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Body Size Structure and Sex Ratio in a Population of the Common Lizard *Zootoca vivipara* (Lichtenstein, 1823) from SW Poland

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Short communication

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We present data on the population structure, body size variations and allometric growth patterns for a common lizard (*Zootoca vivipara*) population from Southwestern Poland. We measured 339 lizards (89 males, 75 females, 63 subadults and 111 juveniles). The sex ratio did not differ from 1:1; however, we recorded intra-seasonal variations. There was significant sexual size dimorphism (males were smaller in body length), as well as tail length (males had longer tails) and body mass dimorphism (females were heavier). We also found sexual differences in the allometric pattern of tail growth, i.e. there was an isometry for males but a negative allometry for females.

Key words: ecology, Lacertidae, population structure, scaling.

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Body size is one of the most essential and easily attainable parameters for the condition of an animal, which is correlated with its fecundity (e.g. HORVÁTHOVÁ *et al*. 2013a,b; ROITBERG *et al*. 2013), mating success (OLSSON 1993), survival (CALSBEEK & SMITH 2007; ROTGER *et al*. 2020) and overall fitness (OLSSON *et al*. 2007). Another important population characteristic is the sex ratio. Males and females are usually expected to occur in equal proportions in a population; however, the sex ratio may often deviate from 1:1. Such deviations may indicate differences in the sex-specific mortality rate (i.e. due to predation pressure, infection vulnerability, etc.) or sex-specific migrations. It also may indicate a high level of intrasexual competition; for example, when males are more abundant in the population than females. A deviated sex ratio often precedes a population decline (e.g. LE GAILLARD *et al*. 2005; GRAYSON *et al*. 2014). Variations in the body size structure and sex ratio reflect important aspects of population dynamics; therefore, it is important to collect such data in the course of the long-term monitoring of selected populations. There is a growing importance for large data sets in interspecific or interpopulation studies in the fields of ecology, physiology, morphology, etc. (e.g. MEIRI 2010; MEIRI *et al*. 2012; HORVÁTHOVÁ *et al.* 2013a, b; JANICKE & FROMONTEIL 2021), and it is crucial to provide wide and diverse population parameters for different species.

The common lizard (*Zootoca vivipara* Lichtenstein, 1823) is a small lacertid, with a snout-vent length (SVL) that reaches up to 70-80 mm (DELY & BÖHME 1984). It is the most widespread terrestrial reptile species; however, in many areas the populations are declining (AGASYAN *et al.* 2017). The common lizard is a non-territorial, insectivorous lizard (DELY & BÖHME 1984; VACHEVA & NAUMOV 2020). It lives in humid habitats up to 2500 m a.s.l. In most of its range it is viviparous, but oviparous populations are also known (DELY & BÖHME 1984; MAYER *et al.* 2000; RECKNAGEL & ELMER 2019). The age of maturity may also vary between populations, although in

Western Europe common lizards usually mature after the second wintering (see Roitberg *et al.* 2020 for references).

In this study, we present data on the sex ratio and the body size composition in males and females of a common lizard population from Southwestern Poland. Specifically, we explore: (1) if the sex ratio and differences in adult body size are constant throughout the seasons; and (2) we provide pilot estimations of the sex-specific growth allometry in the study population.

Material and Methods

Study area

The studied population inhabits a mid-forest meadow located in north-west Wrocław (N 51º17′14′′, E 16º94′99′′), in the forest called "Las Rędziński" – an area protected within the NATURA 2000 Network ("Dolina Widawy", PLH 020036). It is an alluvial meadow of *Cnidion dubii* in the Widawa River Valley. The meadow is also inhabited by sand lizards (*Lacerta agilis*); however, preliminary observations suggested that although both species are syntopic, *Zootoca vivipara* is more prevalent on the meadow edges and *Lacerta agilis* in the central part of the meadow. The site is used for public recreation; however, more intensive human activity can usually be observed on the weekends and after noon. The meadow is mown once per year.

Field protocols

The lizards were captured by hand and with a noose pole. Our field study was carried out from March until the end of September 2021, and there was at least one census conducted per week. Although the lizards were captured at different times of day, on summer days their activity was reduced to the morning hours (7:00-9:00 am). We measured the snout-vent length (SVL; distance from the tip of the snout to the rear edge of the cloaca), as well as the tail length (TL; from the cloaca to the tip of the tail) and total length (TTL = SVL + TL) with a 1 mm accuracy using a digital calliper (Schmith®). We also recorded the body weight (BW) with a 0.1 gram accuracy using a Pesola® scale. The lizards were photographed and paint-marked for further recognition, following Borczyk (1999).

The sex of an individual was determined by the presence of secondary sexual characteristics, which included abdomen colouration (orange, yellow-orange with dark spots in males; and whiteish, white-yellow in females) and the shape of the tail base (thickened in males, see also Dely & Böhme 1984). The lizards were assigned to juvenile (0+), subadult (1+) and adult (2+) categories, based on a combination of their size, colouration and date of capture. The study was carried under a permit from the Polish Authorities No. WPN.6401.212.2019.MH.1.

Statistical analysis

Prior to each analysis, we determined if our data met the assumptions for the particular test (e.g. normal distribution, homogeneity of variance, etc.). To test if the sex ratio differed from the expected 1:1, we ran the χ^2 test for all males and females in the entire sample. We also tested if the sex-ratio changed during the seasons. We tested the male-to-female ratio month-by-month, starting with the date of the first capture (28th March – 27th May, 28th May – 27th June, and so on), using the binominal test since the sample size for most months was less than 30 individuals.

To analyse the allometric relationship pattern, we regressed the log-transformed TL against the log-transformed SVL. The slopes were calculated using a reduced major axis regression. Our H_0 was that both of sexes showing isometrical growth patterns. We tested if the slopes differed from 1. Specimens with autotomy and/or regrown tails were excluded from the allometric analysis and the body-weight comparisons.

Results

Body size

We measured 339 common lizards (89 males, 75 females, 63 subadults and 111 juveniles, see Figures 1 and 2). The females had a longer SVL (t = -4.824, df = 161, $p < 0.0001$) but they were not heavier (t = -1.499, df = 132, p = 0.136). There were no statistically significant differences in BW when corrected for the TTL (ANCOVA test $F_{1,131} = 0.866$, p = 0.354), but there was a statistically significant difference when corrected for the SVL (ANCOVA test $F_{1,131} = 25.058$, $p < 0.001$). However, the males had longer tails at a given SVL (ANCOVA test $F_{1,131} = 14.143$, $p < 0.001$) (see Table 1 and Figure 3).

Sex ratio

The overall sex ratio (male:female; 1.18:1) did not differ from the expected 1:1 ratio (χ^2 test = 1.0305, df = 1, p = 0.31). However, the sex ratio changed throughout the seasons, i.e. in spring, males were more common than females, then the sex ratio changed towards females, and again at the end of the sampling period it became biased towards males (see Table 2).

Allometry

Male tail length increased isometrically in relation to the SVL, whereas the females showed a negative allometry (Table 3 and Figure 3).

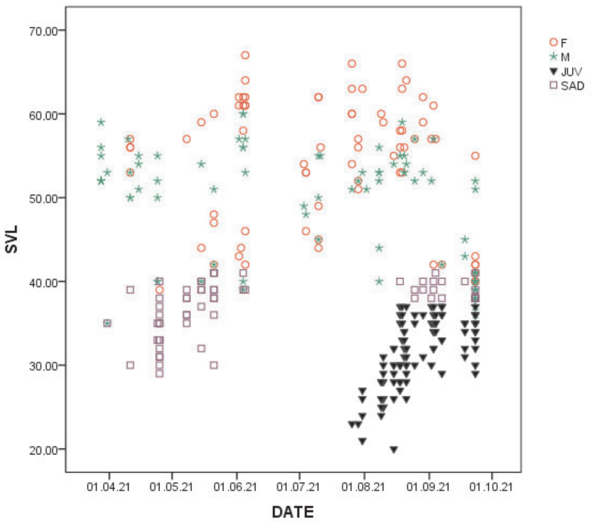

Fig. 1. Scatterplot of the snout-vent length (SVL) and the date of capture of common lizards (*Z. vivipara*). M – males, F – females, JUV – juveniles, SAD – subadults.

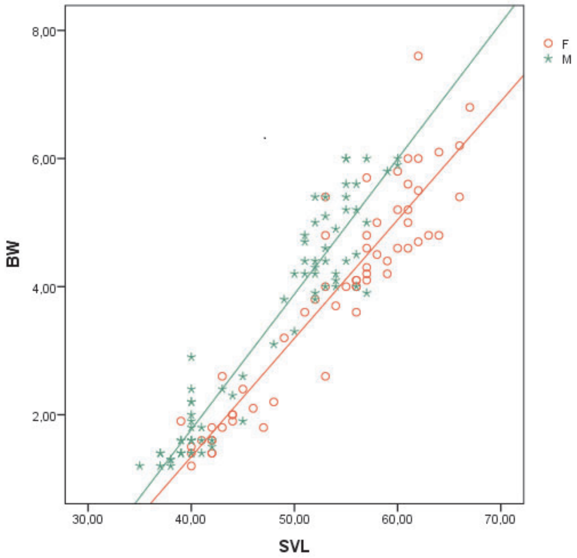

Fig. 2. Relationship between the body weight (BW) and the snout-vent length (SVL) in adult male (M) and female (F) common lizards (*Z. vivipara*).

Table 1

Descriptive statistics of adult, subadult and juvenile common lizards (*Z. vivipara*) from southwestern Poland. The sample size (N), mean ± SD and range (minimum-maximum) are given for each of the parameters. Snout-vent length (SVL) and tail length (TL) are provided in millimetres and body weight (BW) is in grams. Individuals with lost or regenerated tails were excluded from the TL and BW samples

	Males	Females	Subadults	Juveniles
SVL	48.1±7.27 (35-60) N=89	53.9±8.03 (39-67) N=75	37.1±0.32 (29-41) N=63	31.6±0.41 (20-37) N=111
TL	80.2±13.6 (46-106) N=73	77.9±11.28 (55-101) N=61	64.2±0.79 (42-78) N=54	53.8±0.94 (30-72) N=100
BW	3.43±1.62 (1.2-6.0) N=73	3.85±1.63 (1.2-7.6) N=61	1.38±0.98 (0.8-2.0) N=54	0.81±3.01 (0.2-1.6) N=100

Table 2

Seasonal changes in the sex ratio for the common lizards (*Z. vivipara*) population from southwestern Poland. Deviations from the expected 1:1 ratio were tested with the binominal test (for the months with less than 30 individuals) and the chi-square test (when the sample size was bigger than 30 individuals)

	28.03-27.04	28.04-27.05	28.05-27.06	28.06-27.07	28.07-27.08	28.08-27.09	Whole season
M:F ratio	20:5	10:7	9:14	7:15	11:18	32:16	89:75
p	0.004	0.63	0.41	0.13	0.27	0.029	0.31

Table 3

Allometric coefficients from the Reduced Major Axis Regression of the log-transformed tail length (logTL) against the log-transformed SVL, for males (M) and females (F) of the common lizard (*Z. vivipara*)

Character	Sex	Intercept	Intercept 95% Confidence Intervals		Slope	Slope 95% Confidence Intervals		r^2	*t* (*df=130*)	p
Baseline:	logSVL									
logTL	F	0.25	0.11	0.4	0.87	0.67	1.08	0.21	1.535	0.13
	M	0.17	0.03	0.3	1.09	0.89	1.29	0.41		

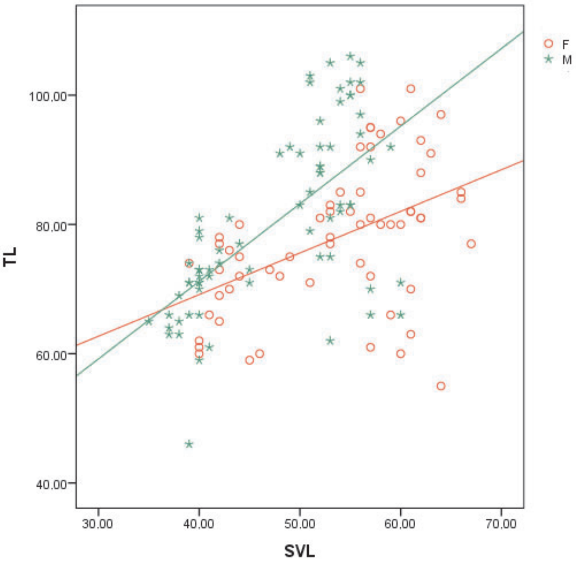

Fig. 3. Relationship between the tail length (TL) and the snout-vent length (SVL) in adult male (M) and female (F) common lizards (*Z. vivipara*).

Discussion

Sex ratio

In the study population of common lizards in Southern Poland, the sex ratio did not differ from the expected 1:1. However, the sex ratio may differ between populations and in different years. In other studies, authors have reported both male or female-biased sex ratios, as well as equal male/female proportions; for example Antczak *et al.* (2019) reported a sex ratio ranging from 0.73:1 to 2.6:1, whereas Maślak *et al.* (2010) reported 1.51:1 and Pilorge (1987) reported a ratio from 1:1 to 1:2. The differences between populations may result from sex-biased predation, sex-specific dispersal strategies, different survival rates during hibernation, individually different maternal investment or simply other environmental differences (e.g. Pilorge 1987; Maślak *et al.* 2010; Antczak *et al.* 2019).

At the beginning of the sampling period, the sex ratio was clearly male-biased and the same was true for the end of the period. This result may simply reflect a sampling artifact, since males leave the hibernacula earlier than females and are more active when searching for a mate. In our study, during first three field days (28 March, 31 March and 10 April), only males were captured and the first female was captured on the 11th of April. Thus, males may have been oversampled in the spring, due to their higher activity and greater detection probability, and that may have altered the sex ratio. Similarly, females may have been detected more often in the summer when they were gravid and often let us approach to a shorter distance before escaping (see Bauwens & Thoen 1981). Alternatively, the subsequent gradual decrease in the relative male numbers may have resulted from higher predation pressure, as some avian predators hunt more adult males than females (e.g. Gröndlund *et al.* 1970; Antczak *et al.* 2019).

Body size

Female common lizards are usually larger than males (e.g. Pilorge 1987; Šmajda & Majláth 1999; Guillaume *et al.* 2006; Ekner *et al.* 2008; Liu *et al.* 2008; Arribas 2009; Horváthová *et al.* 2013a; Roitberg *et al.* 2020) and our findings confirmed a larger female body size in our study population. As the female body size is correlated with fecundity (e.g. Bauwens & Verheyen 1987; Horváthová *et al.* 2013a, b; Roitberg *et al.* 2013; Recknagel & Elmer 2019), fecundity selection may be the main selective pressure favouring larger-bodied females. Also, although the common lizard males are not territorial, they invest a lot of energy and take risks during mate searching, male-male competition and copulation (Gvozdík & van Damme 2003).

The body size ranges of juveniles and subadults partly overlapped. The smallest 1+ subadult had an SVL of 29 mm (captured in April), whereas the largest juvenile caught in September had a 37 mm SVL. This pattern might reflect the effect of an early vs. late date of birth. An individual that was born relatively late, i.e. in late summer, would not have enough time to grow larger than conspecifics born in July. This may also be due to a variable individual growth rate, since the size classes largely overlap between the age classes in lizards (e.g. Borczyk & Paśko 1999).

Allometry

The choice of a proxy for body size is often complicated by the allometric nature of the growth pattern in lizards (Schmidt-Nielsen 1991; Kratochvil *et al.* 2003; Meiri 2010; Borczyk *et al.* 2014). This is especially important in sexually dimorphic species, where some body parts are subjected to different selection pressures (due to different reproductive roles), and thus may follow different ontogenetic trajectories in males and females (Kratochvil *et al.* 2003; Borczyk *et al.* 2014). The tail grows isometrically in males when scaled against the SVL; whereas in females, a negative allometry is observed. This may be explained by two alternative hypotheses. Firstly, the females decrease their tail growth and allocate their energy to abdomen elongation. In turn, this increases their potential reproductive output, since there is a high correlation between abdomen length and fecundity in female lizards (Braña 1996; Horváthová *et al.* 2013a, b; Roitberg *et al.* 2013). The second explanation may by the "morphological constraint" hypothesis, in which it is assumed that tails are relatively longer in males in order to provide space for their copulatory organs and musculature (Barbadillo *et al*. 1995; Barbadillo & Bauwens 1997). The TL is more correlated to the SVL in males than in females (r^2 of 0.41 vs 0.21, respectively), which may suggest that this ratio is under a stronger selection pressure in males.

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Author Contributions

Research concept and design: B.B.; Collection and/or assembly of data: K.M.J.; Data analysis and interpretation: B.B.; Writing the article: B.B.; Critical revision of the article: B.B., K.M.J.; Final approval of article: B.B., K.M.J.

Conflict of Interest

The authors declare no conflict of interest.

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