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ORIGINAL PAPER

Escape behavior of the green lizard (*Lacerta viridis*) in the Slovak Karst

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Abstract The escape behavior of the green lizard (*Lacerta viridis*) was investigated in natural conditions of the Slovak Karst, Slovakia. The seasonal changes of approach distances and types of escape behavior were monitored for both sexes, also in relation to differences in anthropogenic influence. In our study, the escape behavior of green lizard changed significantly during the season, and differ significantly between localities and in respect to human disturbance. At the beginning of the season, females stayed in close proximity to a refuge and hid immediately after being disturbed. Among males, the distance to and from a refuge was longer and any accessible protrusions were used to hide. The approach distance was greater among males. During the mating period, approach distance for females and males was similar and both sexes hid in a refuge. However, after the mating period, the approach distance for females was decreasing, whereas that of males begun to increase.

Keywords Antipredator behavior · Escape behavior · Approach distance · *Lacerta viridis* · Slovakia

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Introduction

Predator–prey encounters have lead to antipredatory escape responses in many living organisms, and several theoretical models describing the escape behavior of prey in relation to a potential predatory pressure were proposed (Ydenberg and Dill 1986; Antczak et al. 2005; Broom and Ruxton 2005; Cooper and Frederick 2007). For instance, Ydenberg and Dill (1986) assume that an animal chooses escape as a response to an approaching predator when the risk of predation is higher than the costs of escaping (flight initiation distance, approach distance). However, antipredatory behavior is costly both directly in terms of body condition and indirectly due to loss of time which could be spent foraging or mate searching (Martín et al. 2003; Cooper and Peréz-Mellado 2004; Sih et al. 1990; Crowley et al. 1991; Martín and López 1999). Overall, the risk increases with the distance to the refuge because more time is required to reach it (Bulova 1994).

If escape behavior is energetically costly, it should be especially important for ectotherm animals, such as lizards, where the body temperature is influenced by the environment (Huey 1982). In fact, some of the lizard species compensate distances to nearest safe place by longer escape distances (Snell et al. 1988; Dill and Houtman 1989; Cooper 1997; Ekner et al. 2008). However, since usage of refuges may be costly for lizards (Sih 1992), the escape decisions can be affected by thermal costs of refuge (Martín and López 2000b). The flight distance in lizards is influenced by several factors, e.g., the speed and direction of the approaching predator (Cooper 2003a, b), the frequency of attacking, the type of habitat, and the age of a lizard (Whiting et al. 2003), as well as autotomy (Formanowicz et al. 1990; Ekner et al. 2008). The human-caused disturbance of lizards in their natural habitat has a

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harmful effect because it can lead to modifications in the animals' behavior and the health status (Diego-Rasilla 2003a, b; Amo et al. 2006). It may be especially significant for species living in areas of particular touristic interest and/or farming activity.

Therefore, the aim of our study was to examine the escape behavior approach distance and the type of escape of the green lizard (*Lacerta viridis*). We focused on sexual and seasonal differences in relation to the habitat and differences in the anthropogenic influences in the two localities in the Slovak Karst National Park.

Material and methods

Study area

The study was conducted in the Slovak Karst National Park, the Biospheric Reserve on the southward slopes of Zádiel Plateau (altitude of 598 m). The area is a part of the Inner Carpathians in the Southeastern Slovakia (48°36′ N, 20°52′ E). The climate is warm with low humidity and average temperatures of −4°C in January and 19–20°C in July. The average annual air temperature ranges from 5.7°C to 8.5°C. The average rainfall is 700 mm/year. The studied area was 14,000 m^2 in total, out of which 8,000 m^2 with high anthropogenic influence (vineyard and cultivated soil) and 6,000 m^2 with low anthropogenic influence (out of hiking paths in the National Park). Natural predators in the studied localities include *Coronella austriaca*, *Falco tinnunculus*, *Buteo buteo*, *Corvus corax*, *Erinaceus europaeus*, *Mustela nivalis*, *Vulpes vulpes*, and *Martes martes* (personal observation).

Study species

The green lizard (*L. viridis*) is large lizard (up to 120 mm snout-to-vent length) from the family Lacertidae. The green lizard is a ground-dwelling and strongly diurnal species. It is insectivorous and actively chases and consumes a range of spiders and insects. Slovak populations represent the northern edge of the distribution of this lizard species and, despite being assigned the least concern category according to the International Union for Conservation of Nature Red List of Threatened Species, *L. viridis* is locally threatened by general habitat loss, afforestation of suitable sites, and predation.

During the study period, we recorded a total of 1,914 escape reactions (795 males, 712 females, 158 juvenile, and 246 unidentified gender). Excluded from the statistical analyses were cases when the sex was unidentified and juveniles (12.8% of all records). The exact approach distance and the type of escape were not always recorded and, therefore, sample sizes differed slightly between analyses. The study was regularly performed during their active season from March to September in three consecutive years (1997–1999) with a 10-day interval on two localities with different levels of anthropogenic influence.

Field work

The ambient temperature was measured in a sheltered place. Approach distances were recorded for every registered green lizard along the marked path of the same length in every observation. The approaching distance, defined as the shortest distance between escaping lizard and approaching person, was measured with a tape measure accurate to 5 cm. To avoid confounding effects that influence the lizard escape, the same person (I.M.) wearing the same clothing performed all approaches in a similar way. The distance was measured from the place where the lizard was resting to the place where the approacher was standing when the lizard started to escape.

For the purpose of the analysis of the lizards' sexual behavior, the study period (a year) was divided into three seasons: premating, mating, and postmating period. In one analysis, when is not important to divide mating status of lizards', the analysis was carried out using the following months as factors.

According to the field observations, lizards' escape reactions were divided into the six basic types:

A. The lizard is in a maximum distance of 1 m from a burrow or den with the head usually pointing to it or oriented perpendicularly to it;
B. The lizard is more than 1 m away from the burrow; short scuttle followed by running to the burrow;
C. The lizard is close to the den; it reacts to the disturbance from a distance of over 5 m by slowly crawling to the burrow;
D. The lizard is in open space; when disturbed, it displays a series of scuttles to available shelters (bush, stones, tall grass), but not to the burrow, "chase";
E. The lizard is in open space; a series of short and long quick scuttles in the uncovered area (not towards a shelter or burrow);
F. Quick direct escape from a distance of over 1.5 m straight to the burrow.

Statistical analysis

We used full general linear model (GLM) with all potential two-way and three-way interactions to test differences in types of escape and approach distances between genders, during the season, and in different localities. The Kolmogorov–Smirnov test (Z=5.64, P<0.001) showed that data differed from the normal distribution, despite being log transformed before analyses in order to reduce variance between variables. Analyses were conducted using the SPSS v.12 statistical package. All basic statistical analyses were applied according to the recommendations of Zar (1999).

Results

The mean ± SE approach distance of the green lizard was 1.93±0.03 m. The GLM model explains 34.5% of the total variation in approach distances ($F_{1,153}$=2.460, P<0.0001) with sex and interactions of sex and season having significant effect on the approach distance (Table 1; Fig. 1).

Both sexes also show seasonal changes in usage of different types of escape behavior (Fig. 2), which was related to changes in sexual activity due to progress in breeding season. In both sexes, the type of escape behavior differed significantly from equal proportion between behaviors (χ^2=68.64, df=10, P<0.001 and χ^2=161.88, df=10, P<0.001 for females and males, respectively). However, in the premating period, the differences in types of escapes between sexes were not significant (χ^2=3.06, df=5, P=0.69), but during the mating (χ^2=12.22, df=5, P=0.03) and postmating (χ^2=16.33, df=5, P=0.006) periods, escapes between sexes differed significantly.

Approach distances from localities with different levels of human disturbance were investigated. We compared 296 approach distances of males (n=296, mean ± SE=1.924± 0.068) from the locality with anthropogenic influence (vineyard) and the 498 approach distances (n=498, mean ± SE=2.313±0.055) from the locality without this influence. Differences were statistically significant (Mann–Whitney U=57829, P<0.0001); longer approach distances were recorded in the habitat without the presence of human factor.

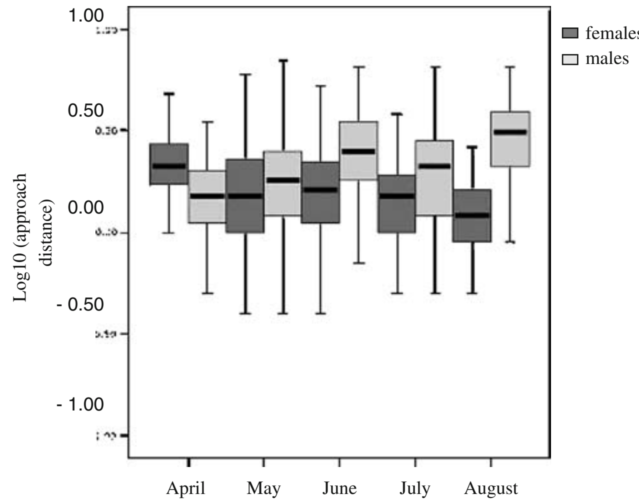

Fig. 1 Escape distance (in meters) of the green lizards in relation to sex and season. Values are presented as mean ± SE and min–max interval

Discussion

The escape behavior in lizards is influenced by several factors such as the speed and direction of the approaching predator (Cooper 2003a, b), the persistence of attacking, the type of habitat, the age of the lizard (Whiting et al. 2003), the distance to the nearest refuge (Bulova 1994), the type of refuge and microhabitat (Martín and López 2000a, b), and autotomy (Formanowicz et al. 1990), as well as human disturbance (Diego-Rasilla 2003a; Amo et al. 2006). Interestingly, our results suggest that the escape behavior of the green lizard (approach distance and the type of escape) changed during the season. The time of the season and especially the mating status (premating, mating, and postmating period) influenced the approach distances. Escape distance among males rapidly increased during and after the mating period. During the mating season,

Table 1 Factors affecting the approach distances (expressed as log-transformed value) of the green lizard according to sex, months, and locality

	Type III sum of squares	*df*	Mean square	*F*	*P*
Corrected model	15.628(a)	153	0.102	2.460	0.000*
Intercept	3.179	1	3.179	76.565	0.000*
Sex (m, f)	0.372	1	0.372	8.950	0.003*
Month	0.048	4	0.012	0.290	0.885
Locality	0.004	1	0.004	0.089	0.766
Type of escape	0.323	5	0.065	1.554	0.171
Sex (m, f)×month	0.949	4	0.237	5.713	0.000*
Sex (m, f)×locality	0.004	1	0.004	0.101	0.751
Month×locality	0.086	4	0.022	0.518	0.722

The final model includes the net variable effect, as well as interactions between independent variables. Values are log transformed

m males, *f* females, *df* degrees of freedom, *F* F statistics, *P* probability of statistical significance

*P<0.05, significant values

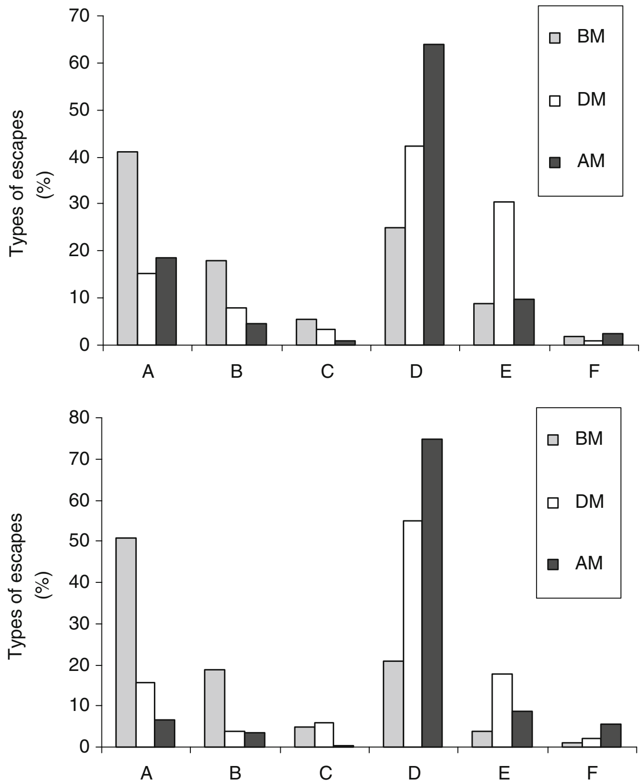

Fig. 2 Seasonal differences in the proportion (in percent) of escape behavior types in females (*upper panel*) and in males (*bottom panel*) of the green lizard. Types of escape: *A* the lizard is in a maximum distance of 1 m from a burrow or den with the head usually pointing to it or oriented perpendicularly to it; *B* the lizard is more than 1 m away from the burrow; short scuttle followed by running to the burrow; *C* the lizard is close to the den; it reacts to the disturbance from a distance of over 5 m by slowly crawling to the burrow; *D* the lizard is in open space; when disturbed, it displays a series of scuttles to available shelters (bush, stones, tall grass), but not to the burrow, "chase"; *E* the lizard is in open space; a series of short and long quick scuttles in the uncovered area (not towards a shelter or burrow); *F* quick direct escape from a distance of over 1.5 m straight to the burrow. The season was divided into three periods: *BM* before mating, *DM* during mating, *AM* after mating

approach distances of both sexes equalized and shortened in comparison with those prior to the mating season because lizards invested energy and attention into mating and became less alert. After mating, the cost of incubation and egg laying was high and resulted in short approach distance among females. Aggression associated with territoriality during the reproductive period could reduce the ability of the mating animal to escape in response to the approaching predator (Marler and Moore 1988; Antczak et al. 2005). In several studies, unwillingness to escape among gravid females was observed. Moreover, the passed distance was lower in comparison with nongravid females or males (Schwarzkopf and Shine 1991; Brana 1993). In both sexes, the approach distances were greater in habitats with low anthropogenic influence. However, other factors like the progress of the breeding season exerted their influence as well. The study of the escape behavior of *Podarcis muralis* showed shorter distances in the biotope with high anthropogenic influence in comparison to the natural conditions. The lizards which stayed away from the refuge reacted in greater approach distances except for the study conducted in the hiking area (Diego-Rasilla 2003a). Contrary to this, lizards in the high predation pressure locality were more wary and escape from longer distances (Diego-Rasilla 2003b). The human disturbance influenced the approach distance in three species of the genus *Liolaemus* (Tropiduridae; Labra and Leonard 1999). Lizards can learn to recognize a threat and develop a suitable antipredator behavior, reducing its costs by appropriately assessing the degree of predation risk (Diego-Rasilla 2003a).

Ambient temperature caused shortening of the approach distances, influenced the realized escape type, as well as reduced the activity of the lizards (Rand 1964; Cooper 2003a; Diego-Rasilla 2003b). We also found that, in the cold beginning of the season, lizards preferred quick escape directly to the burrow from a short distance (type A), while in the summer, they preferred long escapes to the more or less sheltered places, but never into the burrow (types D and E). When the vegetation cover was sparse, escape distances were greater. For instance, escape distances from grass and bushes were lower in *H. propinqua* because these places are considered as refuge places. They escaped to the burrows only when the ambient temperature was between 31°C and 50°C. In the morning, when they left their refuge, they remained in close proximity. As soon as they reached their optimal body temperature, they did not escape to the burrows until the ambient temperature was too high and were threatened by exhaustion from the heat (Cooper 2000). Similarly, in our study, the monitored green lizard preferred short escapes directly to the burrow in the colder months and preferred long escapes to sheltered places but not to the burrow in warm period. At the beginning of the type A season, the short escape directly to the burrow is preferred. During the season, the type of escape markedly changed. The ambient temperature or weather changes could cause rapid changes in escape behavior. During the summer, lizards exploit the advantages of the protrusion of the terrain. Types E and D are common, when lizards did not hide but run for a longer distance or to sheltered place (trees, bushes).

In conclusion, the escape behavior of the green lizard is sex-related and changes a lot as the season progress. At the beginning of the season, females stay in close proximity to refuge and hide immediately after being disturbed. The distance from refuge is larger in males and they use microhabitat protrusions to hide. The approach distances are bigger in males. During the mating period, approach distances of females and males equalize and they hide in microhabitat refuge. After the mating period, the approach distance of females decreases, whereas that of males increases.

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