Errata

Influences of Human and Livestock Density on Winter Habitat Selection of Mongolian Gazelle (*Procapra gutturosa*)

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Human and livestock related disturbances of habitat selection by ungulates are topics of global concern, as they have profound impacts on ungulate survival, population density, fitness, and management; however, differences in ungulate habitat use under different human and livestock densities are not fully understood. Mongolian gazelle (*Procapra gutturosa*), an endemic ungulate species on the Asia-European steppe, faces varying intensities of human and livestock disturbances in the area around Dalai Lake, China. To investigate how habitat selection strategies vary as disturbance intensity changes, we randomly set 20 transects containing 1486 plots, on which we conducted repeated surveys of 21 ecological factors during the winters in the period of 2005–2008. We aimed to: 1) determine the critical factors underlying habitat selection of the gazelles; 2) determine the gazelles' habitat preferences in this area; 3) determine how habitat selection varies with disturbance intensity and explore the primary underlying mechanism. We used binary-logistic regressions and information theoretic approaches to build best-fit habitat selection models, and calculated resource selection functions. Sixty-six herds, 522 individuals, and 499 tracks were recorded. Our results indicate that snow depth and aboveground biomass are the main factors affecting habitat selection by Mongolian gazelle throughout the district in winter. Thin snow cover and abundant aboveground biomass are preferred. Avoiding disturbance was the primary factor accounting for habitat selection in low disturbance areas, although with increasing human or livestock-related disturbance, gazelle maintained a reduced distance to the source of the disturbance. Presumably owing to that shift, movement costs were more important as disturbance increased. In addition, Mongolian gazelle selected habitats based on topographical features promoting greater visibility where disturbance was lower. We suggest several management implications of our findings for this ungulate species will contribute to the effective conservation of Mongolian gazelle in the Dalai Lake area.

Key words: Dalai Lake, habitat selection, human disturbance, information theoretic approach, Mongolian gazelle, *Procapra gutturosa*

INTRODUCTION

Habitat change has profound effects on habitat use, survival, population density, and the fitness of animals (Stuart et al., 2004). Slight changes in key ecological factors may alter the habitat selection strategy of wild animals (Johnson, 1980; Cain et al., 2008). Studying habitat requirements and determining the impacts of primary ecological factors and key resources on habitat selection may thus provide valuable data for species protection and habitat management.

As ungulates are the main prey for large carnivores and play critical roles in food webs, their population dynamics, distributions and habitat selection are important for management of grassland ecosystems (Gao et al., 1996; Wang et al., 1997). Impacts of human activity, livestock, and other herbivores on steppes thus represent a global concern (Boyce and McDonald, 1999; Manly et al., 2002). Such knowledge may provide valuable information on ungulate habitat use, life history, and interspecific relationships and biodiversity conservation in grassland ecosystems (Boyce and McDonald, 1999; Manly et al., 2002; Stuart et al., 2004). Environmental modification caused by human and livestock-related disturbance can also alter landscape structure resulting in habitat loss or degeneration (Mace and Waller, 1996). Such disturbances may result in habitat selection shifts of

ungulates, thereby allowing them to meet foraging and other critical resource requirements (Hernandez and Laundre, 2005). An ungulate's response to disturbance depends on perceived threats and both the potential benefits and costs of the response (West et al., 2002; Beale and Monaghan, 2004). The primary response mechanism may be attributable to the ungulate's perception of a threat from approaching humans or livestock, balanced against the costs incurred in moving to a different habitat (Stillman and Goss-Custard, 2002). If the effect of the disturbance is significant, ungulates may migrate out of the area, ignoring other habitat requirements in order to avoid the disturbance. In contrast, if the cost of moving is greater, they may be more tolerant of disturbance (Yasué, 2006).

As a keystone species on the Asia-European steppe (one of the main herbivores and critical prey for carnivores), Mongolian gazelle (*Procapra gutturosa*) was listed in Category II of the National Protected Wild Animals of China in 1989 (Wang, 2003). They are endemic ungulates and historically were widespread on the Asia-European steppe (Lushchekina et al., 1983). Mongolian gazelles were once widespread in north China with a population of 300,000–500,000 before the 1950s (Gao et al., 1996). Due to poaching, human disturbance, and overgrazing, the number decreased to < 30,000 individuals in 1995 and < 8000 in 2000 with a distribution of less than 75,000 km^2 in the transboundary area of China, Mongolia, and Russia, which was only 25% of that in the 1950s (Gao et al., 1996; Wang et al., 1997; Jiang et al., 1998; Li et al., 2001; Jin and Ma, 2004; Olson et al., 2005). Given both the reduced population size and limited habitat area, habitat change may drastically shift the habitat selection strategy of the Mongolian gazelle (Lhagvasuren and Milner-Gulland, 1997; Leimgruber et al., 2001; Mueller et al., 2008). Research to date, however, has focused primarily on morphology, taxonomy, reproduction, diet, grazing behavior, population structure, activity rhythm, and diseases (Jiang et al., 1993, 2003; Gao et al., 1995; Olson et al., 2005; Ito et al., 2006; Luo et al., 2008; Liu et al., 2009, 2010). Studies of habitat use by Mongolian gazelle are urgently needed, especially studies of the impacts of human and livestock-related disturbances on its habitat selection, so as to establish a conservation plan for this species and a management strategy for the grassland ecosystem.

As a consequence of human population growth and the development of stockbreeding around Dalai Lake during recent decades, overgrazing and steppe degradation have increased (Jin and Ma, 2004). Grass harvesting in late fall, sympatric livestock grazing, and extremely cold weather with strong winds and deep snow result in severe forage shortages for Mongolian gazelle in winter (Jin and Ma, 2004; Luo et al.,

2008). Obtaining forage and response to disturbance are therefore important factors affecting survival and habitat selection by Mongolian gazelle. Furthermore, since the 1980s, Mongolian gazelle movements have been hindered due to the local government and residents setting fences to mark the boundaries between neighboring pastures and protect fodder sources. To efficiently manage the transboundary areas, human activities and livestock grazing have been forbidden within the regions within 10 km of the border between China and Mongolia except by special permission. As a result, intensities of human and livestock-related disturbances are low in this area. This difference in land use provided us with the opportunity to compare habitat selection strategies under different disturbance intensities.

The goals of this study were: (1) determine the critical factors underlying habitat selection of the gazelles; (2) determine the gazelles' habitat preferences in this area; and, (3) determine how habitat selection varies with disturbance intensity and explore the primary underlying mechanism.

MATERIALS AND METHODS

Ethics statement

The land we accessed includes a protected area and transboundary regions between China and Mongolia. All field studies were permitted by relevant authorities, including the Management Bureau of Dalai Lake National Nature Reserve and the Frontier Force of Hulunbeir. The field studies involved a protected species (Mongolian gazelle, Category II of the National Protected Wild Animals of China). Thus, an animal ethics approval was granted by Animal Ethics Commission of the College of Wildlife Resources, Northeast Forestry University. Our observation and fieldwork were designed so as not to affect the behavioral rhythm and survival of Mongolian gazelle.

Study area

The study area was located around Dalai Lake (47°45′50″–
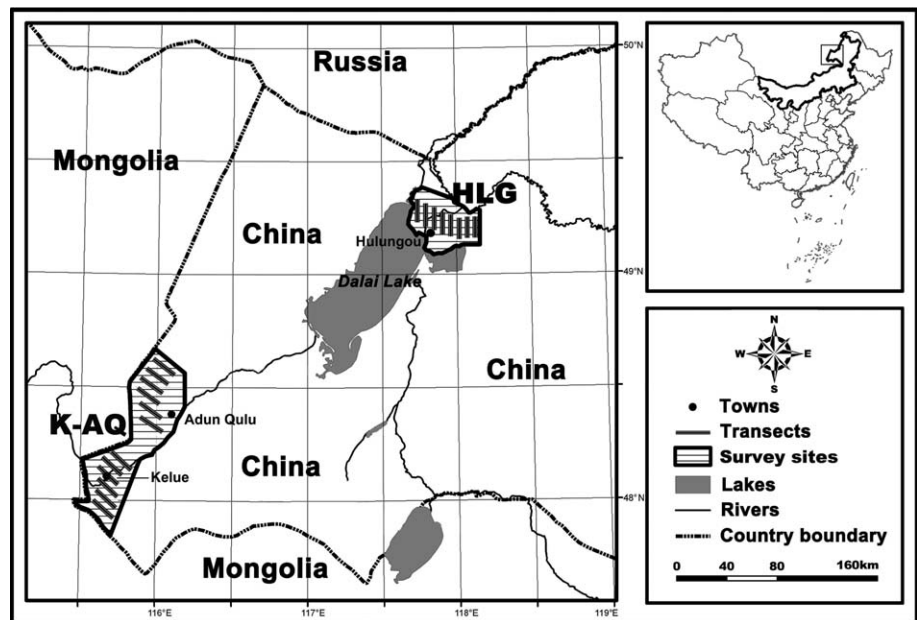
Fig. 1. Study area of habitat selection of Mongolian gazelle around Dalai Lake, Inner-Mongolia, China, in winters of the 2005–2008 period. Gray lines denote the transects we set for surveys. The comparative study was carried out between Kelue-Adun Qulu (K-AQ) and Hulungou (HLG).

49°20′20″N, 115°30′10″–120°30′10″E), Inner-Mongolia, China (Fig. 1). Altitude in this area ranges from 500–800 m. The climate is temperate continental characterized by aridity, wide diurnal, annual and inter-annual temperature variation, and cold winters with strong winds. Annual mean temperature there is 0.4°C with 3100 sunlight hours and a frost-free period of 125–130 days per year. Annual precipitation in this area is 200–350 mm which is concentrated in June to August, and the annual evaporation is 5–6 times greater than input via precipitation (Chronicle of Hulun Lake Compiling Committee,

1998). The area around Dalai Lake contains 653 plant species (Luo et al., 2008). The major vegetation type there is steppe, and desert steppe, semi-desert steppe, and meadow are extensively concomitant in small patches. Vegetation is dominated by *Achnatherum splendens*, *Stipa krylovii*, *Aneurolepidium chinenses*, *Stipa grandis*, *Salsola collina*, *Allium mongolicum*, *Artemisia frigida*, and *Caraganarob stenophylla* (Luo et al., 2008). Three hundred and seventy-two vertebrate species are found in the area, including 30 fishes, one amphibian, three reptiles, 303 birds, and 35 mammals

Table 1. Habitat selection factors recorded in the surveys of Mongolian gazelle around Dalai Lake, Inner-Mongolia, China, in winters in the 2005–2008 period.

Factors (units)	Descriptions
Presence/absence (1/0)	Presence–1, absence–0.
Altitude (m)	We recorded the altitude of the center of each 2 m × 2 m plot using a handheld GPS.
Slope (°)	We extracted the slope of the center of each 2 m × 2 m plot by ESRI ArcGIS 9.2 on 1:50000 DEM of the study area.
Aspect	We extracted the aspect of the center of each 2 m × 2 m plot by ESRI ArcGIS 9.2 on 1:50000 DEM of the study area. We extracted four categories: S67.5°E-S22.5°W, N22.5°E-S67.5°E, S22.5°W-N67.5°W, S67.5°W-N22.5°E.
Slope position	We estimated the position of each center of 2 m × 2 m plot on the slope and recorded three categories: lower, middle, upper.
Wind direction	We estimated the wind direction at the center of 2 m × 2 m plot and recorded nine categories: windless, N, NE, E, SE, S, SW, W, NW.
Wind power	We estimated the wind power at the center of 2 m × 2 m plot and recorded four categories: windless, light, moderate, strong.
Visibility (m)	We measured the maximal viewable distances on eight directions (north (N), northeast (NE), east (E), southeast (SE), south (S), southwest (SW), west (W), northwest (NW)) at 0.8 m height level by laser ranging telescope at the center of 2 m × 2 m plot and calculated the mean value.
Water distance (m)	We extracted the distance from the center of each 2 m × 2 m plot to the nearest open water by ESRI ArcGIS 9.2 on the 1:50000 hydrology vectorgraph.
Ground condition	We estimated the character of land-surface within each 2 m × 2 m plot as four categories: sandy, clayey, muddy, gravelly.
Snow depth (cm)	We measured the snow depths using a steel meter stick on five random points within each 2 m × 2 m plot and calculated the mean value.
Plant height (cm)	We measured the heights of 25 random plant culms within each 2 m × 2 m plot and calculated the mean value.
Vegetation cover (%)	We estimated the percentage of projection of aboveground vegetation cover to the area of each 2 m × 2 m plot.
Vegetation type	We determined vegetation type in each 2 m × 2 m plot by primary plant species. We recorded four categories: *Stipa* spp., *Aneurolepidium chinnenses*, *Stipa* spp.+ *Aneurolepidium chinnenses*, Herbage.
Species number (species)	We identified all the plants in each 2 m × 2 m plot and counted the total number of plant species.
Density (culms/m²)	We established five 0.5 m × 0.5 m subplots at the center and four corners of each 2 m × 2 m plot. We counted plant culm number within each subplot and calculated their mean value to estimate the plant density per 1 m².
Aboveground biomass (g/m²)	We collected aboveground parts of plants in five 0.5 m × 0.4 m subplots at the center and four corners of each 2 m × 2 m plot. We air-dried (60°C) the collections to constant weights and calculated their mean weight to estimate aboveground biomass per 1 m².
Road distance (m)	We digitized 1:50000 transportation map of study area and calculated the distance from the center of each 2 m × 2 m plot to the nearest road (including railroad, expressway, state road, provincial highway, county road and grassland road) by ESRI ArcGIS 9.2.
Fence distance (m)	We recorded all the corners of each fence by GPS and mapped a fence digital graph by linking corners in ESRI ArcGIS 9.2. We calculated the distance between the center of each 2 m × 2 m plot and nearest fence.
Settlement distance (m)	We recorded the settlement positions (including towns, villages, houses, wigwams or tents) by GPS. We drew a digital map of settlement and measured the distance from each 2 m × 2 m plot center to nearest settlement by ESRI ArcGIS 9.2.
Human activity distance (m)	We measured distance to the nearest human activity from the center of each 2 m × 2 m plot using a laser ranging telescope.
Livestock distance (m)	We measured distance to the nearest livestock individual from the center of each 2 m × 2 m plot using a laser ranging telescope.

(Chronicle of Hulun Lake Compiling Committee, 1998). Main livestock species around Dalai Lake are domestic sheep (*Ovis aries*), goat (*Capra aegagrus hircus*), cattle (*Bos taurus*), horse (*Equus caballus*), and camel (*Camelus bactrianus*). Livestock and human population were increased to 4 million and 450,000 respectively in this area in 2007, as a consequence of rapid stockbreeding development and human population growth during recent decades (Luo et al., 2008). The main soil types include chestnut soil, dark meadow soil, gray meadows soil, boggy soil, saline soil, alkali soil, and sandy soil (Chronicle of Hulun Lake Compiling Committee, 1998).

We carried out field surveys in Kelue town and Adun Qulu town (K-AQ, 1235.8 km²), located near the national boundary between China and Mongolia, and Hulungou town (HLG, 753.6 km²) near Dalai Lake (Fig. 1), as these two sites were the only strongholds of the Mongolian gazelle population round Dalai Lake (Luo et al., 2008).

Data collection

We located and surveyed 20 transects from December 2005 to March 2006, with a length of 15 km for each transect. Twelve transects (180 km in total length) were placed in the K-AQ area and eight (120 km in total length) in the HLG area (Fig. 1). In each site (K-AQ and HLG), we placed the first transect by randomly selecting the starting point and direction (we generated two random numbers ranging from minimums to maximums of the latitudes and longitudes of the site and used them as the latitude and longitude of the starting point of the first transect; then, we generated another random number ranging from 0 to 360 (°) and used it as the direction (0°-north, 90°-east, 180°-south, 270°-west) of the starting point of the first transect; random number generations were processed in Microsoft Excel). The remaining transects were established at a parallel distance of 10 km from the first transect. We repeated the surveys along these transects once each winter (December to next March) from 2006 to 2008.

We walked along each transect at a speed of 3 km/h and counted the number of individual humans and livestock within 1 km of both sides of these transects using a laser range telescope (Apresys PRO 1500 SPD, Los Angeles, California, USA). We measured 21 vegetation and habitat factors in 2 m × 2 m plots at the transect starting point and at 1 km intervals along the transect (Table 1). While traversing each transect, we recorded presence and the number of Mongolian gazelle herds that were observed within 1 km of both sides of the transect, counted the individuals in each herd, measured the distance of each herd from the transect by the laser range telescope, and recorded its location using a GPS receiver (Garmin eTrex Vista H, Olathe, Kansas, USA). In addition we recorded presence of gazelle using tracks, foraging signs, dung-groups, and bedding sites along transects. When an individual or sign of gazelle was detected, a 2 m × 2 m plot, with the location of the individual or track as the plot center, was set and habitat and vegetation characteristics were recorded. Vegetation and habitat factors were recorded in 1486 plots (929 in K-AQ and 557 in HLG).

Statistical analyses

We analyzed the data from the K-AQ and HLG areas separately using similar statistical methods in SPSS 13.0 software, and considered the data across years as independent. We calculated densities of human and livestock for each transect (density = recorded number of individuals/(2 km × 15 km)), and used them as indicators of disturbance intensities. We used Kolmogorov-Smirnov (K-S) tests to check their normality and the data in both K-AQ (K-S test $P = 0.64$) and HLG (K-S test $P = 0.59$) areas were normally distributed. We, thus, used independent samples t-tests to detect any differences in disturbance densities between these two areas.

Taking plots as the sampling units, we calculated Moran's I values for the raw data of the habitat variables for twenty distance classes (100 m, 200 m, …, 1900 m, 2000 m) in the software package SAM (Rangel et al., 2006), to assess the effect of spatial autocorrelation. As Moran's I values for all the variables were between –0.2 and 0.2 at distance classes of > 400 m, we excluded the plots with distances of < 400 m from other plots in the subsequent analyses. In total, 779 plots in K-AQ and 416 plots in HLG were included in the following analyses. We used K-S tests to check normality of all the variables. If any variable were non-normal (K-S test $P < 0.05$), we made ln-transformations (see Results). We, then, used independent samples t-tests to test for differences in habitat parameters between K-AQ and HLG areas. In order to reduce the interaction between variables, we calculated pairwise Pearson's correlation coefficients between all variables. If any coefficient was > 0.70, we removed the variable with higher deviation within this variable pair (see Results).

An information theory approach was used to establish best-fit habitat selection models for Mongolian gazelles. We used Akaike's information criterion (AIC) to compare candidate models and ranked them by $\Delta AICc$ (Burnham and Anderson, 2002). Relative likelihood of each model was assessed by Akaike weights ($AICw$). We then chose the models with the $\Delta AICc$ values of < 2 as competing habitat selection models (Burnham and Anderson, 2002). To assess contributions of the factors to habitat selection of gazelles, we followed Manly et al. (2002) to build binary-logistic regression formulas between presence/absence of the gazelles and habitat variables,

Table 2. Results of independent samples t-tests of the ecological factors affecting habitat selection of Mongolian gazelle between K-AQ and HLG areas around Dalai Lake, Inner-Mongolia, China, in winters in the 2005–2008 period.

	K-AQ ($n = 609$)		HLG ($n = 297$)		F^*	P^{**}
	Mean	SE	Mean	SE		
Altitude (m)	635.711	83.304	573.971	65.814	432.230	0.070
Slope (°)	7.084	12.505	5.762	11.545	2.821	0.499
ln Aspect	1.467	0.941	1.725	0.463	0.652	0.125
ln Slope position	0.698	0.332	0.666	0.317	0.717	0.527
ln Wind direction	1.500	0.121	1.410	0.414	0.632	0.423
ln Wind power	1.124	0.374	1.080	0.430	0.593	0.608
Visibility (m)	1580.750	312.977	1451.424	448.591	1203.621	0.046
Water distance (m)	2159.657	731.877	1809.583	1406.134	586.690	0.000
ln Ground condition	1.031	0.153	0.914	1.201	0.204	0.080
Snow depth (cm)	10.815	1.412	10.455	1.856	2.222	0.321
ln Plant height (cm)	35.267	0.712	21.234	0.587	11.571	0.000
Vegetation cover (%)	60.520	20.101	44.321	18.257	7.554	0.023
ln Vegetation type	0.431	0.607	0.852	0.647	0.213	0.000
Species number (species)	3.989	1.646	3.482	1.691	0.984	0.218
Density (culms/m²)	106.004	31.321	79.004	28.878	23.349	0.000
Aboveground biomass (g/m²)	76.524	24.575	44.377	18.221	19.317	0.011
Road distance (m)	2419.211	1251.023	1806.571	1316.652	596.778	0.038
Fence distance (m)	2483.331	1057.211	1360.442	1332.113	1365.257	0.002
Settlement distance (m)	2577.634	1427.915	1702.187	802.248	968.801	0.000
Human activity distance (m)	2421.490	2389.821	1925.635	1287.047	268.383	0.000
Livestock distance (m)	1584.214	1979.305	945.514	1088.757	1026.522	0.000

Note: *, F value for independent samples t-test; **, P value for independent samples t-test.

and ranked the variables by their explanatory power (R^2).

To analyze the gazelle's preference relative to each habitat factor and to explain the response of Mongolian gazelle to human and livestock disturbance in winter, we classified the factors based on their means and maximum-minimum variations and calculated habitat selection function (*E*) of each factor class (Boyce and McDonald, 1999; Li et al., 2001; Boyce et al., 2002; Manly et al., 2002). The model in Boyce and McDonald (1999) was used in this study. Habitat selection function ranges from –1 to 1, with values of > 0.1, < –0.1, and –0.1–0.1 indicative of preference, avoidance, and random selection of a habitat resource, respectively. We did not calculate habitat selection functions for the factors that were excluded according to the Pearson's correlation analyses. Furthermore, we compared the habitat selection functions and the explanatory pow-

Table 3. Pairwise Pearson's correlation coefficients of the ecological factors of habitat selection of Mongolian gazelle in K-AQ (under the diagonal) and HLG (above the diagonal) areas around Dalai Lake, Inner-Mongolia, China, in winters in the 2005–2008 period.

	Altitude	Slope*	ln Aspect*	ln Slope position	ln Wind direction*	ln Wind power*	Visibility	Water distance	ln Ground condition*	Snow depth	ln Plant height
Altitude	–	0.444	0.437	0.329	0.101	0.332	0.439	–0.002	0.332	–0.443	0.003
Slope	0.362	–	0.112	0.356	0.112	0.301	–0.549	0.001	0.258	–0.779	0.239
ln Aspect	0.443	–0.021	–	0.702	0.221	–0.128	–0.443	–0.291	0.009	0.281	–0.415
ln Slope position#	0.617	0.122	–0.043	–	0.815	0.777	0.444	–0.001	0.666	–0.561	–0.101
ln Wind direction#	–0.023	0.233	0.674	–0.231	–	0.320	0.107	–0.219	–0.551	–0.005	0.129
ln Wind power#	0.542	0.200	0.012	0.634	0.023	–	0.333	–0.198	0.559	–0.541	0.009
Visibility	0.594	–0.431	–0.179	0.436	0.111	0.221	–	0.449	0.449	–0.444	–0.210
Water distance	0.104	–0.005	–0.143	0.098	0.002	–0.101	0.217	–	0.014	0.100	0.627
ln Ground condition	0.472	0.103	–0.009	0.788	–0.726	0.810	0.443	0.327	–	–0.388	–0.298
Snow depth	–0.219	–0.225	0.348	–0.442	–0.168	–0.543	–0.334	0.098	–0.328	–	0.605
ln Plant height	0.003	0.122	–0.219	0.088	–0.003	0.112	–0.101	0.554	–0.349	0.541	–
Vegetation cover	0.111	–0.219	0.008	0.446	0.228	–0.453	0.107	0.549	0.337	–0.287	0.214
ln Vegetation type	0.178	–0.177	0.082	0.191	–0.002	0.211	0.243	0.443	0.235	–0.333	–0.256
Species number	0.156	–0.111	0.092	–0.017	0.339	–0.005	0.159	–0.337	0.101	0.431	–0.049
Density#	–0.126	–0.100	0.093	–0.142	0.005	–0.010	–0.228	–0.444	–0.232	0.214	0.439
Aboveground biomass	–0.105	0.194	–0.008	–0.102	0.002	0.001	0.313	–0.559	–0.253	0.491	0.666
Road distance#	0.122	–0.048	–0.111	0.422	0.001	–0.231	–0.318	0.032	0.102	–0.257	–0.223
Fence distance	0.008	–0.045	–0.223	0.332	–0.002	0.029	–0.125	–0.120	–0.111	–0.337	–0.446
Settlement distance#	0.324	0.257	–0.084	0.239	–0.005	0.229	–0.101	0.384	0.135	–0.143	0.358
Human activity distance	0.104	–0.254	0.003	–0.104	0.001	–0.268	–0.328	0.253	0.003	0.278	–0.516
Livestock distance#	0.009	0.004	–0.123	–0.238	0.157	–0.033	–0.332	0.653	–0.346	0.429	–0.542

	Vegetation cover	ln Vegetation type	Species number	Density*	Aboveground biomass	Road distance*	Fence distance*	Settlement distance	Human activity distance	Livestock distance
Altitude	0.201	0.089	0.232	–0.221	0.001	0.325	0.002	0.459	0.100	0.002
Slope	–0.431	–0.239	–0.004	0.112	0.239	0.002	0.005	0.491	–0.419	0.120
ln Aspect	–0.003	0.088	–0.001	0.128	–0.192	–0.204	–0.443	0.012	0.003	–0.362
ln Slope position#	0.554	0.219	–0.001	–0.328	–0.009	0.521	0.306	0.119	0.201	0.198
ln Wind direction#	0.309	0.104	0.222	–0.014	–0.001	0.001	–0.136	0.110	–0.005	0.431
ln Wind power#	–0.326	0.117	0.012	0.104	–0.007	–0.124	–0.019	0.387	–0.198	0.141
Visibility	0.224	0.198	0.201	–0.111	0.428	–0.198	0.015	–0.225	–0.247	–0.458
Water distance	0.672	0.541	–0.299	–0.581	–0.610	–0.001	–0.098	0.115	0.391	0.549
ln Ground condition	0.551	0.881	0.007	–0.194	–0.315	–0.018	–0.281	0.281	–0.112	–0.418
Snow depth	–0.299	–0.419	0.501	0.213	0.385	–0.332	–0.224	–0.148	0.391	0.376
ln Plant height	0.319	–0.264	–0.111	0.394	0.516	–0.116	–0.410	0.351	–0.559	–0.613
Vegetation cover	–	–0.332	0.611	0.661	–0.444	–0.431	0.515	–0.005	0.004	–0.347
ln Vegetation type	–0.415	–	0.338	–0.337	–0.614	–0.583	0.317	0.004	–0.127	0.271
Species number	0.629	0.258	–	0.668	0.102	–0.099	–0.513	–0.217	–0.301	–0.117
Density#	0.910	–0.294	0.793	–	0.917	–0.210	–0.581	0.331	–0.384	–0.661
Aboveground biomass	–0.549	–0.639	–0.118	0.912	–	0.782	–0.351	–0.398	–0.312	–0.610
Road distance#	–0.495	–0.687	–0.234	–0.120	–0.099	–	0.666	0.661	0.416	–0.519
Fence distance	0.463	0.398	–0.442	–0.432	–0.323	0.727	–	0.732	0.881	0.719
Settlement distance#	0.114	–0.121	–0.216	0.383	–0.486	0.669	0.885	–	0.599	0.671
Human activity distance	–0.010	–0.005	–0.180	–0.329	–0.222	0.495	0.669	0.694	–	0.601
Livestock distance#	–0.259	0.328	–0.254	–0.553	–0.587	–0.491	0.216	0.811	0.517	–

Note: #, variables excluded in the analyses of habitat selection of Mongolian gazelles in the K-AQ area; *, variables excluded in the analyses of habitat selection of Mongolian gazelles in the HLG area.

Table 4. Candidate models, $\Delta AICc$s and $AICw$s of habitat selection of Mongolian gazelle in K-AQ and HLG areas around Dalai Lake, Inner-Mongolia, China, in winters in the 2005–2008 period.

	Models	K^a	$\Delta AICc$	$AICw$
K-AQ area				
1*	Snow depth+biomass+cover+visibility+fence distance+ln ground condition+ln vegetation type+human activity distance+slope+water distance+ln aspect	11	0.000	0.559
2	Snow depth+biomass+cover+visibility+fence distance+ln ground condition+ln vegetation type+human activity distance+slope+water distance+species number+ln aspect	12	2.285	0.178
HLG area				
1*	Snow depth+biomass+ln plant height+ln slope position+visibility+water distance+settlement distance+ human activity distance+ln vegetation type+species number+cover	11	0.000	0.623
2	Snow depth+biomass+ln plant height+ln slope position+visibility+water distance+settlement distance+ human activity distance+ln vegetation type+altitude+species number+cover+livestock distance	13	2.096	0.199

Note: [a], variable number in the model; *, best-fit model.

RESULTS

ers of the ecological factors between K-AQ and HLG to detect differences in habitat selection strategies.

We recorded 522 individuals (306 in K-AQ and 216 in HLG) belonging to 66 herds (44 in K-AQ and 22 in HLG) and 499 tracks (316 in K-AQ and 183 in HLG) of Mongolian gazelles in the winters of 2005–2008. The average group size was 6.95 ± 1.05 individuals in the K-AQ area, with a mean sex ratio of male:female = 0.47 ± 0.22 and 0.58 ± 0.61 fawns in each group. While, in the GLH site, the average group size was 9.82 ± 2.36 individuals, and the mean sex ratio (male:female) and fawn numbers were 0.39 ± 0.21 and 0.79 ± 0.53 for each group. Human and livestock densities were significantly greater ($P = 0.010$) within HLG (3.591 ± 1.674 individuals/km^2 and 27.007 ± 16.095 individuals/km^2) than that in K-AQ (0.434 ± 0.017 individuals/km^2 and 3.021 ± 0.211 individuals/km^2).

Aspect, slope position, wind direction, wind power, ground condition, plant height, and vegetation type were non-normally distributed (K-S test P values were < 0.05) and ln-transformed (Table 2). The results of independent samples t-tests showed no significant differences of altitude ($P = 0.070$), slope ($P = 0.499$), ln aspect ($P = 0.125$), ln slope position ($P = 0.527$), ln wind direction ($P = 0.423$), ln wind power ($P = 0.608$), ln ground condition ($P = 0.080$), snow depth ($P = 0.321$), and species number ($P = 0.218$) between K-AQ and HLG (Table 2). Visibility ($P = 0.046$), water distance ($P = 0.000$), ln plant height ($P = 0.000$), vegetation cover ($P = 0.023$), ln vegetation type ($P = 0.000$), density ($P = 0.000$), aboveground biomass ($P = 0.011$), road distance ($P = 0.038$), fence distance ($P = 0.002$), settlement distance ($P = 0.000$), human activity distance ($P = 0.000$), and livestock distance ($P = 0.000$) showed significant differences between these two areas (Table 2). Based on Pearson's correlation analyses, we excluded density, wind direction, wind power, slope position, settlement distance, road distance, and livestock distance in latter analyses of K-AQ data (Tables 2 and 3). Similarly, density, wind direction, wind power, aspect, slope, road distance, fence distance, and ground condition were excluded for HLG (Tables 2, 3).

The K-AQ area modeling exercise resulted in one model with $\Delta AICc$ < 2.000 (Table 4). This best-fit model ($\Delta AICc = 0.000$, $AICw = 0.559$, $R^2 = 0.987$) included 11 habitat factors

Table 5. Results of binary-logistic regressions of the best-fit models of habitat selection of Mongolian gazelle in K-AQ and HLG areas around Dalai Lake, Inner-Mongolia, China, in winters in the 2005–2008 period.

Variables	Standard coefficient (r)	t	P	R^2
K-AQ area: $F_{11, 768} = 136.025$, $R^2 = 0.987$, $P < 0.010$				
Snow depth	−0.851	−3.107	< 0.010	0.352
Biomass	0.714	10.295	< 0.010	0.297
Slope	0.676	7.018	< 0.010	0.107
Fence distance	0.616	6.660	< 0.010	0.102
ln Ground condition	0.567	21.259	< 0.010	0.067
Human activity distance	0.205	4.779	< 0.010	0.040
Visibility	0.180	3.890	< 0.010	0.006
Water distance	0.159	−4.709	< 0.010	0.006
ln Vegetation type	−0.135	−4.442	< 0.010	0.006
ln Aspect	−0.124	−2.764	< 0.010	0.003
Cover	0.045	1.334	0.031	0.001
HLG area: $F_{11, 405} = 186.326$, $R^2 = 0.984$, $P < 0.010$				
Biomass	0.879	9.333	< 0.010	0.401
Snow depth	−0.675	10.032	< 0.010	0.315
ln Slope position	−0.336	−7.717	< 0.010	0.101
Species number	0.179	5.320	< 0.010	0.052
Cover	0.169	−4.703	< 0.010	0.041
Visibility	−0.159	−3.875	< 0.010	0.030
Water distance	0.118	2.796	< 0.010	0.020
ln Vegetation type	0.087	2.753	< 0.010	0.012
ln Plant height	0.081	2.459	0.014	0.007
Settlement distance	0.051	1.551	0.022	0.004
Human activity distance	0.006	−0.179	0.048	0.001

(Tables 4 and 5). According to the binary-logistic regression, snow depth ($r = −0.851$, $P < 0.010$, $R^2 = 0.352$), aboveground biomass ($r = 0.714$, $P < 0.010$, $R^2 = 0.297$), slope ($r = 0.676$, $P < 0.010$, $R^2 = 0.107$), and fence distance ($r = 0.616$, $P < 0.010$, $R^2 = 0.102$) affected gazelle presence ($R^2 > 0.100$, Table 5). Other factors had R^2 values of < 0.100 (Table 5). Habitat selection functions indicated that Mongolian gazelle preferred shallow snow (< 5 cm, $E = 0.662$) and greater aboveground biomass (50–75 g/m^2, $E = 0.641$; 75–100 g/m^2, $E = 0.900$; > 100 g/m^2, $E = 0.982$), and selected habitat far from human activity (500–2000 m, $E = 0.193$; > 2000 m, $E = $
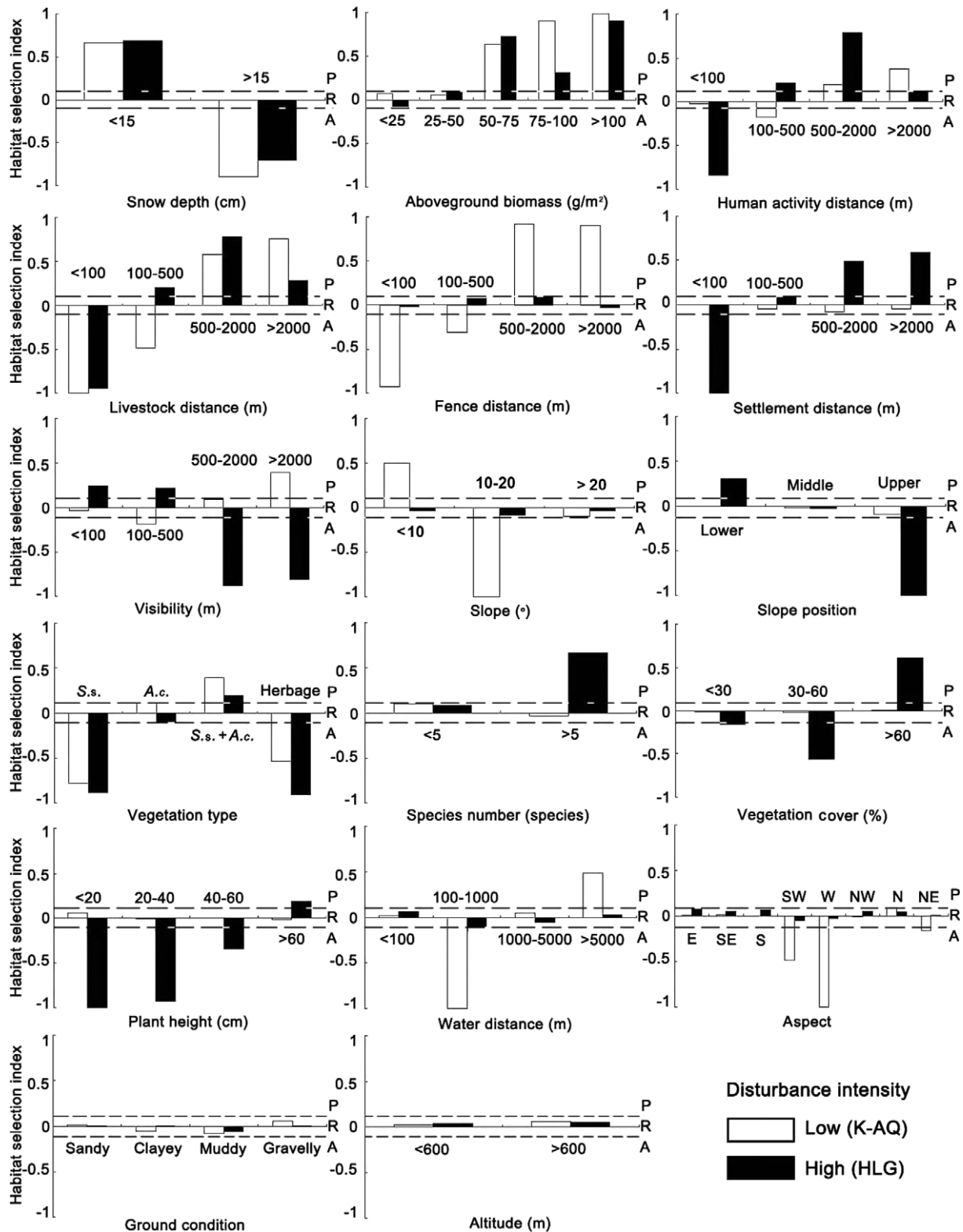
Fig. 2. Habitat selection functions of each habitat class of Mongolian gazelle under different human and livestock disturbance intensities (K-AQ and HLG) around Dalai Lake, Inner-Mongolia, China, in winters in the 2005–2008 period. Broken lines denote habitat selection function dividing values of ± 0.1. Bars between two broken lines (–0.1–0.1), above the upper broken line (> 0.1) and below the lower broken line (< –0.1) respectively indicate random selection (R), preferring (P) and avoidance (A). In the histogram of vegetation type, *S.*s. = *Stipa* spp., *A.c.* = *Aneurolepidium chinnenses*, *S.*s.+*A.c.* = *Stipa* spp.+*Aneurolepidium chinnenses*. In the histogram of aspect, N = north, NE = northeast, E = east, SE = southeast, S = south, SW = southwest, W = west, NW = northwest.

0.371), livestock (500–2000 m, $E = 0.578$; > 2000 m, $E = 0.758$) and fence (500–2000 m, $E = 0.920$; > 2000 m, $E = 0.900$). Wider visibility (> 2000 m, $E = 0.395$), low slope terrain (< 10°, $E = 0.500$), vegetation type of *Aneurolepidium chinnenses* ($E = 0.122$), *Stipa* spp.+*Aneurolepidium chinnenses* ($E = 0.394$) and long open water distance (> 5000 m, $E = 0.486$) were used in the near boundary areas. Other factor classes had habitat selection functions of –0.1 –0.1, indicating random selection (Fig. 2).

For the HLG area, one model achieved $\Delta AICc < 2.000$ (Table 4), and 11 factors were included in this best-fit model ($\Delta AICc = 0.000$, $AICw = 0.623$, $R^2 = 0.984$) (Tables 4, 5). Aboveground biomass ($r = 0.879$, $P < 0.010$, $R^2 = 0.401$), snow depth ($r = -0.675$, $P < 0.010$, $R^2 = 0.315$), and ln slope position ($r = -0.336$, $P < 0.010$, $R^2 = 0.101$) had R^2 values > 0.100 (Table 5). Other factors achieved R^2 values of < 0.100 (Table 5). Snow depth, ln slope position, and visibility were negatively correlated with the presence of Mongolian gazelle (Table 5). The gazelles preferred shallow snow cover (< 15 cm, $E = 0.687$) and greater aboveground biomass (50–75 g/m², $E = 0.731$; 75–100 g/m², $E = 0.310$; > 100 g/m², $E = 0.910$). They avoided human activity (100–500 m, $E = 0.210$; 500–2000 m, $E = 0.781$; > 2000 m, $E = 0.109$), livestock (100–500 m, $E = 0.208$; 500–2000 m, $E = 0.781$; > 2000 m, $E = 0.283$), and settlement (500–2000 m, $E = 0.490$; > 2000 m, $E = 0.588$). Reduced visibility (< 100 m, $E = 0.242$; 100–500 m, $E = 0.211$), lower slope position ($E = 0.311$), *Stipa* spp.+*Aneurolepidium chinnenses* ($E = 0.205$) vegetation type, greater vegetation species richness (> 5 species, $E = 0.661$), higher cover (> 60%, $E = 0.609$), and larger plant height (> 60 cm, $E = 0.190$) were selected in this area. However, we found only random selection for other factor classes, based upon habitat selection functions falling between –0.1 and 0.1 (Fig. 2).

DISCUSSION

The factor selection procedure excluded parameters relating to wind and vegetation density from analyses of data from both the K-AQ and HLG areas due to their high correlations with other ecological variables. Although both topographic and demographic conditions contributed to variable selection, the best-fit habitat selection models included discrepant variables between the two sites. Slope, aspect and ground condition were excluded for the HLG model, and slope position was rejected by the K-AQ model, as these parameters represent different topographic characteristics and habitat variation between the two sites that promote different relationships between the sites themselves and other environmental parameters. Distances to the nearest road and fence were excluded in the HLG model and settlement and livestock distances were rejected by the K-AQ model as they exert different kinds of demographic effects and conditions are not homogeneous between these two areas.

Snow cover and aboveground biomass

The results indicated that snow depth and aboveground biomass were limiting factors for habitat selection of Mongolian gazelle in both K-AQ and HLG in winter, as they explained 30–40% of the variation for the models for those sites. The gazelles preferred lighter snow cover and higher aboveground biomass. Snow cover is essential for habitat

selection of wild animals in winter (Sweeney and Sweeney, 1984). Increasing snow depth has a significant negative effect on food supply by covering nutritious evergreen forbs or half-shrubs, forcing ungulates to consume greater quantities of taller grasses and woody browse with lower nutrition, and increasing energy costs of movement, digging in the snow to obtain forage, or avoidance of predators and disturbance (Parker et al., 1999; Doerr et al., 2005). These phenomena have been reported for Dall's sheep (*Ovis dalli*), elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), and white-tailed deer (*Odocoileus virginianus*), suggesting that snow cover is critical for ungulate habitat selection in winter (Rachlow and Bowyer, 1998; Poole and Mowat, 2005). Our results are consistent with those of previous studies in that Mongolian gazelle selected shallow snow depth (< 15 cm) and rarely used deeper snow habitat to reduce energy cost and get enough food (Doerr et al., 2005).

As the only source of forage, aboveground biomass is another limiting factor impinging upon survival and habitat selection by ungulates (Poole and Mowat, 2005). Our results implied that Mongolian gazelles preferred habitat with abundant forage in both K-AQ and HLG, which is consistent with findings from research on Mongolian gazelle in the eastern Mongolian steppe by Leimgruber et al. (2001), Ito et al. (2006), and Mueller et al. (2008). However, Jin and Ma (2004) indicated that forage abundance is a secondary factor in habitat selection by Mongolian gazelle in spring when medium and lower aboveground biomass were preferred. We considered this difference a result of inter-seasonal trade-offs. Because of starvation and severe body weight loss in winter, optimizing foraging is critical to survival and ungulates may neglect requirements related to other factors. By contrast, when forage availability improves in spring, the importance of forage abundance is reduced and other factors receive increased emphasis (Dumont et al., 2000). Similar phenomena have been reported in Przewalski's gazelle (*Procapra prezwalskii*), Przewalski's horse (*Equus przewalskii*) and oribi (*Ourebia ourebi*) (Liu and Jiang, 2002; Pereladova et al., 2002; Mduma and Sinclair, 2008).

Human activity and livestock grazing

Our results support conclusions reported in previous studies that there is a threshold of 0.5 km to 5 km from human and livestock disturbances for normal ungulate activity (Mahoney and Schaefer, 2002; Frid, 2003). Comparison of habitat selection strategies between K-AQ and HLG indicated that Mongolian gazelle respond differently to different intensities of human activity and livestock grazing disturbances. Disturbance had a more significant impact on gazelle activity in the K-AQ area, while gazelles used habitat < 500 m from disturbance in the HLG area. This suggests that there might be a trade-off between perceived threat associated with disturbance and costs of moving out of an area. In the HLG area, greater densities of human/livestock may reduce the opportunity for Mongolian gazelles to be distant from these disturbances. High costs in searching for and moving into habitats that are distant to such disturbances might make the gazelles more tolerant to human/ livestock activities. In contrast, human activity and livestock grazing are restricted in the K-AQ area, thus, there might be

increased availability of forage for gazelles, along with fewer disturbances to potentially interfere with movement. In this area, avoiding disturbance may serve as the primary mechanism underlying habitat selection by Mongolian gazelle. Such behavioral responses have also been reported for elk, mule deer, and white-tailed deer (*Odocoileus virginianus*) (Pauley et al., 1993; Parker et al., 1999; Doerr et al., 2005).

Similar responses to the nearest fence were also indicated in winter habitat selection of Mongolian gazelles: as livestock population and grassland grazing intensity is much higher in the HLG area than that in the K-AQ area, local people established more fences in order to manage their pastures and divided the grassland into many small patches. Thus, greater fence density in the HLG area results in a much lower availability of habitat far from fence, and the gazelles are more tolerant to fence disturbance, generating random selection for this ecological parameter. The opposite condition was indicated in the HLG area: due to the lower fence density in this site, gazelles are more sensitive to fence disturbance and thus prefer habitat distant to fence and avoid habitat close to fence disturbance. A reversed pattern of selection on settlement disturbance was implied by our results: in the HLG area, as most of the settlements are permanent houses and sheepfolds, Mongolian gazelles avoid the severe disturbance from them and prefer distant habitat from the settlements. However, because of the controlling of the trans-boundary areas by the army and local government, settlements in the K-AQ area are usually temporary tents. The gazelles may acclimate to this kind of disturbance with low intensity and show random selection on this ecological variable.

Visibility

Selection based upon visibility could be considered an important variable allowing animals to evaluate disturbance and predation risk. Research on elk and mule deer reveals that disturbance intensity and predation risk are lower with decreased visibility (i.e., in covered habitats) (Altendorf et al., 2001; White and Berger, 2001; Dussault et al., 2005), which may be related to difficulties of humans and predators in recognizing animals under conditions where visibility is constrained (Dussault et al., 2005). Predators of Mongolian gazelles in the Dalai Lake area include wolf (*Canis lupus*), red fox (*Vulpes vulpes*), golden eagle (*Aquila chrysaetos*), steppe eagle (*Aquila nipalensis*), upland buzzard (*Buteo hemilasius*), and, especially, humans (illegal hunting). In the current study, as higher human and livestock disturbance intensities might mean higher predation risk by human, the gazelles preferred reduced viewable range habitat (< 500 m) in the HLG area and selected > 2000 m maximum viewable distance sites in the K-AQ area. This difference suggests that gazelles prefer covered habitats under high disturbance intensity, perhaps as a mean of avoiding disturbance or seeking cover and thereby reducing their risk of predation while simultaneously obtaining more browsing and resting time. In contrast, they selected open habitat and high forage quality under low human and livestock disturbance intensities, despite the risk that the threat of disturbance and predation may increase. We considered our finding to be a reflection of a trade-off between avoidance of disturbance/predation and foraging (Dussault et al., 2005). Animals should pursue the most important limiting factor foremost while the influence of less important factors should contribute only secondarily (Dussault et al., 2005). As avoiding disturbance/predation is critical for survival under high disturbance intensity (HLG area), gazelles first select covered habitat and ignore other habitat factors. When disturbance intensity declines (in K-AQ area), however, gazelles could select open habitats with higher food availability so as to enhance forage intake, which is the most important limiting factor in this area.

Topography

Our results indicated that Mongolian gazelle selected topographical characteristics more strictly in the K-AQ area compared to the HLG area. They clearly preferred gentle slope (< 10°) and strongly avoided steep topography (10°–20°) in the K-AQ area, while they randomly selected slope in the HLG area. As no significant difference of topographical variables between the two sites could be detected (independent samples *t*-tests of altitude, slope, aspect, slope position, and ground condition were $P > 0.05$). This finding is likely to represent a trade-off between requirements for forage and topographical factors. Frequent human and livestock disturbance and serious competition for forage between gazelles and domestic ungulates in the HLG area likely prompted gazelle to focus on the fulfillment of their foraging demands at the expense of taking other factors into account. For the K-AQ area, however, selection was more strongly influenced by topography, as forage supply was relatively abundant. Similar findings have been reported from studies of habitat use by elk, red deer (*Alces alces*), mule deer, and caribou (*Rangifer tarandus*) (Rettie and Messier, 2000; Kie et al., 2002; Boyce et al., 2003; Dussault et al., 2005).

Management implications

Habitat management is essential for conservation of Mongolian gazelle. Higher forage availability and lighter snow cover are critical for the survival of Mongolian gazelle around Dalai Lake in winter (Gao et al., 1995; Dumont et al., 2000; Jin and Ma, 2004; Doerr et al., 2005; Poole and Mowat, 2005). Thus, artificial snow clearing and provision of supplementary forage will presumably be valuable approaches for its population management. As human disturbance and livestock grazing intensity increased, Mongolian gazelle showed greater resilience to disturbance and used habitat with reduced distances to disturbance sites. Under lower disturbance pressure, Mongolian gazelle preferred more open habitats and gentler slope than under higher disturbance intensity. The differences in habitat selection strategies indicated that, in the K-AQ area, human and livestock population controls need to be continued and that human activity and domestic ungulate grazing restrictions need to be enforced. In the HLG area, we suggest that control of the livestock population, along with conservation education for members of the local communities, establishment, enforcement and execution of effective grassland utilization policies, logical pasture household responsibility and livestock grazing system foundation are imperative for conservation of Mongolian gazelle. These measurements need to be developed based on further detailed habitat research on Mongolian gazelle.

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Reproductive Strategies of Leopard Toad and Mascarene Frog from Giza, Egypt

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I examined the reproductive strategies of leopard toad and mascarene frog by studying their annual vitellogenic cycle, monthly changes of masses of ovary, liver and fat bodies as well as egg size and number in two study areas, Abo Roash and El Mansuriya, and in the years 2001, 2005, and 2008–2009, particularly during the final two years of that period. Based on the presence of the mature ova, I found that vitellogenic cycle is continuous in toad, but discontinuous in frog. Further, leopard body reserves allocated more energy to vitellogenesis than did mascarene frog. Hence, fecundity in toad was higher than that in frog, as associated with higher egg number and size. During oviposition, female mascarene retained a small portion of a clutch, whereas toad shed all egg mass at once. Over the study period, both body and reproductive conditions reacted positively in toad, but negatively in frog. Warm temperature and long photoperiod elucidated ovarian development under high relative humidity in frog. In contrast, in toad, low relative humidity may be an environmental cue for the increase in ovarian mass. Thus, higher sexual activities occurred in spring for toad (dry environment), but in moist summer for frog. Ovarian mass and egg number were temperature-dependent in frog, but independent in toad. Relative humidity correlated significantly and negatively to egg size in both populations. It also related inversely to egg number in toad, but not in frog. Hence, eggs of the frog are controlled by both temperature and humidity in summer season. Rainfall had no effect on sexual parameters in both species.

Key words: reproductive traits, vitellogenesis, liver, fat bodies, climate regimes

INTRODUCTION

The leopard toad, *Bufo regularis* and mascarene frog, *Ptychadena mascareniensis* are widely distributed through Egypt. They share the same habitats and environment in most geographical localities. Their typical reproductive sites are temporary and shallow water bodies.

Field studies in Giza areas revealed that intense sexual activities began after sunset till midnight in leopard toad, whereas at dawn in mascarene frog. Moreover, male reproductive cycles of both species are of typical prolonged breeders and continuous with a generally breeding time extended between March and September/October (Akef and Schneider, 1990, 1995). However, in contrast, little is known about their female reproduction, especially regarding their sexual traits, which are the core of their life histories due to their ability to control population dynamics (Smirnov, 1992; Chen et al., 2001; Garcia et al., 2009). Further, seasonal cycles in trait's investment depend on female condition and vary with the geographical distribution (Kyriakopoulou-Sklavounou and Loumbourdis, 1990; Prado and Haddad, 2005; Hartel et al., 2007). They also influenced by the environment (Jørgensen et al., 1978; Rastogi et al., 1983; Saidapur and Hoque, 1995; Shahriza et al., 2010). For example, the onset of massive breeding activity correlated with specific environmental conditions (proximate factors) such as temperature in *Pelophylax bedriagae*, where traits are significantly larger in spring than in summer (Akef, 2012). These data are useful for the development of hypotheses about the evolution of reproductive cycles in anurans in general.

The ovarian annual cycles of mascarene and leopard populations and their control by physiological and environmental factors are not fully known. Hence, an attempt has been made to study the annual reproductive cycles in females of these species.

MATERIALS AND METHODS

Study area and sampling

A total of 157 and 147 adult females for *Bufo regularis* and *Ptychadena mascareniensis*, respectively, were sampled monthly from the same biotops in two neighboring areas, the Abo Rawash (30°01N 31°04E) and El Mansuriya (30°02N 31°11E), at elevation 19 m, Giza governorate, southern Egypt, during 2001, 2005 and from January 2008 to December 2009. Adults captured at nights. Climatic variables obtained from the closest meteorological station at similar elevation (Central Laboratory for Agricultural Climate in Dokki, Giza), 25 km apart from the sample locality. As shown in Table 1, the climate of the study area with maximum temperatures (in °C) and photoperiod (daylength in hour (h) occur in summer (June–August). Rainfall in mm, however, is rare and very low, with a maximum 0.17 mm in January 2008. Relative air humidity (%) rose during October–December interval. The lowest mean values of moonlight in hour (h) existed during April–June 2008 and May–July 2009.

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Sample treatment

Female body mass (BM) was weighed to the nearest 0.01 g and snout-vent length (SVL) of adults was measured to the nearest 0.01 mm with a caliper. Mature ovary mass (OM), liver mass (LM), abdominal fat body mass (AFBM) and inguinal fat body mass (IFBM) were weighed to the nearest 0.01 g with an electronic balance (Scaltec balance, SBA 31).

Histological examination of ovary

A piece (10%) from the left and right ovarian tissue were excised and fixed in Bouin's solution, dehydrated with ethanol (70%, 90%), embedded in paraffin wax, sectioned at 7 μm (at least three cuts/ovary) and stained with haematoxylin and eosin. The total numbers of oocytes were estimated by pooling data from both ovaries. The follicular diameters were measured with an ocular micrometer. The classes of follicles that investigated were: previtellogenic follicles (PVFs up to 0.5 mm), early vitellogenic follicles (EVFs up to 0.90 mm for toad and up to 0.80 mm for frog), late vitellogenic follicles (LVFs = mature ova), based on the occurrence of the nuclei in the animal pole was over 0.90 mm for toad and over 0.80 mm for frog.

Measurement of clutch and egg sizes

Total number of mature ova in freshly prepared ovaries was counted following the method of Berger and Uzzell, 1980; Kyriakopoulou-Sklavounou and Loumbourdis, 1990, where a 10% of the ovary was weighed, and the mature eggs from this piece were placed in Petri dishes and counted. Diameters of the mature oocytes were also taken (20 oocytes) to verify monthly variations in the diameter of mature ova.

Statistical analysis

Because the organ variables usually varied more significantly with BM than SVL, linear regression residuals of $\log_{10}$-transformed organ mass as well as sexual traits (dependent) against $\log_{10}$-BM (independent) were calculated and used as indices. I calculated body condition index using a linear regression of $\log_{10}$ body mass (dependent) versus $\log_{10}$ length (independent) and using the residuals of the regression as the index. I then averaged the residuals for each year and correlated these average residuals with the environmental variables by using bivariate, Pearson's correlation coefficients (r). Analysis of variance (ANOVA) was applied to examine monthly changes in the residuals. Significance tests were also made using Mann–Whitney U-test. Only months with $n \geq 3$ were used. A probability level of 0.05 or less was considered as significant. All statistical analyses were performed using SPSS version 15. Means cited in the text are $\pm$ 1 SD.

Table 1. Monthly means of T (temperature in °C), RH (relative humidity in %), PP (photoperiod in h), ML (moonlight in h) and rainfall (in mm).

	J	F	M	A	M	J	J	A	S	O	N	D
2008												
T day	15.68	17.13	25.32	27.71	28.97	31.68	31.55	32.6	30.84	25.9	22.85	19.05
T night	12.44	14.35	20.61	23.1	24.52	27.08	27.14	28.26	26.81	22.12	18.71	15.35
RH	61.9	55.1	47.35	44.3	48.35	54.1	62.77	61.23	59.63	64.68	66.7	62.81
PP	10.28	10.9	11.73	12.67	13.48	14.98	14	13.52	12.68	11.8	10.92	10.32
ML	14	12	12	10	9	10	11	13	14	13	12	12
Rainfall	0.17	0.097	0	0	0	0	0	0	0	0.15	0	0
2009												
T day	17.43	18.4	19.8	24.57	27.45	32.55	32.57	31.35	30.84	28.05	22.06	18.85
T night	13.38	14.25	15.27	19.85	23.06	27.48	28.29	27.28	26.45	23.68	18.62	15.13
RH	59.1	54	55.61	54.77	51.35	49.53	59.06	60.74	58.3	60.9	62.93	61.97
PP	10.75	10.82	11.6	12.53	13.53	14.98	14	13.53	12.7	10.92	10.92	10.32
ML	13	13	13	11	10	10	9	11	12	13	13	12
Rainfall	0	0.014	0	0	0	0	0	0	0	0	0	0
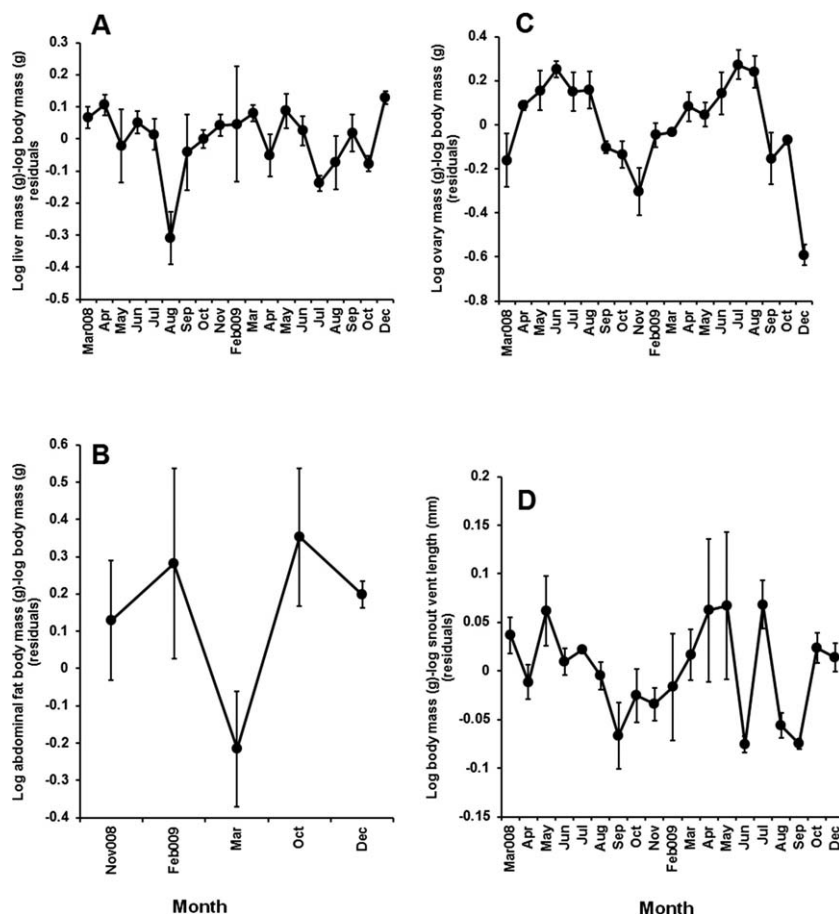
Fig. 1. Monthly changes of the liver **(A)**, abdominal fat body **(B)**, ovary **(C)** and body condition index **(D)** of adult mascarene frog. Data are expressed as means ± SE of mean. Sample sizes are indicated in Table 2.

RESULTS

Annual variations in masses of energetic reserve organs

In frog, LM showed significant monthly variation ($F_{18,49}$ = 2.74, P = 0.003, Fig. 1A), with the lowest mean values in summer (August 2008, July 2009). AFBM like LM affected by month changes ($F_{10,25}$ = 3.06, P = 0.03, Fig. 1B), and showed the lowest mean values during reproduction and exhibited large peaks during non-breeding phase. AFBM not correlated to sexual organ, traits or to LM (P > 0.05). LM had

significant negative correlation with OM (r = –0.28, P = 0.02, n = 68), but not with sexual traits (P > 0.05).

In toad, LM was affected by month variation ($F_{21,70}$ = 2.52, P = 0.002, Fig. 2A), with the largest peak in June associated with sudden drop in July 2008 and verified more or less increase during fall months of the year 2009. After October 2008, LM decreased gradually to reach minimum mean value in March 2009. AFBM altered significantly by month variation ($F_{19,43}$ = 2.56, P = 0.005, Fig. 2B), but IFBM was not affected by change of the month ($F_{19,31}$ = 1.42, P = 0.19, Fig. 2C). However, they depleted sharply in March 2009, with the beginning of the reproductive cycle and were grown in the non-breeding period. OM was negatively and significantly correlated to LM (r = –0.282, P = 0.007, n = 92), AFBM (r = –0.41, P < 0.001, n = 63), but not to IFBM (r = –0.233, P = 0.10, n = 51). Egg size and number correlated inversely and significantly to AFBM ($r_{egg\ size}$ = –0.33, P < 0.01) and ($r_{egg\ number}$ = –0.36, P < 0.01). Conversely, IFBM was not correlated to sexual organ and traits (P > 0.05). Egg number, not size,

was related negatively to the LM (r = –0.27, P < 0.01). The latter was positively correlated to AFBM (r = 0.55, P < 0.0001, n = 63) and IFBM (r = 0.33, P = 0.02, n = 51).

Annual cycle of ovarian activity

In frog, OM residuals (reproductive condition) showed monthly variation ($F_{18,49}$ = 8.70, P < 0.0001, Fig. 1C) and offered better reproductive condition in summer, with the largest peaks in June 2008 and July 2009. It reacted more strongly with BM (r = 0.50, P < 0.0001, n = 68) than with SVL (r = 0.23, P = 0.055, n = 68). OM did not correlate to either egg size or egg number (P > 0.05). In leopard toad, OM was influenced by month variation ($F_{21,70}$ = 3.33, P < 0.0001, Fig. 2D) and displayed better reproductive condition in spring-summer period, with the largest peaks in April 2008 and June 2009. After December 2008, ovarian size increased progressively in winter and spring (March–April) months. OM interacted more or less equally to both log BM (r = 0.72, P < 0.0001, n = 92) and SVL (r = 0.66, P < 0.0001, n = 92). It was correlated significantly and positively to clutch size (r = 0.45, P < 0.0001) and egg size (r = 0.27, P < 0.01).

Annual vitellogenic cycle

In mascarene frog, mature follicles were absent in December 2008, November 2009 and totally by January month for the two years studied where oocytes seemed to be in a resting stage and previtellogenic follicles were recruited for vitellogenesis in February (Fig. 3A), whereas in the leopard toad, all types of oocytes presented throughout the year (Fig. 3B). Moreover, frog had significantly more previtellogenic follicles than toad (Mann–Whitney U-test Z = –5.02, P < 0.0001, Fig. 4A, E). By contrast, leopard toad had significantly higher early (Mann–Whitney U-test Z = –4.71, P < 0.0001, Fig. 4B, F) and late vitellogenic follicles (Mann–Whitney U-test, Z = –2.59, P < 0.01, Fig. 4C, G).

Additionally, in mascarene frog, monthly change had significant effect on mature egg size ($F_{18,49}$ = 3.85, P < 0.0001), but not on egg number ($F_{18,49}$ = 1.21, P = 0.28). During breeding season, both mature egg number and size in 2008 showed three peaks in June (6038.8 ± 2938.95/100 g BM, size = 0.95 ± 0.04 mm), August (7742.40 ± 5074.31/100 g BM, size = 0.93 ± 0.09 mm) and October (3501.70 ± 3170.92/ 100 g BM, size, 0.92 ± 0.02 mm). In 2009, they increased in May (4354.20 ± 3489.77/ 100 g BM, size = 0.98 ± 0.09 mm), July (5061.20 ± 399.60/100 g BM, size = 0.98 ± 0.04 mm) and October (4034.00 ± 1029.73/ 100 g BM, size = 0.93 ± 0.01 mm). Annual egg size cycle correlated positively and significantly to their number (r = 0.31, P < 0.01, n = 68). In addition, log SVL not correlated to both log egg size or to log egg
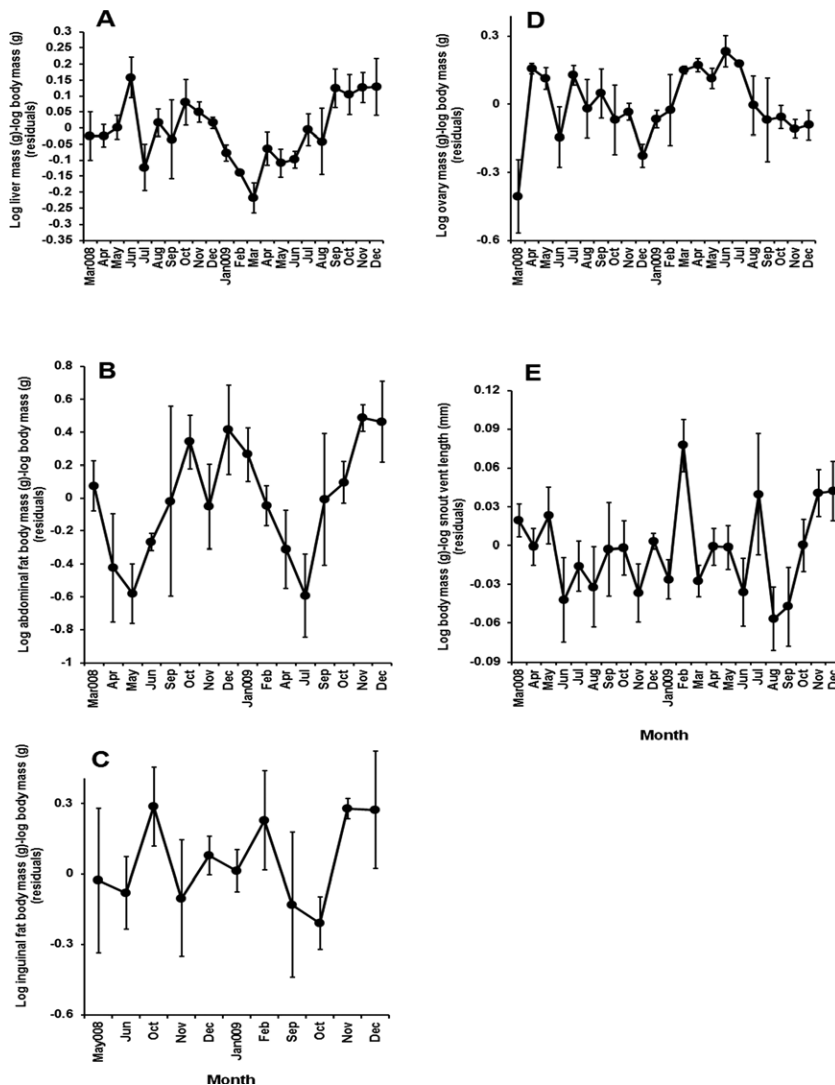
Fig. 2. Monthly changes of the liver **(A)**, abdominal fat body **(B)**, inguinal fat body **(C)**, ovary **(D)** and body condition index **(E)** of adult leopard toad. Data are expressed as means ± SE of mean. Sample sizes are indicated in Table 3.
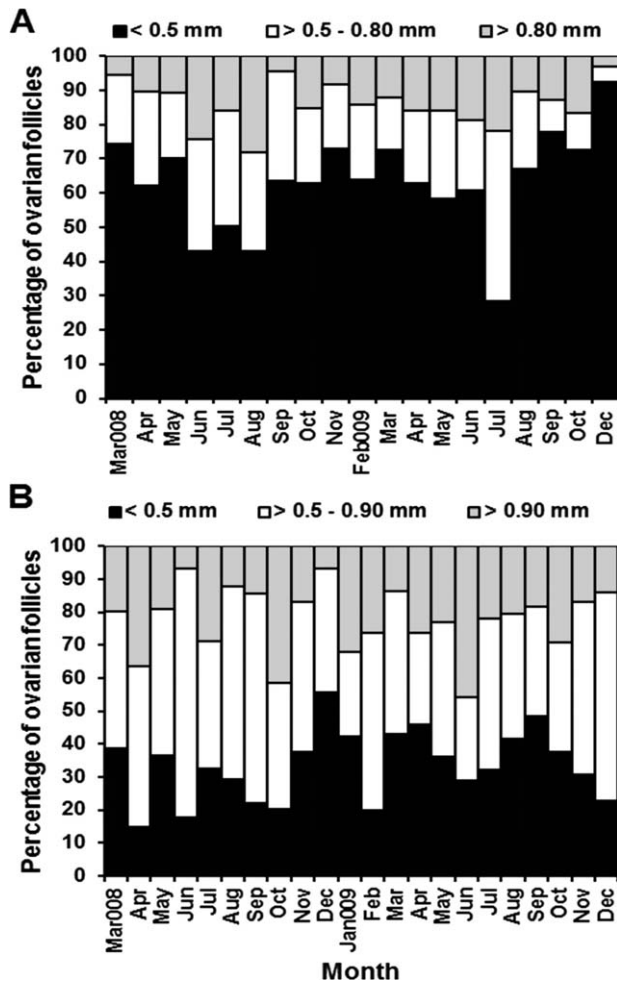
Fig. 3. Percentage of each ovarian size class from total number of follicles by month in mascarene frog **(A)** and leopard toad **(B)**. Sample sizes are indicated in Tables 2 and 3.

number. Log BM also not correlated to log egg size, but related significantly and positively to log clutch size (r = 0.28, P = 0.02).

In leopard toad, annual egg size and number cycles affected by month variation ($F_{21,70}$ = 2.11, P < 0.01) and ($F_{21,70}$ = 5.27, P < 0.0001), respectively. During reproduction, they rose in April (14223.70 ± 6212.83/100 g BM, size = 1.12 ± 0.03 mm) and July 2008 (9308.40 ± 4446.24/100 g BM, size = 1.02 ± 0.03 mm). In October 2008, second peak of egg size was recorded (1.05 ± 0.09 mm). From December 2008 to January 2009, the number of eggs increased significantly (1848.60 ± 625.89/100 g BM versus 4538.70 ± 11118.10/100 g BM, Mann–Whitney U-test Z = −2.46, P < 0.01). In 2009, they peaked in April (22787.70 ± 7860.58/100 g BM, size = 1.12 ± 0.07 mm) and June (6478.20 ± 3073.65/100 g BM, size = 1.07 ± 0.09 mm). Third peak of egg number was found in October 2009 (4611.70 ± 2393.05/100 g BM). Egg number and size exhibited positive significant relationship with each other (r = 0.38, P < 0.0001). Both log body size and log mass had no correlation with log egg size (P > 0.05). Nevertheless, these correlated to log egg number (r_{SVL} = 0.27, P = 0.016) and (r_{BW} = 0.26, P = 0.02).

Ovipositing strategies varied between species studied,
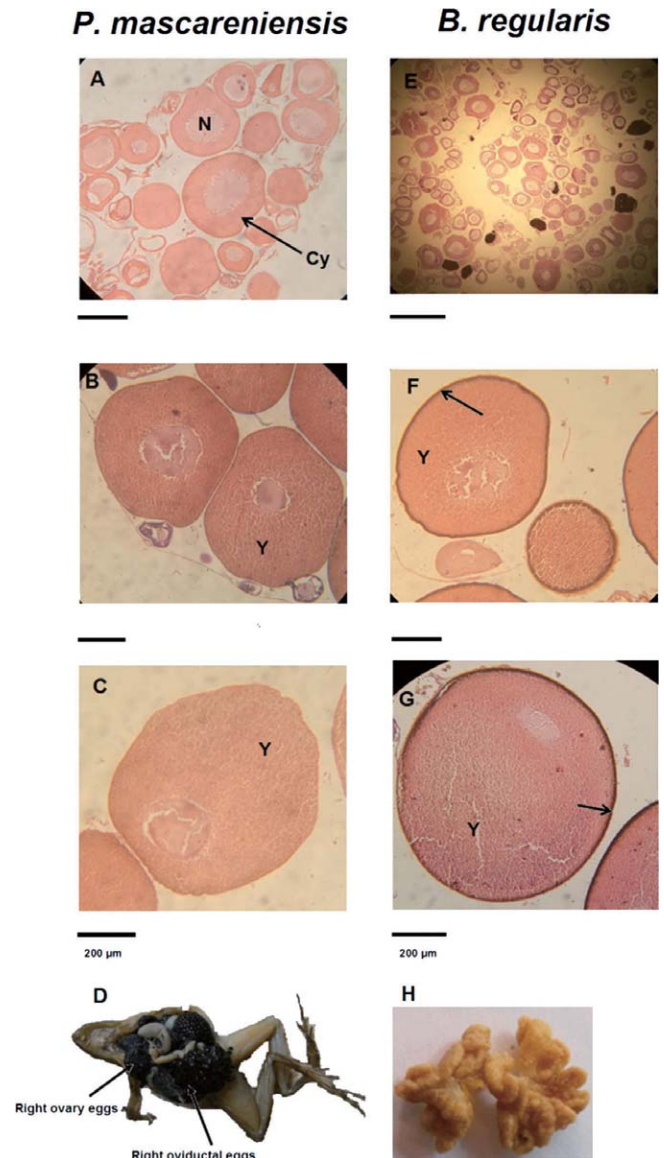
Fig. 4. Cross sections of ovary of *P. mascareniensis* **(A–C)** and *B. regularis* **(E–G)** showing: previtellogenic follicles in February **(A)** and April **(E)**; early vitellogenic follicle with yolk (Y) in June **(B)** and in March **(F)**; late vitellogenic follicle with nucleus at the animal pole in August **(C)** and in May **(G)**. Pigmentation is intense at the periphery (arrows); N, nucleus, Cy, cytoplasm. Scale bar is 200 μm. **(D)** Mature eggs in ovary and in the proximal end of the oviduct of adult mascarene frog with SVL of a 45.90 mm (BM of a 8.21 g), collected on March 30, 2008. Note that all the eggs in the oviduct are isometric. **(H)** Ovary of leopard toad collected on April 21, 2008 (BM 44.2 g/SVL 77.8 mm) devoid of mature eggs.

where female toad lays all ripe eggs (Fig. 4E, H) in one clutch during oviposition, while female frog retained a small portion of a clutch (Fig. 4D).

Body and reproductive conditions across years (effect of climate change)

Individual's body condition with positive residuals could be considered to be in better condition than individuals with negative residuals (Figs. 1D, 2E, 5). No significant differ-
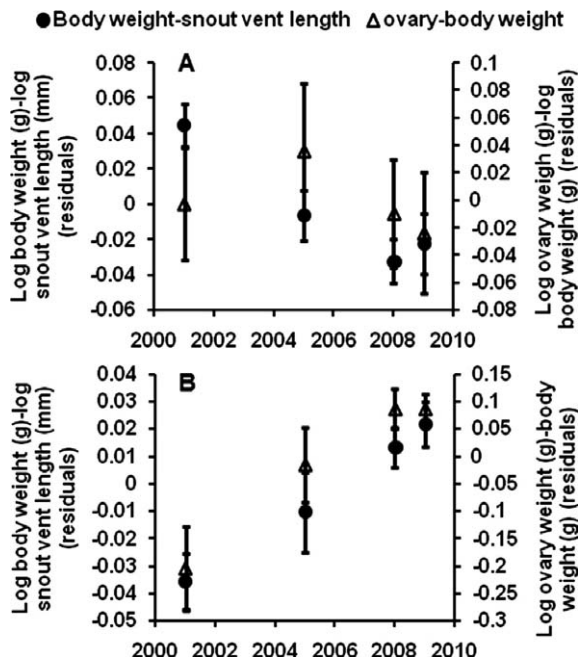
Fig. 5. Body and reproductive conditions in adult mascarene frog **(A)** and leopard toad **(B)** across years. Data are expressed as means ± SE of mean and the sample sizes are indicated in Tables 2 and 3.

Table 2. Changes in the mean of body mass (BM), snout-vent length (SVL) and ovary mass (OM) of adult mascarene frog. Data are expressed as the means ± 1 SD (n = sample size).

Month	n	BM (g)	SVL (mm)	OM (g)
2001				
Feb	3	13.00 ± 1.73	50.83 ± 1.53	0.88 ± 0.45
Mar	4	10.00 ± 0.01	48.38 ± 1.49	0.78 ± 0.45
Apr	3	10.00 ± 2.00	47.2 ± 5.70	0.68 ± 0.24
May	4	8.15 ± 1.58	48.75 ± 4.21	0.83 ± 0.53
Jun	3	8.67 ± 1.15	45.67 ± 3.06	1.08 ± 0.24
Jul	5	8.68 ± 0.84	48.18 ± 1.65	1.26 ± 0.55
Aug	6	12.33 ± 1.97	50.83 ± 2.21	1.87 ± 1.38
Sep	9	12.11 ± 1.35	49.07 ± 3.00	1.37 ± 0.55
Oct	3	12.67 ± 3.06	49.07 ± 3.04	1.07 ± 0.39
Nov	3	10.00 ± 0.01	47.00 ± 1.73	0.79 ± 0.18
Dec	3	10.00 ± 1.73	50.17 ± 5.48	0.19 ± 0.09
2005				
Feb	3	9.73 ± 1.99	49.00 ± 2.65	0.61 ± 0.27
Mar	8	11.20 ± 2.13	49.13 ± 2.95	0.90 ± 0.43
Apr	8	8.75 ± 1.87	42.33 ± 3.33	0.84 ± 0.35
May	3	8.57 ± 1.78	44.30 ± 3.98	0.78 ± 0.47
Jun	4	9.65 ± 3.29	48.41 ± 5.15	1.57 ± 0.77
Jul	4	8.50 ± 1.49	48.64 ± 5.24	1.49 ± 0.80
Aug	3	7.23 ± 1.97	45.20 ± 4.95	1.02 ± 0.46
2008				
Mar	3	10.93 ± 0.65	49.93 ± 1.90	0.74 ± 0.31
Apr	7	8.18 ± 1.59	45.76 ± 3.79	0.84 ± 0.23
May	3	8.47 ± 1.33	43.22 ± 3.60	1.12 ± 0.67
Jun	4	9.45 ± 2.06	47.79 ± 4.13	1.52 ± 0.61
Jul	3	8.23 ± 0.06	44.57 ± 0.40	1.01 ± 0.38
Aug	4	9.08 ± 0.62	47.93 ± 2.31	1.16 ± 0.32
Sep	3	8.50 ± 2.86	48.93 ± 4.29	0.56 ± 0.21
Oct	4	9.18 ± 2.26	48.70 ± 3.21	0.59 ± 0.22
Nov	5	6.94 ± 1.14	43.54 ± 1.66	0.31 ± 0.16
2009				
Feb	3	9.83 ± 3.75	49.10 ± 5.02	0.76 ± 0.27
Mar	3	9.77 ± 2.73	48.07 ± 4.90	0.80 ± 0.28
Apr	4	9.58 ± 2.22	45.43 ± 2.71	1.06 ± 0.44
May	3	8.47 ± 1.85	42.78 ± 2.42	0.83 ± 0.40
Jun	3	6.87 ± 0.89	45.40 ± 3.33	0.75 ± 0.22
Jul	3	11.23 ± 3.28	48.43 ± 4.12	1.92 ± 0.41
Aug	3	7.23 ± 1.96	45.20 ± 4.95	1.02 ± 0.46
Sep	3	7.10 ± 0.61	46.07 ± 1.51	0.42 ± 0.17
Oct	4	9.43 ± 0.29	47.30 ± 1.01	0.71 ± 0.09
Dec	3	9.17 ± 1.42	47.07 ± 2.82	0.21 ± 0.06

ence was recorded in body or reproductive condition between the years 2008 and 2009. However, body condition in 2009 was better than that in 2008 for both species. Body condition residuals during 2008–2009, significantly affected by month variation in frog ($F_{18,49}$ = 1.97, P = 0.03, Fig. 1D, Table 2) and toad ($F_{21,70}$ = 1.95, P = 0.02, Fig. 2E, Table 3). Both species exhibited general annual profile with more or less similar monthly changes in 2008 and in 2009. In frog, it peaked positively in March, May, and July 2008 and in May, July (as OM and sexual traits) and October. In leopard toad, body condition maximized positively by March and May 2008 and February, July and November/December 2009. It increased as masses of liver or/and fat bodies during non-breeding season. Body condition index had no correlation with the OM index and sexual traits in both species (P > 0.05).

In frog, body condition residuals in 2001 (Fig. 5A, Table 2) showed significant higher mean value than that in 2005 (Mann–Whitney U-test Z = −2.73, P = 0.006), 2008 (Mann–Whitney U-test Z = −3.97, P < 0.0001) and 2009 (Mann–Whitney U-test Z = −2.93, P = 0.003). In contrast, reproductive condition had no significant variation among years (P > 0.05) (Fig. 5A, Table 2). Unlike frog, in leopard toad, body condition in 2001 (Fig. 5B, Table 3) was significantly lower than that of the year 2008 (Mann–Whitney U-test Z = −3.73, P < 0.0001) and 2009 (Mann–Whitney U-test Z = −4.01, P < 0.0001. OM (Fig. 5B, Table 3) in 2001 (3.86 ± 0.68) was significantly lower than that of the year 2008 (6.65 ± 0.72, Mann–Whitney U-test Z = −2.83, P = 0.005) and 2009 (9.24 ± 0.71, Mann–Whitney U-test Z = −2.65, P = 0.008). However, no significant differences found between 2001 and 2005 in body and reproductive conditions (P > 0.05).

Meteorological effects
Sexual parameters. – During 2008–2009, in both spe-

cies, rainfall cycle not correlated to any parameter examined. In leopard toad, monthly changes in aerial temperature had no relationship with masses of sexual or storage organs as well as sexual traits, whereas relative humidity cycle was significantly and negatively correlated to cycles of both egg size (r = −0.49, P = 0.02) and number (r = −0.44, P = 0.04). Annual photoperiod cycle was positively correlated to OM cycle (r = 0.49, P = 0.02). Moonlight correlated negatively to OM (r = −0.43, P = 0.047) and egg size (r = −0.51, P = 0.02).

In mascarene frog, relative humidity negatively correlated to egg size (r = −0.58, P < 0.01). Besides, aerial temperature related significantly and positively to OM (r = 0.68, P < 0.002 during day; r = 0.50, P = 0.03 at night) as well as egg number (r = 0.48, P = 0.04 during day, r = 0.47, P = 0.04 at night). In frog, photoperiod cycle correlated positively to

Table 3. Monthly mean of body mass (BM), snout-vent length (SVL) and ovary mass (OM) of adult leopard toad. Data are expressed as the means ± 1 SD (*n* = sample size).

Month	*n*	BM (g)	SVL (mm)	OM (g)
2001				
Jan	3	36.33 ± 19.66	72.83 ± 10.41	4.52 ± 2.72
Feb	3	53.33 ± 20.23	78.00 ± 7.09	4.84 ± 2.97
Mar	3	54.67 ± 12.86	82.17 ± 5.97	8.15 ± 7.15
Apr	3	37.33 ± 6.43	76.67 ± 3.69	1.80 ± 2.25
May	5	38.67 ± 12.06	79.17 ± 9.93	3.63 ± 3.84
Jun	2	38.00 ± 12.35	71.00 ± 7.19	4.36 ± 2.19
Jul	4	29.00 ± 1.41	72.00 ± 1.41	4.23 ± 2.22
Aug	4	52.45 ± 8.41	83.38 ± 0.48	9.43 ± 8.07
Sep	2	45.50 ± 4.95	80.75 ± 3.89	2.50 ± 1.84
Oct	4	44.00 ± 14.05	77.75 ± 10.05	2.95 ± 3.07
Nov	3	36.80 ± 8.66	75.33 ± 4.73	1.76 ± 1.69
Dec	2	29.00 ± 1.41	68.00 ± 0.01	1.14 ± 1.22
2005				
Feb	4	52.98 ± 19.50	76.78 ± 8.47	11.36 ± 9.66
Mar	6	39.48 ± 11.66	73.33 ± 7.94	5.07 ± 3.99
Apr	3	25.53 ± 5.06	60.17 ± 6.25	4.78 ± 1.07
May	4	51.48 ± 17.48	78.81 ± 7.49	4.24 ± 3.99
Jun	3	32.60 ± 7.97	73.83 ± 4.19	4.97 ± 3.56
Jul	4	36.83 ± 16.54	74.14 ± 7.06	4.49 ± 4.65
Aug	4	32.23 ± 3.16	73.38 ± 1.25	3.60 ± 3.00
2008				
Mar	4	31.55 ± 15.87	64.95 ± 10.26	1.64 ± 1.15
Apr	8	44.80 ± 24.79	73.79 ± 13.24	16.91 ± 5.84
May	7	40.20 ± 10.51	71.62 ± 7.19	6.79 ± 4.12
Jun	4	34.63 ± 7.20	71.65 ± 2.77	6.13 ± 1.69
Jul	3	43.60 ± 7.20	76.13 ± 3.37	6.67 ± 0.58
Aug	3	52.37 ± 27.11	80.33 ± 14.19	13.32 ± 6.78
Sep	4	48.60 ± 23.03	76.78 ± 7.44	13.29 ± 4.97
Oct	4	56.80 ± 6.44	82.55 ± 1.89	8.67 ± 8.54
Nov	4	43.63 ± 3.11	77.61 ± 3.67	4.74 ± 1.64
Dec	4	47.75 ± 7.15	77.40 ± 3.44	5.47 ± 0.94
2009				
Jan	5	61.22 ± 13.89	86.12 ± 7.52	7.71 ± 2.51
Feb	3	71.73 ± 11.71	83.93 ± 3.67	12.35 ± 10.24
Mar	3	53.70 ± 16.82	82.03 ± 8.10	6.36 ± 5.00
Apr	4	44.38 ± 17.92	74.57 ± 12.24	7.53 ± 4.26
May	5	47.50 ± 9.84	77.40 ± 5.93	8.00 ± 2.11
Jun	3	54.07 ± 7.20	71.65 ± 2.76	9.37 ± 2.55
Jul	3	58.37 ± 23.15	79.60 ± 6.55	2.85 ± 1.81
Aug	3	34.77 ± 27.11	72.78 ± 14.19	8.16 ± 3.00
Sep	3	59.73 ± 20.12	86.30 ± 7.53	5.58 ± 3.89
Oct	3	67.53 ± 11.62	87.40 ± 4.76	11.25 ± 10.51
Nov	6	76.32 ± 9.34	88.42 ± 5.22	8.62 ± 3.89
Dec	6	60.97 ± 20.61	81.03 ± 12.42	9.09 ± 2.44

cycles of OM (r = 0.83, *P* < 0.0001), and egg number (r = 0.55, *P* = 0.02). Annual moonlight cycle correlated negatively to OM cycle (r = –0.51, *P* = 0.02).

Body condition and energetic reservoirs. – In leopard, annual photoperiod cycle correlated negatively to AFBM cycle (r = –0.54, *P* < 0.01) and IFBM (r = –0.52, *P* < 0.01). In mascarene frog, photoperiod correlated to AFBM (r = –0.65, *P* < 0.002), as was the case for temperature, which correlated negatively to AFB cycle (r = –0.59, *P* < 0.008 during day; r = –0.58, *P* < 0.009 at night) and LM cycle (r = –0.54, *P* = 0.018 during day; r = –0.55, *P* = 0.015).

Annual body index cycle correlated negatively to moonlight cycle in mascarene frog (r = –0.51, *P* = 0.03), but not in leopard toad.

DISCUSSION

Both species studied showed discontinuous breeding cycles in a similar pattern for other anuran species living in Mediterranean area. However, they exhibited different vitellogenic patterns, where it was continuous with mature ova being held in the leopard ovary throughout the year, as found in *Bufo variabilis* in Israel (Jørgensen, 1984) and *Bufo boulengeri* in Egypt (Akef, 2013). In contrast, it is discontinuous in mascarene frog like anuran species inhabiting northern Mediterranean areas (Rastogi et al., 1983; Delgado et al., 1990; Tsiora and Kyriakopoulou-Sklavounou, 2002).

In the present study, leopard liver mass was inversely correlated to the ovarian mass and egg number, suggesting that the lipidic support of liver to the vitellogenesis is occurred as supposed by Follett and Redshaw (1974) in *Xenopus* laevis. Similarly, abdominal fat body mass was negatively correlated with the ovarian mass and sexual traits which suggests that it merely serves as an energy reservoir in female reproduction as mentioned for some anuran species (e.g., Pancharatna and Saidapur, 1985; Díaz-Páez and Ortiz, 2001; Prado and Haddad, 2005). Conversely, in mascarene frog, sexual organ and traits showed no correlation with the abdominal fat body, proposing that the energy needed for the vitellogenesis may not be directly from the fat body. However, this is not the case, as the mass of the abdominal fat markedly decreased during reproduction and this may be a reason for the lack of relationship with the sexual parameters. Further, although there was no relationship between the mass of the liver with sexual traits throughout the year but in August 2008 as well as July and October 2009 it decreased strongly at the peak of the sexual parameters. However, from the annual oogenic profile, it is clear that less energy is shunted to egg production and development during reproduction, and this may explain why it stopped in some months during the non-breeding phase. Thus, the role of storage reserve organs remains uncertain for vitellogenesis in the latter species.

Ovipositing mode varied between species studied; where leopard female shed, all mature eggs in a clutch, whereas mascarene frog retained a small portion of a clutch after each oviposition. This retention may facilitate multiple ovipositions during the reproductive season (Ritke and Lessman, 1994). It may also be important to scale body mass with sexual parameters, which may be responsible for the significant positive clutch size/body mass variation within their individuals. This shows that clutch size regulated by body mass, and hence the larger leopard toad is more fertile than the mascarene frog. This finding is in agreement with the general rule that within and among species, heavier individuals produce more eggs (Prado and Haddad, 2005; Tomašević et al., 2008; Akef, 2013). Based on the results of vitellogenesis and ovipositing strategies, consumption of fat reserves by female leopard toad is intense and deflect more energy for both vitellogenesis and oviposition than frog species.

In the species studied, the increase in the body condition and fat body mass during fall period could be explained as storage of relatively larger energy prior to winter for ener-

getic requirements as done by terrestrial anurans, which depend primarily on lipid stores (e.g., Jones, 1980). Further, accumulations of glycogen in the leopard liver in October, as well as fat body lipid stocks in December 2008 were utilized in increasing the number of ripe eggs and continuous ovarian growth during January–February 2009. The latter condition also reported for some anuran species (Delgado et al., 1990; Loumbourdis and Kyriakopoulou-Sklavounou, 1996; Lu, 2004). Mascarene frog, unlike leopard toad, did not show any signs of sexual activity during the November/December–January period. As such, female leopard invested energy needed for reproduction during winter, while the main energy expenditures for female mascarene are used for body.

Although no correlation was found between body condition versus sexual organ and traits in both species studied, reduction in mascarene body condition by June and August 2008 happened at the time of peaking of sexual organ and traits, marking body's participation in the sex operations this year. However, during 2009, their parallel increase in July and October suggests that there were a better nutritional state and/or habitat quality (Sztatecsny and Schabetsberger, 2005) in this year. In leopard toad, body condition and masses of storage organs reduced in April 2008 as well as during January and June 2009, in accordance with the augmentation of sexual parameters, indicating that they conferred high energy for sexual activities in these months. According to previous reports, egg production and ovarian growth must, therefore, rely on body reserves like *Rana muscosa* (Bradford, 1983) and *Pelophylax perezi* (Delgado et al., 1990). Moreover, in the leopard population the largest peak of the body condition occurred in February 2009, just prior to the beginning of breeding activity, which may reflect high physical and reproductive fitness (Green, 2001), followed by sudden severe drop in March as masses of the reserve organs at the time of the first wave of egg-laying.

The fluctuation of body condition with large-scale climatological events recorded in this study is consistent with the results of Tryjanowski et al. (2006) in that the body size of two water frog parental species (*Pelophylax ridibundus* and *Pelophylax lessonae*) increased significantly, whereas decreased non-significantly in their hybrid *Pelophylax esculentus*. Furthermore, changes in body condition (in terms of length-weight relationship) across years have been used to assess the general growth rates of populations. In this way, developmental changes of mascarene frog across years may be induced by some degree of food deprivation at the larval stage. On the other hand, due to a peak of activity in the summer as temperatures rise in the small sized water bodies, leading to the decrease in the level of oxygen concentration required for tadpoles' tissues. This may explain in part why mascarene frog are smaller when development occurs at higher temperatures (Tumlison and Trauth, 2006).

In this study, *Bufo regularis* preferred spring climate to achieve intensive sexual activities that is why or may be responsible for the insignificant correlation between annual cycles of temperature and sexual parameters, because most activities occurred in spring and decreased during summer. Moreover, rainfall had no correlation with reproductive traits in both species. Taken together these results suggest that neither temperature nor rainfall control sexual activities of

Bufo regularis. In addition, the largest ovarian mass of toad species existed in April 2008 and June 2009, in concomitant with the lowest mean values of relative humidity at both months. Moreover, egg number and size correlated negatively to relative humidity, suggesting that toad laid more large eggs in a dry atmosphere than do in moist warm weather. Conversely, mascarene frog showed the largest peaks of sexual organ as well as traits in summer, highlighting that it produces more large eggs in a combined moist–covariance between high temperature and photoperiod and is more opportunistic than toad species. The beneficial effects of the previous ecological parameters on eggs are to balance water loss due to evaporation and accelerate egg hatching. Besides, Chen et al. (2001) reported that tadpoles living in hot spring grow faster. Generally, monitoring the temperature and humidity level is critical and probably indicator for more successful hatch in frog than toad species at this time. Additionally, felicitous tolerance of egg laying in warm weather may be attributed to egg volume, with mascarene frog having the greatest egg volume and thus the greatest ability to resist desiccation (Sota and Mogi, 1992).

Exclusive feeding activity by mascarene and frog populations is reinforced by the significant relationship between the storage organs and photoperiod in a similar pattern for some amphibians (Floyd, 1985). Also noteworthy is the significant correlation between light and ovary cycles. Similar results were found in *Rana catesbeiana* (Horseman et al., 1978) and *Rana leptoglossa* (Saha and Gupta, 2011). However, this correlation was stronger in mascarene frog, which also exhibited significant and positive relationship between cycles of photoperiod and egg number like *Rana tigrina* (Saidapur and Hoque, 1995).

Under such body and environmental constraints, microhabitat size and/or type (aquatic or terrestrial habitat) may also be one of the critical factors influencing egg size in anuran species living in Egypt. For example, female *Pelophylax bedriagae* with the largest ovarian eggs and set eggs in open deep water bodies (over 1.3 mm, Akef, 2012); whereas ovarian eggs in *Bufo boulengeri* which spill eggs in moderate to shallow water bodies was over 1.00 mm (averaged 1.19 mm/year, Akef, 2013). In this study, both species choose shallow water bodies, with female leopard toad preferring large-sized shallow water and had ovarian mature eggs over 0.9 mm (averaged 1.03 mm/year). In contrast, female mascarene frog had the smallest ovarian eggs (over 0.8 mm, averaged 0.93 mm/year) and favors small-sized water bodies for putting eggs.

In order to know which frog species dominates in Egypt where, geographically speaking, it might be important to know how the *Ptychadena mascareniensis* and *Pelophylax bedriagae* are affected by temperature, especially in the summer. According to a study on reproductive traits of large frog *Pelophylax bedriagae* (Akef, 2012) and therein, they showed dissimilar reproduction with differing temperature optimums (the temperature at which development is fastest), where mascarene frog more challenging environmental conditions, as it breeds in areas that have high summer temperatures, from *Pelophylax bedriagae*. For this reason, mascarene frog is more widely distributed in deep southern Egypt areas than *Pelophylax bedriagae* (personal observation).

In conclusion, environmental factors play key roles in

the life history and reproductive traits and are important for structuring and regulating vital activities in mascarene frog communities. Besides, the negative interaction of mascarene body and reproductive conditions against environmental events across years may itself be subject of natural selection. Conversely, internal factors are more effective than external ones in structuring toad communities. Although annual ovary cycle in both species studied influenced positively by daylight, toad exhibited lower sexual activities than mascarene frog in warm condition. This suggests that daylight alone is insufficient to evoke high summer activities, and that the combined action of temperature and daylight is important to elevate summer activities.

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Errata

Volume 31, No 1 (January 2014)

1. In the article "Influences of Human and Livestock Density on Winter Habitat Selection of Mongolian Gazelle (*Procapra gutturosa*)" by Zhenhua Luo, Bingwan Liu, Songtao Liu, Zhigang Jiang, and Richard S. Halbrook, which appeared on pages 20–30, there was an error in the first sentence of the ACKNOWLEDGMENTS section (Page 29, Left, Line 3). The sentence "This research was funded by the National Natural Science Foundation of China (No. 30700075)." should be read as "This research was funded by the National Natural Science Foundation of China (No. 30700075) <u>and the Fundamental Research Funds for the Central Universities (DL13CA08)</u>."

2. In the article "Reproductive Strategies of Leopard Toad and Mascarene Frog from Giza, Egypt" by Mamdouh S. A. Akef, which appeared on pages 37–44, there was an error in the first paragraph of the MATERIALS AND METHODS section (Page 37, Right, Line 14). The beginning sentence "A total of 157 and 147 adult females for *Bufo regularis* and *Ptychadena mascareniensis*,…" should be read as "A total of 157 and 147 adult <u>(gravid)</u> females for *Bufo regularis* and *Ptychadena mascareniensis*,…"