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Densities and Morphology of Two Co-existing Lizard Species (*Lacerta agilis* and *Zootoca vivipara*) in Extensively Used Farmland in Poland*

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The study was carried out in extensive farmland area near the town of Odolanów, Poland. During two breeding seasons (April-May, 2006-2007) lizards were counted on transect routes and captured by hand or by noosing. In total, 123 specimens of *L. agilis* and 153 specimens of *Z. vivipara* were captured. The proportion of males to females wasn‘t differed from the theoretical 1:1 ratio. Almost half of the individuals exhibited tail autotomy at least once in life. In the studied sand lizards significant sex specific differences were found between all morphological traits, i.e. males were shorter, lighter, but had a bigger head. In common lizards significant sex specific differences were detected only in body length, i.e. females were longer. All of the morphological traits were highly inter-correlated.

Key words: Biometry, common lizard, sand lizard, co-occurrence, farmland, Poland.

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Population density is a common biological measurement of population size and is determined by resource availability, both for lizards as well as for interacting species, the partitioning of a resource (CASE & BOLGER 1991; GOTELLI & MCCABE 2002), predation (MASSOT *et al.* 1992) and competition (WRIGHT 1979). A variety of life history traits have been found to be density dependent, e.g. body length and growth rate (WILBUR 1977; CALSBEEK & SMITH 2007). Moreover, other environmental and ecological factors such as temperature, predation pressure, parasites and habitat type all have an influence on several life history traits of lizards (SORCI *et al.* 1996; PÉREZ-TRIS *et al.* 2004).

Farmland is a very important habitat in which to conduct studies of lizards because the majority of European studies have been conducted in other habitats (e.g. CLOBERT *et al.* 2000; DIEGO-RASILLA 2003; LALOI *et al.* 2004; PÉREZ-TRIS *et al.* 2004; STAPLEY & KEOGH 2004). Furthermore, IOANNIDIS and BOUSBOURAS (1997) have shown in a study conducted in Greece that reptilian diversity was highest in man-made modified habitats, the farm-

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land zone, which structurally is also the most diverse. Most papers show that in Europe, especially in the western part of the continent, both of the studied lizard species (*Lacerta agilis* & *Zootoca vivipara*) are endangered and declining (ŠMAJDA & MAJLÁTH 1999; BERGLIND 2005; RASHID 2007, but see: SURA 2003a; SURA 2003b). However knowledge about these reptiles is very sparse and insufficient. The aim of our study therefore, was to characterize the demography of the lizard populations in a landscape fragmented by agricultural practices of Central Europe, which has not (yet) been changed by the Common Agricultural Policy (CAP) being introduced in the European Union.

Material and Methods

Study species

The sand lizard *Lacerta agilis* is a short-legged, rather robust, small to medium sized lizard (up to 110 mm snout to vent length (SVL)) from the family *Lacertidae*. *L. agilis* is a ground-dwelling and strongly diurnal species with one of the widest distribution ranges of all reptiles (BISCHOFF 1984). Sand lizards are largely insectivorous, actively chasing and consuming a range of spiders and insects (CORBETT & TAMARIND 1979). Throughout Poland *L. agilis agilis,* a subspecies of the sand lizard abundant in Northwestern Europe, is found. In northeastern and central Poland *L. agilis chersonensis* is also present.

The common lizard *Zootoca vivipara* is a small lacertid (adult SVL 50-70 mm) with allopatric oviparous (egg-laying) and viviparous (live-bearing) populations. It inhabits fragmented habitats such as peat bogs and heath lands. Common lizards are widely distributed throughout Europe and Asia and their distribution overlaps the polar circle. *Z. vivipara* has the most extensive range of all lacertids, significantly larger than *L. agilis*. They actively forage on invertebrates, especially on insects.

Study area

The study was carried out in April - June 2006 and 2007 near the town of Odolanów, Poland (51°34'N, 17°40'E, elevation 110-170m).

This study area is characterised by intensively farmed land with a varied mosaic of arable fields, meadows, small woodlots and scattered trees and shrubs of different ages, dominated by white willow *Salix fragilis*, silver birch *Betula pendula*, black poplar *Populus nigra* and pine *Pinus silvestris*. It contains both dry sandy areas and moist areas (for details see ANTCZAK *et al.* 2004).

Also in the study area lives one of the most numerous (up to 24 breeding pairs/100 km^2) populations of great grey shrike *Lanius excubitor* (ANTCZAK *et al*. 2004) and both lizard species are an important part of the diet of this bird (ANTCZAK *et al.* 2005).

Lizard surveys

To determine the density of both lizard species, three 200 m transects were set up randomly over the study area, with a minimum distance of 200 m between each of them. A qualified observer walked slowly along each transect and noted down all visible lizards (only observations without catching), trying to determine the species, sex and age of observed individuals. Transects passed through the most important habitats for lizards, namely wastelands and meadows. These procedures were carried out on days with good weather and at the highest lizard activity period, i.e. between 1000 and 1600 hours.

Lizard collection

Sand lizards and common lizards were captured using special herpetology nets (fabric net attached to the end of a metal stick with metal circle) or by hand (not during transect searches). Animals were sexed and aged to three categories: adult, subadult, or juvenile. After measurements the lizards were released in the same place they were captured. Collar scales, used for a different examination (unpublished data), were taken from each lizard. Therefore it is certain that the same lizards were not considered twice in the analyses.

Lizards were counted and captured on 8-24 May 2006 and 23 April-2 May 2007, the differences in the timing are due to differences in weather conditions between the years.

Measurement of morphometric traits

The continuously distributed characters of snout to vent length, head length and head width were measured to an accuracy of 0.1 mm using digital callipers. Body mass (± 0.1 g) was measured with an electronic balance. Additionally, specimens were checked for the occurrence of tail autotomy in both recent and previous life stages.

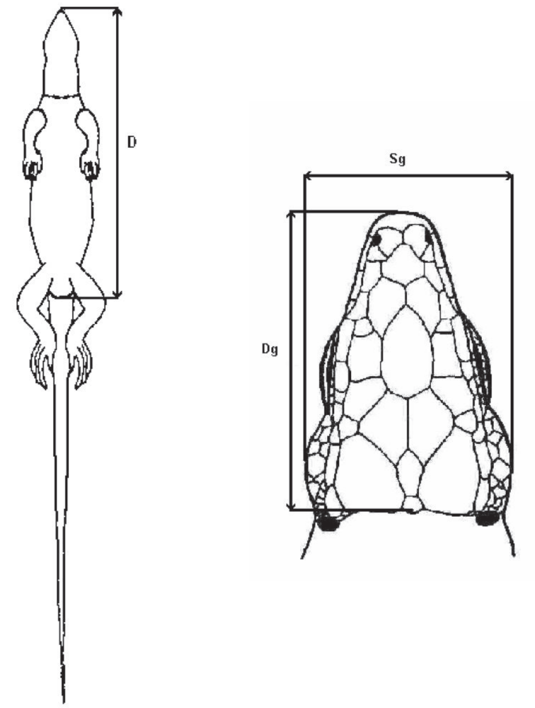

Fig. 1. The main traits in lizards (after MAJLÁTH *et al*. 1997 – modified): body length (D), head length (Dg), head width (Sg).

Data analysis and statistics

For statistical analyses SPSS 12.0 PL was used. Values are presented as means ± standard deviation (SD) as well as minimum and maximum values. All statistical tests are two-tailed.

Results

D e n s i t i e s. A total of 135 individuals of *Z. vivipara* (72.6%) and 51 individuals of *L. agilis* (27.4%) were observed on transect routes. Moreover, during transect counts 12 (6.01% among all observed lizards) specimens not determined to species level were recorded. On average 0.37 (± 0.77) *L. agilis* individuals and 0.98 (± 1.32) *Z. vivipara* individuals were noted on one transect route. The recorded number of *L. agilis* was significantly lower than *Z. vivipara* (T-paired test, $T_{1,137} = 4.747$, $P < 0.0001$), and numbers of both species were not correlated on transect routes ($r_{138} = 0.029$, $P = 0.73$).

L i z a r d c o l l e c t i o n. Over both seasons, 153 (55.4%) individuals of *Z. vivipara* and 123 (44.6%) individuals of *L. agilis* were captured. The proportion of lizard species caught differed significantly from the proportion of lizard species recorded on transects, i.e. *L. agilis* was caught more often than predicted from the transect counts ($\chi^2 = 13.91$, df = 1, $P < 0.001$).

S e x a n d a g e r a t i o. The proportion of males to females was 1:0.71 in *L. agilis* and 1:0.94 in *Z. vivipara*, and in both cases did not differ significantly from the theoretical 1:1 ratio ($\chi^2 = 1.28$, df = 1, $P > 0.2$ and $\chi^2 = 0.04$, df = 1, $P > 0.8$, respectively). In both species the majority of captured individuals were adults (Table 1), and the two species differed significantly in age structure ($\chi^2 = 30.73$, df = 2, $P < 0.001$).

Table 1

Sex and age structure of *Lacerta agilis* and *Zootoca vivapara* caught in the study area. Note that in yearlings and sub-adults sexing is very difficult under field conditions

	Lacerta agilis			*Zootoca vivipara*		
	Males	Females	Unsexed	Males	Females	Unsexed
Juveniles	0	0	25	0	0	14
Sub-adults	1	0	9	13	5	36
Adults	51	37	0	45	40	0

C a u d a l a u t o t o m y. 37.5% individuals of of *L. agilis* (n = 123) and 40.5% individuals of *Z. vivipara* (n = 153) were found to have lost their tail at least once in life. Differences between species in the frequency of autotomy were not significant ($\chi^2 = 0.28$, df = 1, $P > 0.1$). In both species autotomy was recorded more often in adults than in younger individuals (46.6% in adults vs. 16.7% in juveniles and sub-adults of *L. agilis*, $\chi^2 = 11.16$, df = 1, $P < 0.001$ and 51.7% in adults vs. 26.5% in juveniles and sub-adults of *Z. vivipara*, $\chi^2 = 10.03$, df = 1, $P < 0.01$).

M o r p h o l o g y. All studied morphological traits differed significantly between juveniles and adults, as well as between adults and subadults (ANOVA, $P < 0.00001$ in all cases) of both species?, but there were no significant differences between juveniles and subadults within? either species. Between the sexes, differences were significant between every measured trait in *L. agilis* (*t*-test, $P < 0.005$ in all cases), in which males were shorter, lighter, and had larger heads. In *Z. vivipara,* females were significantly longer than males (*t*-test, $t_{99}=-3.79$, $P < 0.0002$).

Moreover, all of the measured traits were highly inter-correlated (Table 3) in both species. Therefore, only data on body length can be used successfully to predict the fresh body mass of lizards ($y = 0.240x + 2.869$, $R^2=0.689$, $P < 0.0001$ and $y = 0.121x + 4.325$, $R^2=0.522$, $P < 0.0001$ for *L. agilis* and *Z. vivipara*, respectively).

Table 2

Morphological characteristics of distinct age- and sex groups of both lizard species. Data are presented as mean ± SD and minimum-maximum values are in brackets

Trait	Yearlings	Sub-adults	Males	Females
Lacerta agilis				
Sample size	25	9	52	37
Body length (mm)	38.65 ± 4,61 (32.70-53.10)	43.90 ± 4.88 (36.20-54.20)	66.52 ± 7.54 (47.50-81.00)	73.50 ± 10.34 (24.00-86.00)
Body mass (g)	1.68 ± 0.53 (1.00-3.60)	2.10 ± 0.61 (1.40-3.20)	9.33 ± 2.75 (3.20-16.00)	11.23 ± 3.02 (4.90-18.10)
Pileus length (mm)	9.09 ± 1.22 (4.50-10.50)	10.30 ± 0.83 (9.30-11.90)	16.33 ± 1.69 (11.40-19.00)	15.35 ± 1.35 (11.60-17.50)
Pileus width (mm)	5.32 ± 0.61 (4.00-6.50)	5.90 ± 0.56 (5.00-6.90)	9.36 ± 1.04 (6.60-11.50)	8.69 ± 1.13 (6.90-12.00)
Zootoca vivipara				
Sample size	14	54	40	45
Body length (mm)	33.91 ± 2.89 (28.00-37.00)	37.71 ± 3.26 (30.30-44.00)	46.14 ± 6.48 (33.00-56.90)	51.76 ± 8.31 (33.80-69.00)
Body mass (g)	1.49 ± 1.03 (0.70-4.40)	1.50 ± 0.78 (0.70-5.50)	3.05 ± 1.71 (1.30-12.15)	3.37 ± 1.13 (1.40-6.00)
Pileus length (mm)	6.75 ± 1.47 (4.00-8.50)	7.60 ± 1.50 (1.00-8.90)	9.77 ± 1.90 (1.00-12.00)	9.77 ± 1.70 (5.00-15.50)
Pileus width (mm)	4.07 ± 1.24 (3.00-7.20)	4.62 ± 0.75 (1.20-6.00)	5.65 ± 0.75 (4.00-6.70)	5.50 ± 0.85 (3.00-8.00)

Table 3

Correlation matrix of measured morphological traits in both studied species. R – Pearson correlation coefficient (sample size given in brackets)

	Body length	Body mass	Pileus length	Pileus width
Lacerta agilis				
Body length	1.000	0.830 (119)	0.829 (120)	0.801 (122)
Body mass	0.830 (119)	1.000	0.854 (118)	0.847 (118)
Pileus length	0.829 (120)	0.854 (118)	1.000	0.936 (120)
Pileus width	0.801 (122)	0.847 (118)	0.936 (120)	1.000
Zootoca vivipara				
Body length	1.000	0.723 (119)	0.790 (147)	0.701 (147)
Body mass	0.723 (119)	1.000	0.543 (119)	0.567 (119)
Pileus length	0.790 (147)	0.543 (119)	1.000	0.644 (148)
Pileus width	0.701 (147)	0.567 (119)	0.644 (148)	1.000

All correlations are significant at the 0.01 level (2-tailed).

Discussion

Z. vivipara and *L. agilis* are among the most numerous and frequently occurring reptile species in Poland (ZIELIŃSKI *et al*. 2005; SURA 2003a; SURA 2003b). Within the study area both lizard species were recorded at high densities. However, they weren't at the same density on all transect routes, and *Z. vivipara* was more common than *L. agilis*. The same result was shown by TRAKIMAS (2005) in Lithuania. This situation could be due to these species preferring different habitats and probably having different tolerances to the same environmental conditions (TRAKIMAS 2005). Sand lizards choose sunny glades, forest borders, forest roads, suburban rubble and slopes with xerothermic vegetation, whereas common lizards prefer wetter and shadier glades, edges of water-meadows, wet forests and other places close to water (BERGER 2000; BUSZKO-BRIGGS & OKOŁÓW 2002). This result was also obtained despite the fact that *L. agilis* is generally more mobile than *Z. vivipar*a (BUSZKO-BRIGGS & OKOŁÓW 2002), and hence should be easier to detect.

In our study, lizards were caught in different proportions than predicted from transect counts. This could be caused by the smaller size of *Z. vivipara* (HOUSE *et al*. 1979) which is consequently more difficult to trap.

In Eurasia the snout to vent length (SVL) of *L. agilis* ranges from 58 to 114 mm (FUHN & VANCEA 1961; MAJLÁTH *et al*. 1997) and the SVL of *Z. vivipara* ranges from 40 to 67 mm (DELY 1978; FUHN & VANCEA 1961; ŠMAJDA & MAJLÁTH 1999). The length of the whole body of adult lizards (including tails) ranges from 121 (100 for juveniles) to 235 mm in *L. agilis agilis* and 121 to 156 mm in *Z. vivipara* (JUSZCZYK 1987). Head length (Lc) of female *Z. vivipara* ranges from 8.6 mm to 12 mm, whereas the Lc of males ranges from 8.1 mm-12.6 mm. Head width (Ltc) of females varies between 4.7 mm-8.2 mm, whereas the Ltc of males is in the range of 4.6 mm-9 mm (FUHN & VANCEA 1961; LÁC 1967; DELY 1978; ŠMAJDA & MAJLÁTH 1999). In *L. agilis* female head length ranges from 14 mm to 19.5 mm, that of males is 14.4-22 mm, whereas head width is between 10-14 mm and 9-16.5 mm for females and males, respectively (FUHN & VANCEA 1961; LÁC 1967; ŠMAJDA & MAJLÁTH 1999). The mean of the body measurements we took of adults of both lizard species are within the already published range, with the single exception of head width and length in the sand lizard.

Sexual dimorphism in lizards is evidenced as differences in many morphometric traits, such as digit length ratios (RUBOLINI *et al*. 2006), cephalic scales (BRUNER *et al*. 2005) or tail length (BARBADILLO & BAUWENS 1997). Generally in many species of lizards males have a larger body size than females (KALIONTOPOULOU 2007), while females possess a larger trunk (KALIONTOPOULOU 2007). However, GVOŽDÍK and BOUKAL (1998) have shown that male sand lizards living in the Czech Republic are smaller and lighter than females, while still having larger heads. This pattern in *L. agilis* was also corroborated by our results. However, in the studied *Z. vivipara* individuals, females were also larger than males, although no other statistically significant differences in the measured traits were found. Such differences (also in other traits) were presented by ŠMAJDA and MAJLÁTH (1999) in their study on common lizards. In a sand lizard study by MAJLÁTH *et al*. (1997), highly significant intersexual differences in all traits were found, with the exception of body length.

In the studied populations of both lizard species, the commonest age class recorded was adult. This could be caused by the season of the study, because in both sand lizards and in common lizards juvenile individuals are born later in time, in summer (JUSZCZYK 1987). If the study had been conducted afterwards, the proportion of age classes of the lizards probably would have been different. On the other hand, NEMES *et al*. (2006) showed that the proportion of lizards in different age classes can be caused by different structural habitat characteristics. Most adult individuals were found only in open coverage habitat. SORCI *et al*. (1996) also suggested that environmental factors (e.g. the thermal environment) have a very important influence on the growth rate of lizards, even more than genetic divergence. He also showed that altitude is another factor that affects differences in growth rate between lizard populations. Lizards located in low altitude sites grew faster than those in the altitude sites.

Another trait which differentiates particular individuals of lizards is the occurrence of tail autotomy. This is used by many species of lizard as a defence strategy to avoid predation (OPPLIGER & CLOBERT 1997; COOPER 2003; HERCZEK *et al*. 2004; LIN & JI 2005). However, the loss of a body part has associated costs. Autotomy can reduce running speed (FORMANOWICZ *et al*. 1990), the ability to escape from predators (DIAL & FITZPATRICK 1984), social status (FOX *et al*. 1990), home range size (SALVADOR *et al*. 1995) and mating success (MARTIN & SALVADOR 1995). In many lizard species a tail is a depot for lipid storage (VITT & COOPER 1986) and its regeneration may require energy, which could otherwise be used for different life processes, e.g. growth or immunological defence (OPPLIGER & CLOBERT 1997). The rate of tail regeneration is lower in parasitized lizards (OPPLIGER & CLOBERT 1997). However, BROWN *et al*. (1995) reported that in some species running speed increased after autotomy. Besides, most of the lipids are concentrated in the proximal portion of the tail (LIN & JI 2005), and a partial tail loss may not severely affect energy storage and locomotory performance. In our study, almost half of the studied lizards had undergone autotomy at least once over their lifetimes. Tail loss was noted more often in adult lizards than younger ones. It is obvious that the adults have lived longer than younger individuals, hence have had more occasions to meet a predator or another factor which resulted in autotomy.

In addition to improved knowledge about the morphology and density structure of the lizards living in a farmland landscape, our results are also important for other reasons. Both lizard species, especially *Z. viviapra*, are an important food component of the great grey shrike and are often presented in shrike's larders (ANTCZAK *et al*. 2005). However, part of the lizard is not directly consumed by the bird after it is killed (NOGALES & VALIDO 1999) and loses some mass over time. The regression models therefore facilitate the establishment of lizard body mass based on body length or head size, variables that are easily collected from individuals killed by shrikes (ANTCZAK *et al.* 2005; PADILLA *et al.* 2005). This method would prove useful in the event of finding such parts in shrikes larders or in their pellets.

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