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Estimates of Toad Headed Agama Density in Three Steppe Habitats of Mongolia

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Abstract

The toad headed agama (*Phrynocephalus versicolor*) ranges across the arid steppe regions of southern and western Mongolia and represents one of the most common reptiles in the country. However, few details of the species' population characteristics exist, which may be important for evaluating population trends and assessing its conservation status. We estimated toad headed agama density in Ikh Nart Nature Reserve, Mongolia based on surveys conducted in the summers (Jun-Sep) of 2005, 2006, 2008, and 2009. We conducted surveys in three steppe habitats including tall grassland (*n* = 7), shrub-steppe (*n* = 7), and semi-shrub steppe (*n* = 8), and calculated density using Distance methods. Mean density across all surveys was 66 agamas/ha (95 % C.I. = 48-92; range: 24/ha to 112/ha). Agamas occurred in highest density in shrub-steppe and lowest in semi-shrub across years. Density was similar between shrub-steppe and tall grassland. However, density in these habitats was significantly higher than in semi-shrub steppe. Our results provide baseline estimates of toad headed agama density, and indicate that agamas are capable of reaching higher density than previously recorded. Our results also suggest that agamas benefit from the cover afforded by more structurally complex vegetation communities like those found in shrub-steppe and tall grassland habitats.

Keywords: agama, density, *Phrynocephalus versicolor*, lizard, Mongolia, steppe

1. Introduction

Precise estimates of a species' population density provide a baseline for understanding life history patterns, monitoring population trends, and for some species, developing conservation strategies (BUCKLAND et al. 2001). Among vertebrates, lizards often exhibit highly variable densities that fluctuate seasonally, and in some ecosystems represent the most abundant species. In Mongolia, the lizard fauna is diverse and includes at least 13 species, many of which remain poorly studied (TERBISH et al. 2006b). Among the most widespread species in the country is the toad-headed agama (*Phrynocephalus versicolor*) (Fig. 1), which ranges across the Gobi Desert and Altai mountains, covering an area approximately a third of Mongolia's land area, and extending into southern Tuva, northern China, and southern Kazakhstan (ANANJEVA & TUNIYEV 1992; TERBISH et al. 2006a; GUO & WANG 2007). Toad headed agamas occupy a variety of steppe, semi-desert, and desert habitats and are considered one of the most abundant lizard (and vertebrate) species in northern Asia (ANANJEVA et al. 1997; ROGOVIN et al. 2001; WANG & FU 2004; TERBISH et al. 2006a, 2006b). However, few studies have estimated the density of the species and in many regions, distribution has been assumed based on maps of potentially suitable habitat (TERBISH et al. 2006b). Similarly, research on the species has focused mainly on taxonomy (PANG et al. 2003; WANG & FU 2004; GUO & WANG 2007) and details of the species' basic ecology are lacking (TERBISH et al. 2006a).

We conducted surveys of toad-headed agamas in steppe and desert-steppe habitats in central Mongolia using Distance sampling methods (BUCKLAND et al. 2001) during the summer months of 2005, 2006, 2008, and 2009. Our objectives were to 1) provide baseline estimates of agama density and 2) compare density between major habitat types.

Fig. 1: Toad-headed agama (*Phrynocephalus versicolor*) in Ikh Nart Nature Reserve, Mongolia. Photo © R. Reading.

2. Methods

Study area

We estimated agama density in the Ikh Nart Nature Reserve, which is located in Dornogobi Aimag of central Mongolia (45°43´N - 108°39´E, Fig. 2) (READING et al. 2006). Ikh Nart is a relatively small protected area (666 km^2) established in 1996 to protect a population of argali sheep (*Ovis ammon*) and the unique landscape of the region (MYAGMARSUREN 2000). The reserve occurs at the junction of steppe and semi-desert eco-zones in Mongolia (MURZAEV 1948) and includes grasslands, shrublands, and semi-shrublands in open, gently rolling terrain, and more rugged, rocky outcrops separated by narrow drainages (JACKSON et al. 2006). Vegetation is generally sparse and consists mainly of xerophytic and hyperxerophytic species (READING et al. 2006). Climate is arid and highly variable throughout the year. Temperature ranges from -40 to +43 °C and precipitation averages < 200 mm per year, falling mostly as rain during the summer (June, July, and August).

Toad-headed agamas occur widely throughout the reserve, but appear most abundant in steppe habitats (READING et al. 2006). The species hibernates during the winter (November to April), emerges in late April and remains active until October. Three other lizard species have been recorded in the reserve including Mongolian racerunner (*Eremias argus*), multi-cellated racerunner (*E. multiocellata*), and Gobi racerunner (*E. przewalskii*) (READING et al. 2006; TERBISH et al. 2006b). These species are rarely encountered and occur in low density relative to agamas in the region.

Line Transect Surveys

We conducted line transect surveys to estimate agama density in three steppe habitats using Distance methods (BURNHAM et al. 1980). We established ten 300 m parallel transects, each spaced 50 m apart in the following habitats: 1) Tall grassland, which was dominated by needle grass (*Achnatherum spendens*; Poaceae), characterized by sandy soils, and typically found in alluvial drainages; 2) Shrub-steppe, which was dominated by pea shrub (*Caragana pygmaea*;

Leguminosae), characterized by sandy soils, and typically found in open plains; and 3) Semi-shrub steppe, which was dominated by *Reaumuria* spp. (Tamaricaceae) and *Salsola* spp. (Chenopodiaceae) semi-shrubs, characterized by gravel soils, and typically found in open plains (JACKSON et al. 2006). These habitats represented the primary habitats in the steppe ecozone in the study area. We chose the location of the first transect in each habitat randomly and based transect length on the results of a pilot study in 2005 that estimated optimal transect length for statistical rigor following guidelines in BUCKLAND et al. (2001). We also based transect spacing on observations of agama movements during the pilot study to avoid multiple counts of the same individuals during surveys. We established transects using handheld GPS (Global Positioning System) receivers and compasses and marked them with flagging placed every 3 m.

Surveys involved two researchers slowly walking each transect line in a habitat and recording agama sightings. Researchers measured the perpendicular distance of each agama sighting to the transect line. Surveys were conducted in June, July, August, and September of 2005, 2006, 2008, and 2009, between 1000 h and 1300 h, and at temperatures between 25 and 35 °C, when agamas appeared to be most active. The optimal temperature range (and activity times) of the species is unknown to our knowledge, but estimated from the pilot study and an account of a population in China (QUAN & ZHANG 2006). We measured distances in cm using a tape measure and recorded temperatures at the start of each transect using a handheld weather meter (Kestrel 3000, Nielsen-Kellerman, Boothwyn, Pennsylvannia, USA). In some cases, agamas moved prior to detection, possibly introducing a source of bias into our estimate (BURNHAM et al. 1980). However, these cases were rare and movement distances were short (<50 cm; based on backtracking of agamas).

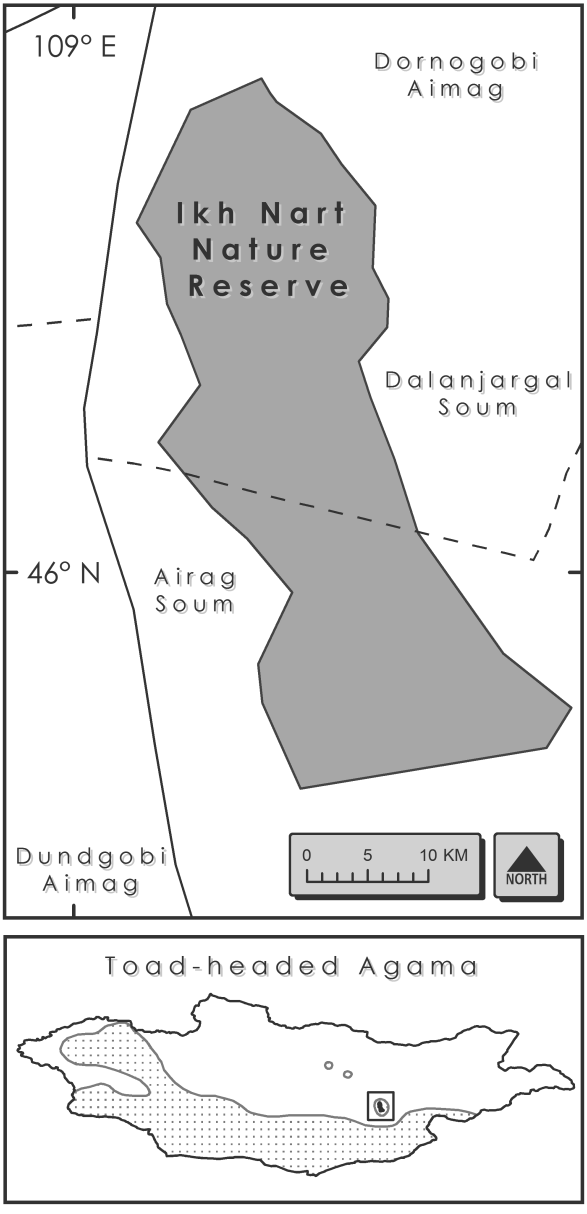

Fig. 2: Map of Ikh Nart Nature Reserve, Mongolia relative to soum (dashed lines), aimag (solid lines), and country (inset below) borders. Distribution of toad-headed agama (*Phyrnocephalus versicolor*) estimated by TERBISH et al. 2006a shown below.

Density estimation

We estimated density as agamas/ha using the computer program Distance 6.0 (THOMAS et al. 2006). We allowed the program to select among a variety of possible estimators, based on minimum Akaike Information Criterion (AIC; -2*ln-likelihood + 2 m, where m = the number of parameters; see LAAKE et al., 1993). Possible estimators included half normal, negative exponential, hazard-rate, and uniform models with cosine, polynomial, hermite polynomial, or no adjustments (BUCKLAND et al. 2001). We selected estimators whose probability detection function model was not significantly different from the distribution of actual observations using a Chi-square Goodness-of-Fit tests (BURNHAM et al. 1980, 1985; BUCKLAND et al. 2001). We set significance at $P < 0.05$ and determined 95 % confidence limits (C.L.) for mean population density estimates.

3. Results

We conducted 22 surveys, including seven in tall grassland, seven in shrub-steppe, and eight in semi shrub-steppe (Table 1). Mean density of all surveys was 66.1 agamas/ha (95% C.L. = 47.8 - 92.2), and ranged from 24.3 agamas/ha (95 % C.L. = 17.1 - 34.8) in semi-shrub steppe in July 2008 to 111.9 agamas/ha (95% C.L. = 90.9 - 137.7) in shrub-steppe during August 2005 (Table 1). Mean density was 75.9 agamas/ha (95 % C.L. = 57.1 - 101.1) for all tall grassland surveys, 87.6 agamas/ha (95% C.L. = 64.2 – 120.3) for all shrub-steppe, and 34.7 agamas/ha (95 % C.L. = 22.1 - 55.3) for all semi-shrub steppe (Fig. 3). Thus, we found significantly lower mean agama density in semi-shrub habitats than in tall grassland and shrub-steppe habitats, which were statistically similar. Agama density was highest in 2005 and 2006 and lowest in 2008 and 2009 (Fig. 4). However, differences between years were not significant based on confidence intervals (Fig. 4).

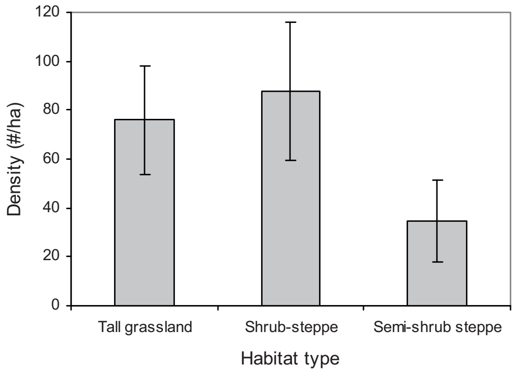

Fig. 3: Mean (± 95 % confidence limits) toad headed agama (*Phrynocephalus versicolor*) density in three steppe habitats in Ikh Nart Nature Reserve, Mongolia. Density estimates based on surveys (n = 22) conducted in summer (June-September) in 2005, 2006, 2008, and 2009 and calculated using Distance methods (BUCKLAND et al. 2001).

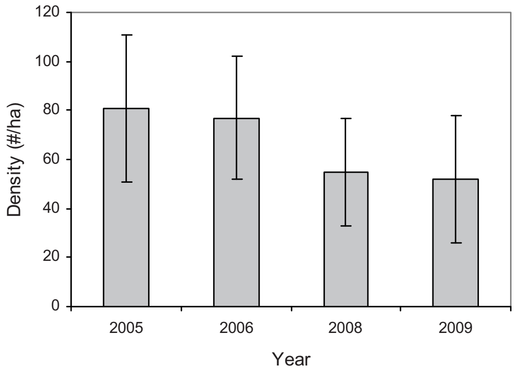

Fig. 4: Mean (± 95% confidence limits) toad headed agama (*Phrynocephalus versicolor*) density in Ikh Nart Nature Reserve, Mongolia in 2005, 2006, 2008, and 2009. Density estimates based surveys (n = 22) conducted in summer (June-September) in three steppe habitats, including tall grassland, shrub-steppe, and semi-shrub steppe, and calculated using Distance methods (BUCKLAND et al. 2001).

Table 1: Toad headed agama (*Phrynocephalus versicolor*) density estimated in three steppe habitats in Ikh Nart Nature Reserve, Mongolia from 2005 to 2008. Estimates based on line transect surveys conducted using Distance methods (BUCKLAND et al. 2001). For details on models used to estimate density, see methods section and THOMAS et al. (2006)

Habitat	*Month*	*Year*	*Density (#/ha)*	*95% C.L.*	*Model*	*Adjustments*
Tall grassland	Jul	2005	102.2	8,024 - 13,026	Hazard$^{\Psi}$	Cosine
	Jun	2006	105.6	7,875 - 14,169	Hazard	None
	Jul	2008	76.1	5,878 - 9,839	Hazard	None
	Aug	2008	54.8	3,902 - 7,681	½ Normal†	None
	Aug*	2008	45.6	3,312 - 6,268	Uniform‡	Poly (2)$^{\lambda}$
	Jul	2009	45.4	3,184 - 6,476	Hazard	None
	Jul	2009	28.3	1,985 - 4,186	Uniform	Cosine
Shrub-steppe	Jul	2005	105.4	6,955 - 15,975	Hazard	Cosine
	Aug	2005	111.9	9,090 - 13,765	Uniform	Poly (2, 4)$^{\lambda}$
	Jun	2006	84.7	6,581 - 10,889	Hazard	None
	Jul	2008	80.9	6,391 - 10,249	Hazard	Poly (4, 6, 8)$^{\lambda}$
	Aug	2008	70.5	4,638 - 10,706	Neg. Exp. $^{\gamma}$	None
	Jul	2009	71.9	4,851 - 10,658	Uniform	Cosine
	Sep	2009	90.6	6,273 - 13,090	Uniform	Cosine
Semi-shrub	Aug	2005	33.2	2,166 - 5,088	Hazard	None
	Jul	2006	36.7	2,458 - 5,382	½ Normal	None
	Jul	2006	40.4	2,935 - 5,566	½ Normal	Cosine (2)
	Jul	2008	24.3	1,705 - 3,475	Hazard	None
	Aug*	2008	32.9	1,717 - 6,287	Neg. Exp.	None
	Jul	2009	27.9	1,512 - 5,150	Hazard	None
	Aug	2009	50.1	3,127 - 8,669	Neg. Exp.	None
	Sep	2009	36.8	2,173 - 6,214	Uniform	Cosine

$^{\Psi}$ Hazard = hazard rate key model: $k(y) = 1 - \exp(-(y/A(1))^{-A(2)})$, where k = the number of samples, y = the distance, and $A(i)$ = the ith parameter in the estimated probably function.

† ½ Normal = half normal key model: $k(y) = \exp(-y^2/(2*A(1)^2))$, where k = the number of samples, y = the distance, and $A(i)$ = the ith parameter in the estimated probably function.

‡ Uniform = uniform key model: $k(y) = 1/W$, where k = the number of samples and W = the wdith of the line transect.

$^{\gamma}$ Neg. Exp. = negative exponential key model: $k(y) = \exp(-y/A(1))$, where k = the number of samples, y = the distance, and $A(i)$ = the ith parameter in the estimated probably function.

$^{\lambda}$ Poly = polynomial; numbers refer to the number of orders used in the adjustment.

* Total number of observations <40, which is the minimum number recommended by the analysis program Distance 5.0 (BURNHAM et al. 1980, LAAKE et al. 1993).

4. Discussion

Toad headed agama density averaged 66/ha and reached 111/ha in Ikh Nart Nature Reserve, indicating that the species probably represents one of the most abundant vertebrates in the reserve. Toad headed agama density in Ikh Nart was higher than estimates elsewhere in Mongolia. For example, ROGOVIN et al. (2001) surveyed 45 1-hectare grids in the northern deserts of Mongolia and reported that agama density averaged 37/ha across them. Our results were also considerably higher than estimates from outside of Mongolia. QUAN and ZHANG (2006), for example, estimated density as 0.6/ha in the Xinjing Zhunge’er Basin, China. Other *Phryno-*

cephalus species have been reported to reach 68 individuals/ha elsewhere in central Asia (SHENBROT et al. 1991).

Toad headed agama density did not vary between years, but did differ between habitat types. Agama density was highest in shrub steppe and tall grassland habitat and lowest in semi-shrub steppe. Although several factors may influence agama density, we suspect that density in Ikh Nart was largely affected by the degree of vegetation cover in each habitat. Other studies in Ikh Nart indicated that vegetation cover was highest in shrub steppe (21%) and tall grassland (46%) and relatively low in semi-shrub steppe (16 %) (JACKSON et al. 2006). Other habitats in the reserve provided from 8 to 13 % vegetation cover and agamas rarely occur in them (JACKSON et al. 2006). The more cover and structural complexity in shrub steppe and tall grassland probably increase survivability by reducing rates of predation. The lesser kestrel (*Falco naumanni*), for example, consumes agamas regularly and appears to represent a main predator of agamas in Ikh Nart. A study of kestrel diet indicated that agamas occurred in 41% of pellets and accounted for 31 % of pellet volume (n = 573) (R. READING, B. SUURI, and ONOLRAGCHAA, in preparation). Field observations suggest that kestrels are more successful at hunting agamas in open areas with little cover (like semi-shrub steppe) than other habitats. At a finer, micro-habitat scale, other factors may affect density within steppe habitats. For example, toad headed agama studies in the northern deserts of Mongolia suggested that the species preferred micro-sites with moderate gravel content, moderate annual grass abundance, and very low shrub crown volume (ROGOVIN et al. 2001).

Although toad headed agamas represent a potential prey item for other species, previous studies indicated that the species occurs infrequently in the diets of carnivores such as corsac (*Vulpes corsac*) and red foxes (*V. vulpes*) (MURDOCH et al. 2010), badgers (*Meles leucurus*) (MURDOCH and SUURI, in review), and Pallas' cats (*Otocolobus manul*) (MURDOCH and READING, unpublished data). The species may represent an important prey resource for the three snakes that occur in the reserve, including the central Asian viper (*Aqkistrodon halys*), Pallas' coluber (*Elaphe dione*), and slender racer (*Coluber spinalis*) (READING et al. 2006). However, the diets of these snake species remain largely unknown. Similarly, agamas may be important to other raptors, such as black-eared kite (*Milvus* [*mirans*] *lineatus*) and upland buzzard (*Buteo hemilasius*), but few studies of raptor diet have been undertaken. The apparent importance of agamas in the diet of lesser kestrels may be of conservation importance as the species is listed as vulnerable species by the International Union for Conservation of Nature (IUCN 2009).

We recommend future studies that evaluate factors affecting agama density and distribution in steppe habitats at multiple scales. We also recommend assessing the potential role of agamas as a prey species and the extent of competition with other sympatric lizard species. Understanding the effects of human activities such as livestock grazing would also inform conservation and management of the species in Ikh Nart.

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References

BUCKLAND, S.T.; ANDERSON, D.R.; BURNHAM, K.P.; LAAKE, J.L.; BORCHERS, D.L.; THOMAS, L. (2001): Introduction to distance sampling: estimating abundance of biological populations. - Oxford University Press, Oxford, United Kingdom.

BURNHAM, K.P.; ANDERSON, D.R.; LAAKE, J.L. (1980): Estimation of density from line transect sampling of biological populations. - Wildlife Monographs **72**:1-202.

BURNHAM, K.P.; ANDERSON, D.R.; LAAKE, J.L. (1985): Efficiency and bias in strip and line transect sampling. - J. Wildl. Managem. **49**:1012-1018.

IUCN (2009): IUCN red list of threatened species. Version 2009.2. - <www.iucnredlist.org>. Downloaded on 01 March 2010.

JACKSON, D.; MURDOCH, J.D.; MANDAKH, B. (2006): Habitat classification using Landsat 7ETM+ imagery of the Ikh Nart Nature Reserve and surrounding areas in Dornogobi and Dundgobi Aimags, Mongolia. - Mongolian J. Biol. Sci. **4**:33-40.

MURDOCH, J.D., MUNKHZUL, T.; BUYANDELGER, S.; READING, R.P.; SILLERO-ZUBIRI, C. (2010): Seasonal food habits of corsac and red foxes in Mongolia and the potential for competition. - Mammalian Biology in press.

MURZAEV, E.M. (1948): The MPR: a physio-geographical description. - Academy of Sciences, Moscow, Russia [in Russian].

MYAGMARSUREN, D. (2000): Special Protected Areas of Mongolia. - Mongolian Environmental Protection Agency and GTZ (German Technical Advisory Agency), Ulaanbaatar, Mongolia.

QUAN, R.-Z.; ZHANG, J.-F. (2006): Studies of daily activity frequency of *Phrynocephalus versicolor*. - J. Bingtuan Education Institute 4.

READING, R.; KENNY, D.; WINGARD, G.; MANDAKH, B.; STEINHAUER-BURKART, B. (2006): Ikh Nart Nature Reserve. - ECO Nature Edition, Ulaanbaatar, Mongolia.

ROGOVIN, K.A.; SEMENOV, D.V.; SHENBROT, G.I. (2001): Lizards of the northern Mongolian deserts: densities and community structure. - Asiatic Herpetological Research **9**:1-9.

SHENBROT, G.I.; ROGOVIN, K.A.; SUROV, A.V. (1991): Comparative analysis of spatial organization of desert lizard communities in Middle Asia and Mexico. - Oikos **61**:157-168.

TERBISH, K.; MUNKHBAYAR, K.; CLARK, E.L.; MUNKHBAT, J.; MONKS, E.M.; MUNKHBAATAR, M.; BAILLIE, J.E.M.; BORKING, L.; BATSAIKHAN, N.; SAMIYA, R.; SEMENOV, D.V. (2006a): Mongolian red list of reptiles and amphibians. - Regional Red List Series Vol. **5**, Zoological Society of London, London, UK.

TERBISH, K.; MUNKHBAYAR, K.; MUNKHBAATAR, M. (2006b): A guide to the amphibians and reptiles of Mongolia. - Munkhiin Useg, Ulaanbaatar, Mongolia.

THOMAS, L.; LAAKE, J.L.; STRINDBERG, S.; MARQUES, F.F.C.; BUCKLAND, S.T.; BORCHERS, D.L.; ANDERSON, D.R.; BURNHAM, K.P.; HEDLEY, S.L.; POLLARD, J.H.; BISHOP, J.R.B.; MARQUES, T.A. (2006): Distance 5.0. Release 2. - Research Unit for Wildlife Population Assessment, University of St. Andrews, UK.

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