

# Mongolian Racerunners (*Eremias argus*) Occupancy in Active and Inactive Siberian Marmot (*Marmota sibirica*) Colonies

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## Abstract

Habitat fragmentation caused by anthropogenic activities alters the distribution, abundance and diversity of wildlife species worldwide. As one example, Siberian marmots have experienced a >75% decline across Mongolia since the 1990s due to human harvests. Burrowing mammals are keystone; ecosystem engineers in many communities because burrowing can directly and indirectly alter the availability of resources, have effects at multiple spatial and temporal scales, and have a significant role in community organization. The deep and complex burrow systems of marmots provide underground shelters with stable microclimates that other vertebrate and invertebrate animals exploit. Our general hypothesis was that marmot colonies positively influence racerunner occupancy probability because burrows offer shelter from environmental conditions, refuges for predation, and a high diversity and number of insects and other prey items. Using occupancy modeling, we showed that the presence of a Siberian marmot colony influenced racerunner occupancy. Marmot active colony + inactive colony-  $\psi$  (AMC+IMC),  $p$  (temp+temp<sup>2</sup>) were the best approximating model. Racerunner detection was highest at approximately 24.3°C. For the aspect and elevation model, foothills had an important influence on lizard occupancy. Our results showed that marmot burrows greatly influence Mongolian racerunner occurrence and suggest that habitat modification by rodent ecosystem engineers exert ecological influence on biodiversity.

**Keywords:** Siberian marmot; Burrow; *Marmota sibirica*; Mongolian lizard; Keystone; *Eremias argus*

## Introduction

Siberian marmots (*Marmota sibirica*) are relatively large (approximately 3.9-4.2 kg as adults), herbivorous rodents that burrow and live colonially. Historically, this abundant and widely distributed species occurred throughout much of the steep, lowland valleys, hills, and mountain slopes of eastern and northeastern Mongolia [1]. Highly endangered in Mongolia (IUCN Red List 'EN'; criteria A2 ad) Siberian marmots have experienced a >75% decline across Mongolia in the 1990s [2]. The burrows of Siberian marmot are complex, with branching tunnels and a variable number of chambers used for food storage, sleeping, and as latrines. Burrow structure differs depending on season and use, with different structures for hibernation, summer use, maternity dens, and protection [3]. Hibernation burrows measured approximately 5-18 m (45m) in length and 0.2-0.5 m<sup>3</sup> in volume in a mountain region of Mongolia [4]. We and others [4-7] hypothesize that Siberian marmots play a keystone role as ecosystem engineers in the ecosystems they inhabit; however, we require more research on the species' ecological role and whether or not marmot colonies represent biodiversity hotspots.

Siberian marmots appear to play a similar ecological role to that of black-tailed prairie dogs (*Cynomys ludovicianus*) in the Great Plains of North America [8-13]. For example, prairie dog and kangaroo rat mounds provide cool, moist microclimates and harbor large numbers of arthropods, the principle prey of lizards, so lizards may also associate strongly with mound habitats for temperature regulation and abundance of prey [14,15]. By providing a network of basking sites for thermoregulation, foraging locations, and refuge for lizards across landscape, burrows likely represent in more favorable habitat and offer higher survivorship than the surrounding landscape. These findings are consistent with research that found lizard abundance correlated with the availability of rodent burrows [16,17].

We examined the influence of marmots on the Mongolian racerunner (*Eremias argus*). The Mongolian racerunner is a small (SVL=30.9-65.8 mm) [18], oviparous Lacertid lizard distributed throughout Mongolia. Endemic to eastern Asia, the species is listed as endangered in South Korea [19,20]. The Mongolian racerunner is the dominant lizard in habitat with dense vegetation. Predation risk likely differs by habitat, depending on the amount of shelter [20]. Main predators of the lizard in Mongolia include the Lesser Kestrel (*Falco naumanni*), Common Kestrel (*F. tinninulus*), Grey Shrike (*Lanius excubitor*), and corsac fox (*Vulpes corsac*) [20,21].

Here, we estimate Mongolian racerunner occurrence in relation to the availability of marmot colonies. More specifically, we examined the influence of colonies on the probability of a racerunner occurring within a given part of the landscape. Our general hypothesis was that marmot colonies positively influence racerunner occupancy probability because burrows offer shelter from environmental conditions, refuges for predation, and a high diversity and number of insects and other prey items. We also examined alternative hypotheses focused on the influence of forest steppe habitats of Hustai National Park, including open plains, foothills, upper slopes, drainages and near springs. Our approach involved 1) developing a set of *a priori* candidate models

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that we believed potentially described racerunner occupancy in the landscape, 2) surveying racerunners at multiple sites to collect detection data and information on marmots and habitat features associated with each site, and 3) using model selection to rank models and evaluate which best represented the data.

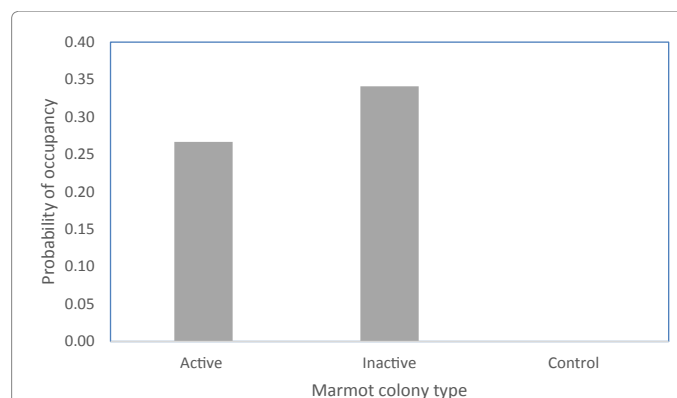
## Study area

We conducted the study in Hustai National Park, situated 100 km southwest of Ulaanbaatar, the capital city of Mongolia, and occupying 60,000 ha at elevations ranging from 1,100 to 1,840 m above sea level. The National Park occurs at the southern edge of the forest-steppe zone and includes mountains, plains, dunes, river valleys, and numerous ravines. Several vegetation types of the forest-steppe and typical steppe zones are represented. The region receives <240 mm of annual precipitation, which falls mostly as rain (80%) from June to August, and temperatures range from -35°C to +38°C. The southern slopes of the park's mountains are covered with petrified soil, while the northern mountain slopes are covered with sandy brown soil [22]. About 88% of the area is covered by grassland and shrub-land steppe and ca 5% is covered by birch-dominated forest. Vegetation is dominated by bunch grass (*Stipa krylovi*), with *Artemisia adamsii*, *Artemisia frigida*, *Agropyron cristatum* and *Cymbario dahurica* as typical species [23]. Marmot density was higher in the park than surrounding areas, with the population density of marmots 70.6 families/km<sup>2</sup> with 100% of colonies occupied in Hustai, whereas only 3 km from the park border the density was 32.5 marmot families/km<sup>2</sup> with only 30% of identified colonies inhabited [2].

## Methods

We surveyed 130 sites, including 45 inactive colony sites, 42 off-colony (i.e., non-colony) sites and 43 sites on active colonies in the summer of 2016. We identified 150 random points and from those selected 130 survey sites based on the similarity of locations (active colony, inactive colony, off-colony) with respect to elevation and presence of rocky outcroppings using a digitized land cover layer using ArcGIS version 10.3 (ESRI, Redlands California, USA) and based on information we obtained from rangers of the national park (Figure 1). We visited all selected points and defined an active marmot colony as one on which we observed living marmots or that exhibited signs of recent marmot activity, including  $\geq 3$  open burrows with fresh scat and tracks. We ensured that sampling sites were spaced >500 m to ensure independence as per Murdoch et al. [24]. In our sampling approach, we surveyed a single of location multiple times within a short time period. During each survey we maintained a list species detected, hence allowing us to construct a "capture history" for each species at the conclusion of sampling [25]. We recorded lizard occupancy 3 times per sampling site in June, July and August.

Each sampling site encompassed a 25 m radius circular plot. For each survey, we marked the plot, then waited for 15 min at a distance of >100 m before beginning the survey to minimize the influence of the single surveyor. We estimated air temperature and wind speed (at the plot center) using a handheld weather station (measured with a Kestrel 3000 Pocket Weather Meter) at the beginning of each survey, then an observer walked through the plot in a zig-zag pattern for 5 min and recorded whether racerunners were present (1) or absent (0). We based the survey time on trials before the study began that indicated racerunners were usually quickly detected and that a longer survey period did not yield new detections. All surveys occurred between 800 and 1700 h.



**Figure 1:** Mongolian racerunner (*Eremias argus*) occupancy probability  $\psi$  (AMC+IMC) as a function of the proportion of active Siberian marmot (*Marmota sibirica*) colony site, inactive colony and control sites within 250 m of each location. Probability estimated from the highest ranked model of occupancy data collected in Hustai National Park, Mongolia from June to August, 2016.

At each site, we quantified habitat on the basis of substrate. We classified habitats by aspect and elevation as 1) a foothill, which included a low hill at the base of a mountain, 2) an upper slope, which included the side of a hill or mountain, 3) an open plain, which included gently rolling gravel plains with short grasses and forbs, or 4) a drainage, which included sites in which surface and sub-surface water naturally flowed from an area.

Occupancy modeling is a statistical tool developed to estimate population parameters and investigate the influence of habitat variables on those parameters [25]. We used single-season occupancy models implemented in the program PRESENCE (v. 4.4, J. E. Hines, Patuxent Wildlife Research Center, Laurel, Maryland, USA) adjusted for detection probabilities. We ranked models by their AIC (Akaike Information Criterion) scores, corrected for small sample size (AIC<sub>c</sub>), and (AIC weight) in the program PRESENCE for model selection [26]. We considered the model with the smallest AIC<sub>c</sub> value to be the best model to fit the data and any model within 2 AIC<sub>c</sub> values as a competing model [26]. We used Akaike weights to assess the strength of evidence of one model versus another model. We report all means  $\pm 1$  standard deviation.

## Results

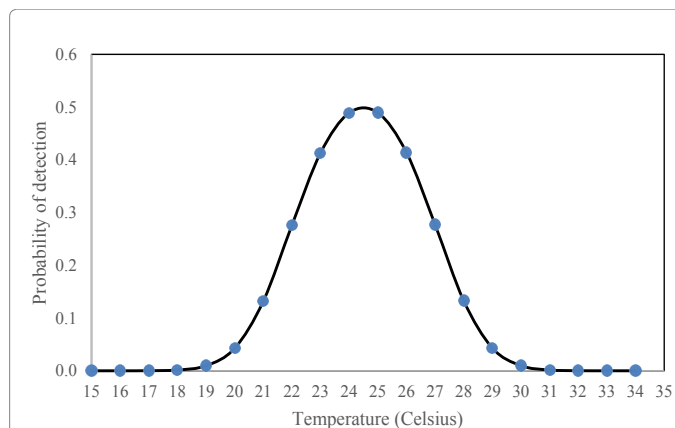
We conducted 390 surveys and detected racerunners during 16.4% (n=59) of them. We detected racerunner at 8 active marmot sites and 12 inactive burrow sites, resulting in a naïve occupancy estimate (i.e., total number of sites where we detected racerunners/total number of sites surveyed) of 0.154 across all sites. Air temperature in the survey ranged from 17.4-38.0°C (mean=24.23  $\pm$  0.26). The mean percent of habitat types surrounding each survey site was: 28  $\pm$  0.2 foothills, 33  $\pm$  0.1 drainages, 25  $\pm$  0.2 open plains and 14  $\pm$  0.1 upper slopes.

Bootstrap analysis indicated that our data fit the assumptions of single-season occupancy modelling [25]. The  $\chi^2$  for the observed data was 4.7417 and probability of this value was 0.49 (mean  $\chi^2$  of bootstrap simulation=4.9348). Given little evidence for a lack of fit, we used model selection procedures to estimate the weight of evidence of all models in the model set.

Model selection results indicated that racerunner occupancy is influenced by the presence of a Siberian marmot colony: Marmot

active colony + inactive colony-  $\psi$  (AMC+IMC),  $p$  (temp+temp<sup>2</sup>) were the best approximating model (Table 1). This model accounted for 96.7% of the AIC<sub>c</sub> weight among the competing models, with no competing model <1  $\Delta$ AIC<sub>c</sub>. Inclusion of foothill to the old burrow  $\psi$  (NAB+foothill),  $p$  (temp+temp<sup>2</sup>) produced the 2<sup>nd</sup> ranked model (AIC<sub>c</sub> weight=1.6%), followed by exclusion of Marmot active colony from the best model (Table 1, AIC<sub>c</sub> weight=0.4%). Remaining models were  $\geq 10.6 \Delta$ AIC<sub>c</sub> from the best model. Beta ( $\beta$ ) coefficients for both marmot active colony and inactive colony were positive, indicating that as the percent of these habitats increased around a given site in the landscape, occupancy probability increased (Table 2). Confidence intervals (95%) around these betas also did not cross zero, suggesting that the effect of these parameters on occupancy was real (Table 2). Considering additional habitat parameters, foothill was the most important factor influencing lizard occupancy (Table 3).

Our top model estimated an effect of temperature on detection probability. Beta estimates from the model (Table 2) indicated that detection probability was 0.87-1.97 (20.8-27.1°C). Racetracker detection was highest at approximately 1.2 (24.3°C) (Figure 2).



**Figure 2:** Mongolian racetracker (*Eremias argus*) probability of detection  $p$  (temp+temp<sup>2</sup>) as a function of temperature. Probability estimated from the highest ranked model of occupancy data collected in Hustai National Park, Mongolia from June to August, 2016.

Covariate name	Description	Measure	Predicted effect on $\psi$	Supporting Literature
<b>Marmot colony</b>	Occupancy probability influenced by active and inactive marmot colony.	Meter	Positive	[7,27,36]
<b>Control site</b>	No sign of marmot burrows or activity	Meter	Negative	[36]
<b>Upper slope</b>	Includes the side of a hill or mountain	Proportion	Negative	[28]
<b>Foothill</b>	Includes a low hill at the base of a mountain	Proportion	Positive	[28]
<b>Drainage</b>	Includes an area in which surface and sub-surface water naturally flows from the site	Proportion	Positive	[28]
<b>Open plain</b>	Includes gently rolling gravel plains with short grasses and forbs	Proportion	Positive	[24,27]
<b>Near spring</b>	Includes lowland and meadow	Proportion	Negative	[28]

**Table 1:** Response variables used to examine Mongolian racetracker (*Eremias argus*) occupancy probability ( $\psi$ ) in Hustai National Park, Mongolia from June to August, 2016.

Model	AIC <sub>c</sub>	$\Delta$ AIC <sub>c</sub>	Weight	Supporting Literature
psi(AMC+IMC),p(temp+temp_sq)	164.51	0	0.9673	6
psi(IMC+foothill),p(temp+temp_sq)	172.62	8.11	0.0168	6
psi(IMC),p(temp+temp_sq)	175.12	10.61	0.0048	5
psi(IMC+OP),p(temp+temp_sq)	175.28	10.77	0.0044	6
psi(foothill),p(temp+temp_sq)	176.36	11.85	0.0026	5
psi(AMC+foothill),p(temp+temp_sq)	177.45	12.94	0.0015	6
psi(AMC+IMC),p(.)	178.8	14.29	0.0008	4
psi(.),p(temp+temp_sq+const)	179.68	15.17	0.0005	6
psi(OP),p(temp+temp_sq)	179.68	15.17	0.0005	5
psi(Drain),p(temp+temp_sq)	179.93	15.42	0.0004	5
psi(AMC),p(temp+temp_sq)	179.99	15.48	0.0004	5
psi(foothill),p(.)	189.95	25.44	0	3
psi(.),p(.)	192.91	28.4	0	2

**Table 2:** Model selection results of Mongolian racetracker (*Eremias argus*) probability of occupancy ( $\psi$ ) showing the fit of 16 models to observed data collected in Hustai National Park, Mongolia from June to August, 2016. All models included temperature (modeled as a polynomial: temp + temp<sup>2</sup>) as a detection (p) covariate. Occupancy covariates included: active Siberian marmot (*Marmota sibirica*) colony (AMC), inactive marmot colony (IMC), control site (CS), foothill (BTM), open plain (OP), drainage (Drain), and upper slope (UPM) within 250 m of a site.

Model $\psi$ (AMC+IMC), (temp+temp <sup>2</sup> )	$\beta$ estimate	SE	UCI	LCI
$\psi$ intercept	-165.756	0.395	-165.361	-166.151
Active marmot colony	164.745	0.518	165.263	164.227
Inactive marmot colony	165.097	0.466	165.563	164.631
p intercept	-91.898	1.188	-90.71	-93.086
Temperature	150.013	0.654	150.667	149.359
Temperature <sup>2</sup>	-61.223	0.726	-60.497	-61.949

**Table 3:** Parameter estimates with standard errors (SE) and upper (UCI) and lower (LCI) confidence intervals for the top three ranked models of Mongolian racetracker (*Eremias argus*) occupancy data collected in Hustai National Park, Mongolia from June to August, 2016. Occupancy ( $\psi$ ) parameters included an intercept and sites (active Siberian marmot, *Marmota sibirica*, colony, inactive marmot colony, foothill). Detection (p) parameters included an intercept and temperature (modeled as a polynomial: temperature + temperature<sup>2</sup>).

For the aspect and elevation model, foothill was an important influence on lizard occupancy (0.55, Table 1). By comparison, the variable importance for drainage=0.20, for open plain=0.15, and for upper slope=0.05.

## Discussion

Most mammals use shelter of some sort either daily or seasonally. The advantages of using burrows, even if just for shelter, are clear because the burrow environment is significantly more moderate than the above-ground environment. For example, soil temperature fluctuates much less even a few centimeters into the soil than it does at the soil surface [27-29]. Burrows also protect their inhabitants from wind, rain, and snow during inclement weather. Several reptiles and birds construct their nests or lay eggs within burrows and insectivorous mammals that frequently have no shelter of their own also live in the burrows created by other species.

Siberian marmot presence and activities can influence species occupancy, abundance, or persistence within a landscape [7,30,31]). Their burrows provide shelter for many native species [29,32], such as corsac foxes [7], red foxes (*Vulpes vulpes*), Pallas' cats (*Otocolobus manul*), badgers (*Meles spp.*) and hedgehogs [33]. Our results indicated that ecosystem engineering by Siberian marmot had a keystone-level effect on Mongolian lizard occupancy within different habitat types in the study area. Impressively, Mongolian lizard occupancy was 96.7% on marmot active and in active burrows (Table 2). Especially interesting was our finding that lower elevation affects lizard occupancy. Occupancy by many other reptiles in other ecological systems were largely associated with rodent burrows, possibly for the availability of habitat patches [15,34], food resources [11,14,15], and dens for hibernacula [35].

Relatively few studies have examined reptile and amphibian habitat relationships [36,37]. Murdoch, et al. [24] showed that Siberian marmot colonies had little influence on toad headed agama (*Phrynocephalus versicolor*) occupancy within a semi-desert ecosystem in Mongolia. Davidson et al. [14] found that the mounds and burrow systems of Gunnison's prairie dogs (*Cynomys gunnisoni*) and banner-tailed kangaroo rats (*Dipodomys spectabilis*) provided important habitat for lizards, with lizard abundance being 2 to 4 times higher on mounds than in adjacent areas without mounds. Prairie dogs and banner-tailed kangaroo rats co-occur in that environment, and Davidson and Lightfoot [11] demonstrated that those species exert distinctive effects on plants and arthropods and that their combined effects are additive and complementary, suggesting that they may have similar effects on lizard communities. In another study, certain species of reptiles and amphibians preferred the open grassland habitat of prairie dog colonies, while others preferred uncolonized, denser grassland habitat [38].

Physical properties of soil, partly dependent on vegetation [39], may affect burrow selection by lizard species [34]. In semi-desert grasslands, the *Caragana* bush provides shelter for racerunners to reproduce and avoid predation [40]. Mongolian racerunners prefer a body temperature lower than the high temperatures of midday in exposed terrain, so move to the cooler thermal environments provided by dense vegetation, thickets, and sand dunes. Ambient temperatures are important for reptiles to maintain key physiological and behavioral processes [41] and can influence microhabitat use [42,43]. Racerunners spent more time in shade and less time in full sun in midday [20].

The Mongolian racerunner's viable temperature range was greater than 28°C, and was less tolerant of low temperatures. Relative to other *Eremias* spp. lizards inhabiting the region, this critical thermal

maximum fell at a moderate level; with some species acclimated to higher temperatures (up to 33°C) [44]. Thermal environments change dramatically with latitude or altitude, with mean air temperature generally decreasing with an increase in latitude or altitude. Our results also provide a measure of the effect of temperature on racerunner detection. Probability of detecting the species at a given site was greatest at 24.3°C based on our model. Furthermore, our model estimated that detection probability is >71.8% between 23.1-25.8°C.

We worked hard to ensure that our active, inactive, and unoccupied sites were similar; however, it is possible that marmots selected some aspects of the environment that we did not consider, such as microclimate. Is so, those differences could also account for our findings, although we believe this unlikely.

Type of habitat may exert an effect on Mongolian racerunner occupancy, but we were unable to account for any effect in this analysis. Habitats at lower elevations, such as foothills, drainages, and open plains had little influence on occupancy probability at the National Park. Still, we believe that other habitat associations would make a good topic for future, more targeted research on the species.

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