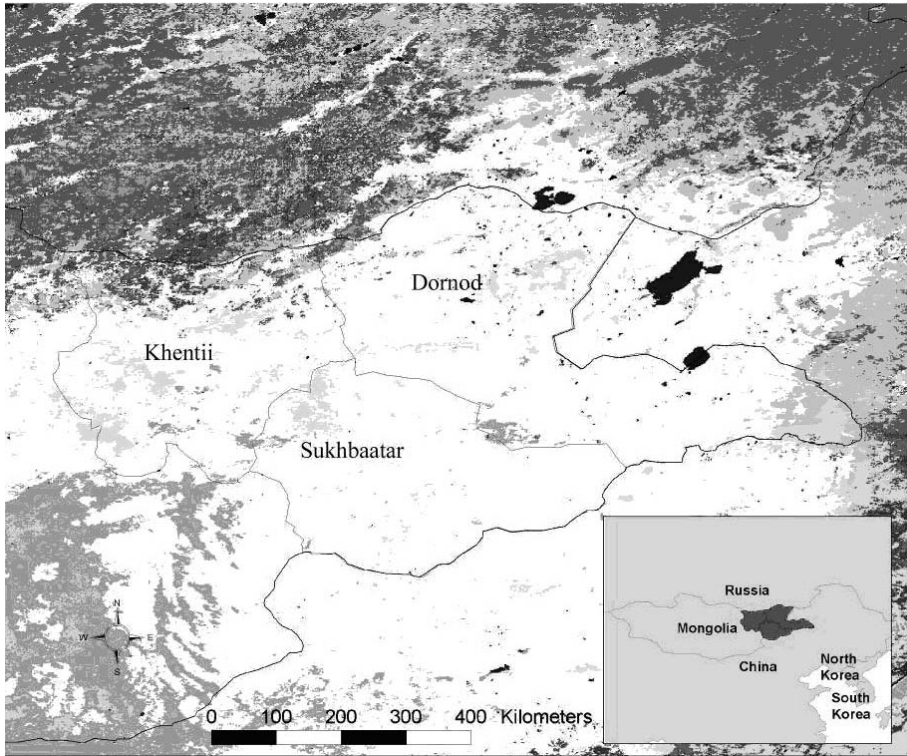


Fig. 2. — The study area, the Eastern Steppe, consists of three aimags: Dornod, Khentii and Sukhbaatar. Land use [lightest areas = grasslands, darker shades = other habitats].

then scanned to the horizon for marmots. Observers rotated once every moving hour with one data recorder ensuring that no animal was counted twice. We recorded radial distance and angle from our position to the observation, location, time, species, number of individuals, habitat, and behavior. For burrow clusters, we exited the vehicle, noted variables, and recorded location data. During road surveys, we recorded locations of target taxa, but not burrow clusters.

Marmots are active during the day, spending much time in or near their burrows. In order to more accurately account for this “lack of detectability” while in their burrows or, conversely, overestimating abundance by using burrow presence alone, we developed a method to accurately determine marmot presence, and we identified a useful unit of measure (the “burrow cluster”) while conducting transects in a timely fashion; these methods and findings are published elsewhere and will be reviewed briefly herein (TOWNSEND 2006). A burrow cluster (our sampling unit) was defined as a burrow (measuring  $> 10.2$  to  $30.5$  cm in diameter) or group of burrows that were within  $\sim 15.2$  m of one another; for each burrow cluster, we measured size (area,  $m^2$ ) and location data (approximate center of burrow cluster) later used to calculate perpendicular distance from transect. Additionally, we noted number of burrows, 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) for each target sized burrow within a burrow cluster. We used this data to determine if burrow clusters were "active" (= marmots present) or "inactive" (= marmots not present).

From the 2005 data, we used binary logistic regression to identify a suite of reliable indicators for each of these classes associated with a probability statement. In 2005, a conservative determination of active was used that consisted of burrow clusters that had either fresh scat or presence of marmot or both. Other burrow characteristics were recorded and analyzed; we completed our analysis on four characteristics (digging, old scat, tracks and debris) in order to identify factors that were positively or negatively correlated with active burrow clusters (Minitab Statistical Software, Release 14). The probability of occupancy was calculated using this equation:

$$P_i = e^{y_i} / (1 + e^{y_i}) \text{ and } \text{Log}(p/p-1) = \beta_0 + \beta_{1x_{1i}} + \beta_{2x_{2i}} \dots + \epsilon_i$$

### *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 and marmots. Data preparation and analysis followed published guidelines (BUCKLAND et al. 2001).

Density estimates of clustered objects ( $D_s$ ) and individuals ( $D$ ) were estimated using the equations

$$\hat{D}_s = \frac{n\hat{f}(0)}{2L} \text{ and } \hat{D} = \frac{n\hat{f}(0)\hat{E}(s)}{2L},$$

respectively (BUCKLAND et al. 2001): where  $n$  is the number of objects detected,  $L$  is the total length of the line,  $\hat{f}(0)$  is the estimated probability detection function of the perpendicular distances evaluated at zero,  $\hat{E}(s)$  is the estimated expected cluster size, and  $\hat{D}_s$  and  $\hat{D}$  is the estimated density of clusters and individuals, respectively (objects km<sup>2</sup>).

Final model selection was based on the lowest AIC (Akaike's Information Criterion) value (BURNHAM & ANDERSON 1998). Goodness of fit ( $\chi^2$ ) 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 most cases in order to improve model fit.

## RESULTS

### *Level of effort*

We completed our transects from 10 June to 31 July, 2005, 5 June to 10 July, 2006, and 12 June to 10 July 2007. In 2005, 3,165 km of transects covering 174,497 km<sup>2</sup> (50 km buffer) were completed. In 2006, 1,776 km of transects covering 161,331 km<sup>2</sup>, and in 2007, 527 km covering 50,497 km<sup>2</sup> were completed (Table 1, Fig. 3A). Transects in 2005 were long and continuous, and in 2006 and 2007, shorter 20 km transects were completed. Study areas overlapped but varied in size from year to year (Table 1, Fig. 3B).

Table 1.

Size of each region and study area (study area is calculated with 50 km buffers for all transects).

| Study area             | Total area (km) | 2005 (km) | 2006 (km) | 2007 (km) |
|------------------------|-----------------|-----------|-----------|-----------|
| Eastern Steppe         | 277,285         | 174,497   | 161,331   | 50,498    |
| Dornod-Sukhbaatar      | 205,500         | 139,846   | n/a       | n/a       |
| Dornod                 | 123,500         | n/a       | 52,645    | 19,355    |
| Sukhbaatar             | 82,000          | n/a       | 55,167    | 16,710    |
| Khenti (N-S transect*) | 82,000          | n/a       | 8,780     | 14,431    |
| Khenti (Transect + Rd) | n/a             | 34,650    | 48,959    | n/a       |

\* N-S transect = north-south transects, Rd = road.

#### *Active and inactive burrow cluster classification*

The results from the binary logistic regression on active burrow clusters ( $n = 124$ ; binary logistic regression:  $G = 174.395$ ,  $df = 4$ ,  $P\text{-value} \leq 0.005$ ) indicated that all characteristics were significantly positively (digging, old scat, and tracks) or negatively correlated (debris) with active burrow clusters. Probability of occupancy exceeds 75% for the combination of digging, tracks, old scat and no debris. We used these criteria to determine active and inactive status for 2006 and 2007 burrow cluster data.

#### *Density estimates for each year*

In 2005, marmot density was 0.123 per  $\text{km}^2$  (Table 2, Fig. 4). The proportion of active burrow clusters (4%) compared to inactive burrow clusters (96%) was low (Table 3).

In 2006, marmot density estimates were highest in Khenti ( $0.674 \pm 0.153$  per  $\text{km}^2$ , Table 4, Fig. 5). Khenti had the highest density of burrow clusters (41.595 per  $\text{km}^2$ ) (Table 5); Sukhbaatar had the second highest density of burrow clusters (12.298 per  $\text{km}^2$ ) (Table 5, Fig. 6). The lowest density of burrow clusters was in Dornod (inactive = 4.484 per  $\text{km}^2$ , active = 0.980 per  $\text{km}^2$ ) (Table 5).

In 2007, marmot density estimates were highest for Dornod (2.538 per  $\text{km}^2$ ) and lowest in Sukhbaatar (0.046 per  $\text{km}^2$ ) (Table 6, Fig. 5). Burrow cluster density was highest in Dornod (80.949 per  $\text{km}^2$ ) and Khenti was roughly half that (28.204 per  $\text{km}^2$ ) (Table 7, Fig. 6). Sukhbaatar had the lowest densities of burrow clusters (12.481 per  $\text{km}^2$ ) (Table 7, Fig. 6). The highest percentage of active burrow clusters was in Dornod (26%) with roughly equal percentage for Khenti (12%) and Sukhbaatar (10%) (Fig. 6).

#### *Comparison between years*

For the Eastern Steppe in 2005, marmot density estimates were the lowest across all years (Table 3, Fig. 4). Marmot density estimates were greater

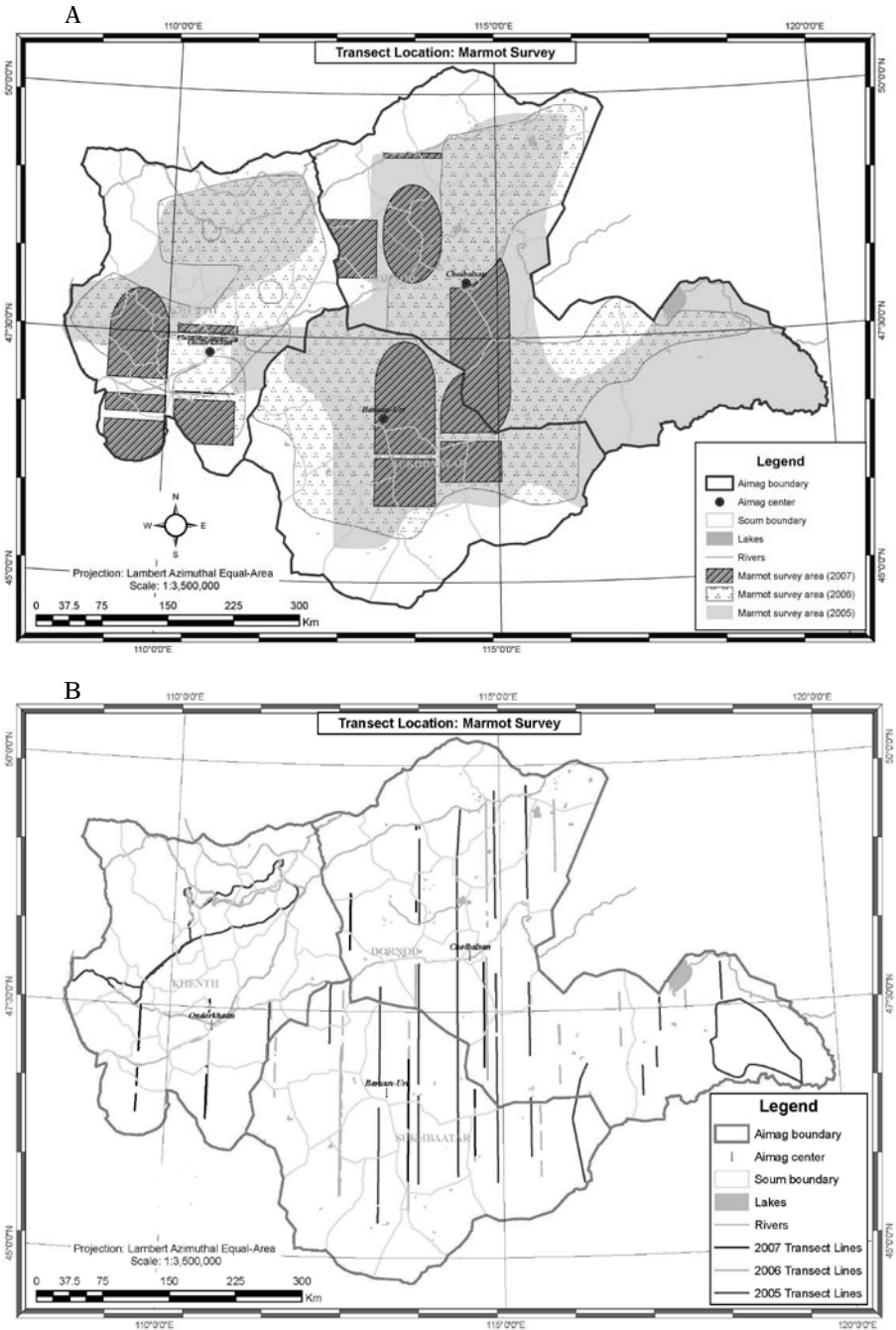


Fig. 3. — A: Study area shown as 50 km buffers around transects for each of the 3 years (2005 = gray, 2006 = dots, 2007 = dark hatch) in the Eastern Steppe, Mongolia. B: Locations of transects (vertical lines) for all years on the Eastern Steppe, Mongolia.

Table 2.

Number of observations, transect number and length, transect width ( $w$  = effective strip width), and size of study area used for distance analysis for estimation of burrow clusters and marmot density estimates in 2005 for the Eastern Steppe ( $\hat{D}$  = density of individuals and  $\hat{D}_s$  = density of clusters).

|                          | # obs.<br>(N) | Transect<br>number | Transect<br>l (km) | Transect<br>w (m) | Density<br>(km <sup>2</sup> ) | CV    | 95% CI      |
|--------------------------|---------------|--------------------|--------------------|-------------------|-------------------------------|-------|-------------|
| Inactive burrow clusters | 1,811         | 10                 | 1965.50            | 150 (300)         | 9.49                          | 18.79 | 6.24-14.44  |
| Active burrow clusters   | 95            | 10                 | 1965.10            | 150 (300)         | 0.423                         | 25.7  | 0.245-0.729 |
| Marmots ( $\hat{D}$ )    | 130           | 12                 | 3148.43            | 400 (800)         | 0.123<br>( $\pm 0.044$ )      | 35.46 | 0.060-0.252 |
| Marmots ( $\hat{D}_s$ )  | 68            | 12                 | 3148.43            | 400 (800)         | 0.065                         | 34.62 | 0.032-0.132 |

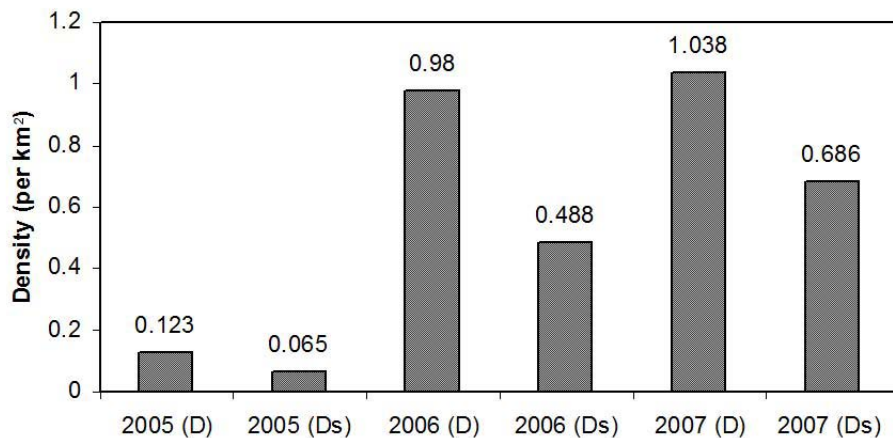


Fig. 4. — Marmot density (no. per km<sup>2</sup>) for the Eastern Steppe for each year (D = density of individuals, Ds = density of groups).

Table 3.

Burrow cluster density (active and inactive) and percentage of total for 2005, 2006 and 2007.

|               | Density per km <sup>2</sup> (%) |            |             |
|---------------|---------------------------------|------------|-------------|
|               | 2005                            | 2006       | 2007        |
| Inactive BuCl | 9.490 (96)                      | 9.924 (81) | 31.462 (80) |
| Active BuCl   | 0.423 (4)                       | 2.280 (19) | 7.914 (20)  |
| Total         | 9.913                           | 12.204     | 39.376      |

Table 4.

Number of observations, transect number and length, effective strip width (ESW), size of study area (km<sup>2</sup>), and density estimates (D = density of individuals, Ds = density of groups) for marmots in 2006 for the Eastern Steppe, Mongolia.

| Location        | No. obs. | No. transects | Transect l (km) | ESW (m) | Area (km <sup>2</sup> ) | Dens. per km <sup>2</sup> (±SE) | CV    | df    | 95% CI      |
|-----------------|----------|---------------|-----------------|---------|-------------------------|---------------------------------|-------|-------|-------------|
| Dornod (D)      | 28       | 21            | 382             | 510     | 53,645                  | 0.197 (±0.125)                  | 63.37 | 23.62 | 0.059-0.655 |
| Dornod (Ds)     | 9        | 21            | 382             | 510     | 53,645                  | 0.043 (±0.020)                  | 47.93 | 20.22 | 0.017-0.110 |
| Khenti (D)      | 270      | 6             | 669             | 510     | 46,014                  | 0.674 (±0.153)                  | 22.64 | 6.03  | 0.391-1.164 |
| Khenti (Ds)     | 133      | 6             | 669             | 510     | 46,014                  | 0.359 (±0.079)                  | 21.88 | 5.27  | 0.208-0.621 |
| Sukhbaatar (D)  | 39       | 26            | 460             | 510     | 55,167                  | 0.108 (±0.045)                  | 42.06 | 28.38 | 0.047-0.247 |
| Sukhbaatar (Ds) | 22       | 26            | 460             | 510     | 55,167                  | 0.086 (±0.035)                  | 40.86 | 25.37 | 0.038-0.194 |
| All (D)         | 337      | 53            | 1512            | 510     | 154,826                 | 0.980                           | 20.81 | 17.17 | 0.635-1.512 |
| All (Ds)        | 164      | 53            | 1512            | 510     | 154,826                 | 0.488                           | 18.28 | 8.66  | 0.323-0.737 |

Table 5.

Number of observations, transect number and length, effective strip width (ESW), size of study area (km<sup>2</sup>), and density estimates for active (Act) and inactive (Inact) burrow clusters in 2006 for the Eastern Steppe, Mongolia.

| Burrow clusters | No. obs. | No. transects | Transect l (km) | ESW (m) | Area (km <sup>2</sup> ) | Dens. per km (±SE) | CV    | df    | 95% CI        |
|-----------------|----------|---------------|-----------------|---------|-------------------------|--------------------|-------|-------|---------------|
| Dornod (Inact)  | 183      | 21            | 382             | 150     | 53,645                  | 4.484 (±1.548)     | 34.52 | 22.84 | 2.239-8.980   |
| Dornod (Act)    | 40       | 21            | 382             | 150     | 53,645                  | 0.980 (±0.809)     | 82.51 | 20.46 | 0.219-4.397   |
| Dornod (All)    | 223      | 21            | 382             | 150     | 53,645                  | 5.465              | 32.32 | 35.68 | 2.883-10.357  |
| Khenti (Inact)  | 158      | 6             | 95              | 110     | 8,780                   | 30.286 (±10.316)   | 34.06 | 5.56  | 13.251-69.222 |
| Khenti (Act)    | 59       | 6             | 95              | 110     | 8,780                   | 11.309 (±6.184)    | 54.69 | 5.21  | 3.084-41.472  |
| Khenti (All)    | 217      | 6             | 95              | 110     | 8,780                   | 41.595             | 29.32 | 9.54  | 21.843-79.210 |
| Sukh* (Inact)   | 412      | 25            | 444             | 98      | 55,167                  | 10.404 (±5.700)    | 54.82 | 24.78 | 3.619-29.911  |
| Sukh* (Act)     | 75       | 25            | 444             | 98      | 55,167                  | 1.894 (±0.962)     | 50.8  | 24.67 | 0.706-5.084   |
| Sukh* (All)     | 487      | 25            | 444             | 98      | 55,167                  | 12.298             | 47.10 | 26.20 | 4.902-80.852  |
| All (Inactive)  | 740      | 52            | 921             | 95      | 117,592                 | 9.924 (±3.180)     | 32.04 | 52.84 | 5.301-18.579  |
| All (Active)    | 170      | 52            | 921             | 95      | 117,592                 | 2.280 (±0.802)     | 35.02 | 52.52 | 1.149-4.525   |
| All (All)       | 910      | 52            | 921             | 95      | 117,592                 | 12.204             | 26.97 | 60.45 | 7.123-20.735  |

\* Sukh = Sukhbaatar.

than 2005 but basically unchanged between 2006 and 2007 (Tables 2, 4 and 6; Fig. 4). In comparing each aimag for 2006 and 2007, estimated marmot densities were much higher in 2007 for Dornod (2.538 per km<sup>2</sup>) and lower in Khenti (0.176 per km<sup>2</sup>) and Sukhbaatar (0.046 per km<sup>2</sup>) than in 2006 (0.197, 0.674, and 0.108 per km<sup>2</sup>, respectively; Fig. 5).

Table 6.

Number of observations, transect number and length, effective strip width (ESW), size of the study area and density estimates (D = density of individuals,  $\hat{D}_g$  = density of groups) for mar-mots for 2007 in the Eastern Steppe, Mongolia.

| Location        | No. obs. | No. transects | Length (km) | ESW (m) | Area (km <sup>2</sup> ) | Dens. per km <sup>2</sup> ( $\pm$ SE) | CV     | df    | 95% CI      |
|-----------------|----------|---------------|-------------|---------|-------------------------|---------------------------------------|--------|-------|-------------|
| Dornod (D)      | 106      | 10            | 136.7       | 477.6   | 19355                   | 2.538 ( $\pm$ 1.311)                  | 51.6   | 12.02 | 0.880-7.318 |
| Dornod (Ds)     | 96       | 10            | 136.7       | 477.6   | 19355                   | 1.633 ( $\pm$ 0.839)                  | 51.35  | 11.79 | 0.568-4.696 |
| Khenti (D)      | 11       | 8             | 118.8       | 477.6   | 14431                   | 0.176 ( $\pm$ 0.162)                  | 92.17  | 7.63  | 0.028-1.093 |
| Khenti (Ds)     | 9        | 8             | 118.8       | 477.6   | 14431                   | 0.176 ( $\pm$ 0.162)                  | 92.17  | 7.59  | 0.028-1.093 |
| Sukhbaatar (D)  | 3        | 8             | 152.3       | 477.6   | 16710                   | 0.046 ( $\pm$ 0.048)                  | 105.39 | 8.47  | 0.006-0.330 |
| Sukhbaatar (Ds) | 2        | 8             | 152.3       | 477.6   | 16710                   | 0.031 ( $\pm$ 0.031)                  | 99.98  | 7.49  | 0.004-0.213 |
| All (D)         | 201      | 26            | 408         | 477.6   | 50496                   | 1.038                                 | 49.03  | 12.7  | 0.380-2.837 |
| All (Ds)        | 107      | 26            | 408         | 477.6   | 50496                   | 0.686                                 | 47.81  | 12.9  | 0.257-1.834 |

Table 7.

Number of observations, transect number and length, effective strip width (ESW), size of the study area, and density estimates for burrow clusters (Act = active, Inact = inactive) for 2007 for the Eastern Steppe, Mongolia.

| Location       | No. obs. | No. trans. | Length (km) | ESW (m) | Area (km <sup>2</sup> ) | Dens. per km <sup>2</sup> ( $\pm$ SE) | CV    | df    | 95% CI         |
|----------------|----------|------------|-------------|---------|-------------------------|---------------------------------------|-------|-------|----------------|
| Dornod (Inact) | 743      | 9          | 127         | 150     | 19,355                  | 59.668 ( $\pm$ 35.25)                 | 59.08 | 59.08 | 16.933-210.260 |
| Dornod (Act)   | 265      | 9          | 127         | 150     | 19,355                  | 21.281 ( $\pm$ 13.864)                | 65.15 | 65.15 | 5.410-83.716   |
| Dornod (All)   | 1008     | 9          | 127         | 150     | 19,355                  | 80.949                                | 46.86 | 10.59 | 30.217-216.860 |
| Khenti (Inact) | 360      | 8          | 119         | 150     | 14,431                  | 24.825 ( $\pm$ 6.737)                 | 27.25 | 8.34  | 13.484-45.704  |
| Khenti (Act)   | 49       | 8          | 119         | 150     | 14,431                  | 3.379 ( $\pm$ 1.041)                  | 30.81 | 8.01  | 1.688-6.766    |
| Khenti (All)   | 409      | 8          | 119         | 150     | 14,431                  | 28.204                                | 24.44 | 9.13  | 16.377-48.573  |
| Sukh* (Inact)  | 229      | 8          | 152         | 150     | 16,710                  | 11.209                                | 94.95 | 7.03  | 1.687-74.479   |
| Sukh* (Act)    | 26       | 8          | 152         | 150     | 16,710                  | 1.273 ( $\pm$ 1.252)                  | 98.39 | 7.03  | 0.182-8.891    |
| Sukh* (All)    | 255      | 8          | 152         | 150     | 16,710                  | 12.481                                | 85.88 | 7.23  | 2.178-71.541   |
| All (Inact)    | 1276     | 25         | 399         | 113     | 50,496                  | 31.462 ( $\pm$ 12.170)                | 38.68 | 24.36 | 14.567-67.955  |
| All (Act)      | 321      | 25         | 399         | 113     | 50,496                  | 7.914 ( $\pm$ 4.409)                  | 55.7  | 24.17 | 2.708-23.133   |
| All (All)      | 1597     | 25         | 399         | 113     | 50,496                  | 39.377                                | 32.93 | 30.85 | 20.466-75.765  |

\* Sukh = Sukhbaatar.

### *Burrow clusters density estimates*

The density of inactive burrow clusters stayed the same from 2005 to 2006, but the density of the active burrow clusters increased (Fig. 6). The density of both active and inactive burrow clusters increased in 2007. The proportion of active burrow clusters increased from 4% in 2005 to 19% in 2006 and 20% in 2007 (Fig. 6).

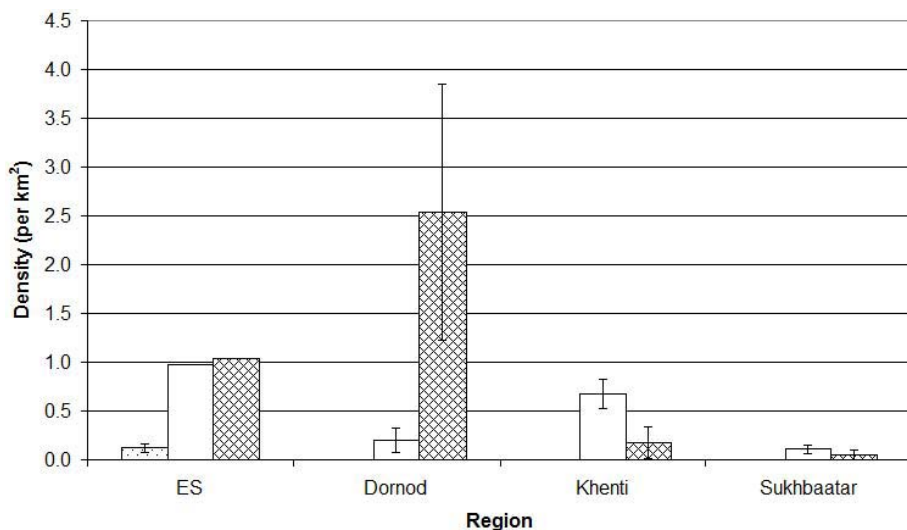


Fig. 5. — Marmot density (no. per km<sup>2</sup>) for the Eastern Steppe (ES) for each aimag for each year: 2005 (dots), 2006 (white), and 2007 (hatch). Error bars show standard error (SE).

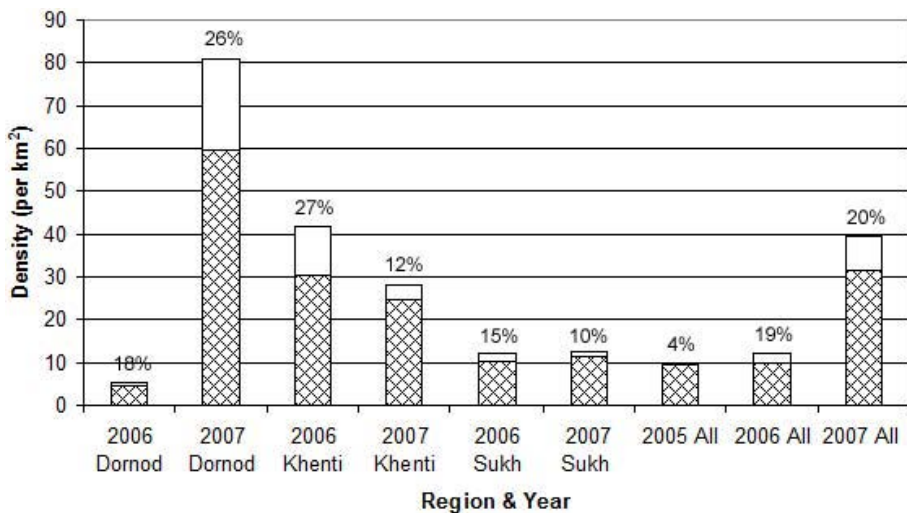


Fig. 6. — Active (white) and inactive (hatch) burrow cluster density (no. per km<sup>2</sup>) for each region and year. Percent active burrow clusters at top of bar.

## DISCUSSION

Our findings from 2005 indicated a catastrophic decline in many areas based on comparison with estimates in the literature (TOWNSEND & ZAHLE

2006, see also BATBOLD et al. 2000). While our sampling effort was not sufficient to show trends, we detected greater densities of marmots in 2006 and 2007 from a low in 2005 for the Eastern Steppe (Figs 4-5). In 2006, the highest marmot and burrow cluster densities were detected in Khenti, which then decreased in 2007. In 2007, we surveyed the southeast corner of Khenti aimag which may support lower numbers of marmots than the mountain steppe to the north, which is where we surveyed in 2005 and 2006. In 2007, we detected the highest marmot and burrow cluster densities in Dornod, which may in part be due to the hunting ban. Marmot and burrow cluster densities stayed low in Sukhbaatar throughout the 3 year study; this finding indicates that Sukhbaatar aimag may not be benefitting from the hunting ban as well as other aimags in the Eastern Steppe. Other factors such as naturally low marmot densities and drying of some areas may be contributing to these low numbers. These results provide evidence that the hunting ban may indeed be aiding the recovery of marmots in the Eastern Steppe; however, Sukhbaatar and, to some extent, the Khenti are not recovering as quickly as Dornod due to unknown factors. Perhaps a more critical measurement of the health and potentially increasing marmot population is the percent of active burrow clusters. Active burrow clusters indicate those areas where marmots are currently extant and presumably breeding; the density and percentage of active burrow clusters increased from 2005, an indication that the population may becoming more healthy. We noted an increase from a low of 4% active overall in 2005 to 19% active in 2006 and 20% active in 2007 (Table 3).

Continuing to monitor marmot density in the Eastern Steppe would help to assess the effectiveness of the marmot hunting ban. Additionally, we have an opportunity to measure the effects of removing a keystone species. If indeed the marmot is a keystone species, then the ecosystem integrity may depend on their presence; there may be particular thresholds of marmot densities below which other taxa cannot persist or thrive. While untested, we believe that marmots may have a strong positive effect on other species like corsac fox, badger, souslik and hedgehog by providing shelter in their vacant burrows. Furthermore, they are prey for animals like the wolf and large predatory birds. Therefore, effective conservation efforts for the Eastern Steppe ecosystem likely rely on conservation of the marmot.

Determining life history parameters would further assist conservation efforts by being able to reliably calculate recovery rates. Siberian marmot life history traits such as fecundity, survivorship, family composition, space use and dispersal distance remain unknown for the Eastern Steppe. Marmots have some peculiarities to their breeding system that are relevant to their recovery. Only half the marmot females of breeding age breed each year, and they generally do not breed until they are 2 years old. When hunting resumes, limits and enforcement of hunting regulations will be important in preventing another massive decline and to further recovery.

Mongolia is well positioned to implement an exemplary role in wildlife conservation. The sustainable, enduring lifestyle of many of its citizens coupled with a heartfelt connection with the natural world make Mongolians ideal stewards. Indeed, changes to the environmental law designed to facilitate community-based natural resource management and wildlife protection bears this out.

We fully support local communities managing their resources within the given guidelines and believe this local management could be particularly useful for conserving marmots. Currently within the Eastern Steppe, 69,211 km<sup>2</sup> (24.4%) are in specially managed zones (National Park, Strictly Protected Area, Nature Reserve, National Historic Monument, and Buffer Zone); however, the key to recovery may be that, in addition to these protected areas, local families are able to participate in protecting and managing their natural resources (214,245 km<sup>2</sup> or 75.6% of the Eastern Steppe) which include marmots. In addition, the political will as expressed by the central government has already aided and can continue to aid recovery through enforcement of existing environmental laws (READING et al. 1998, ZAHLER et al. 2004, WINGARD & ZAHLER 2006).

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