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Sex identification in juveniles of *Lacerta vivipara*

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Abstract. Sex of juveniles was identified by counting ventral scales in the lizard *Lacerta vivipara*. Sex can be determined accurately in more than 95% of cases in the studied populations. Some aspects of the sexual size dimorphism are discussed.

Introduction

Sex ratio plays an important role in the theory of sexual selection and evolution (Bull, 1983; Stearns, 1987). Determining whether an unbalanced adult sex ratio is the result of a difference of mortality between sexes after conception ideally requires the measurement of the primary sex ratio, i.e. the sex ratio at conception. This is rarely possible without sacrificing individuals, which is incompatible with a long term study of population dynamics. At best, sex ratio at birth is the earliest measure of the proportion of sexes one can get; this parameter, however, has often already been influenced by environmental factors, such as temperature of incubation (Packard and Packard, 1988; Pieau, 1987).

In the common lizard, *Lacerta vivipara*, no external variables have been shown to play a role in sex determination (Bull, 1986; Pieau, pers. comm., 1984). However, adult sex ratio in this species, varies between populations and between years within a population (Pilorge, 1987, 1988). A better knowledge of sex ratio at birth should help to clarify at which stage such a variation appears.

Boulenger (1917, 1920), Wermuth (1955), and Bauwens and Thoen (1982) have shown that the number of ventral scale rows differs significantly between males and females. Furthermore, the latter authors have also demonstrated that this number does not change from birth to adult stage for a given individual. The aim of this article is therefore to check the validity of this method of sexing juveniles in the case of our study populations, and possibly to improve it.

Material and methods

Three age samples of lizards were taken from populations on Mont Lozère (France, see Pilorge, 1987 for a more complete description). The sampling sites were chosen close to one another to ensure that individuals were part of the same metapopulation (no significant divergence in enzymatic polymorphism, see Haywood, 1986). The samples were:

1. A sample of adult lizards (95 females, 65 males) captured in June 1987, whose sex was determined using secondary sexual characters (Boulenger, 1920; Bauwens and Thoen, 1982; Smith, 1973; Wermuth, 1955).

2. A sample of one year old individuals (n = 194) captured in June 1988. At this time of year, yearlings were not yet mature, and it was hardly possible to sex them. Fortunately, 59 of them which had been individually marked by toe-clipping (32 females, 27 males) were recaptured in August and were then sexed using secondary sexual characters.

3. A sample of 36 juveniles captured in August 1989 and dissected for determination of sex. In addition to this sample, 17 juveniles captured in August 1988 were sexed *a posteriori* in August 1989 using secondary sexual characters. This provided a total sample of 53 juveniles (27 females, 26 males).

The number of ventral scales were counted using photography of the ventral surface. Ventral scales were counted blindly, i.e. without knowledge of the sexes of the lizards under study. At some points of the body, especially near the collar and near the anal plate, scales are not clearly arranged in a linear way and the number of rows depends on the start and end points. This problem and a possible asymmetry between the two sides were accounted for by using simultaneously the number of scales on the right side (ECr) and on the left side (ECl) in the analyses. As the anal scale is common to both sides, it was not counted.

Comparisons were made using standard discriminant analysis. Possible differences of distributions of ventral scales among samples, were tested using Kruskall-Wallis analysis of variance for k independent samples and the Mann-Whitney U-test for two independent samples. All analyses were performed using SPSS/PC + (Norusis, 1986a, 1986b).

Results

In the three samples, the number of scales differed strongly between males and females (table 1). Individuals were attributed in the correct sex in more than 96% of cases (table 1).

Before calculating the discriminant function based on the data from the three samples, we needed to test whether the distributions of the number of ventral scales did not differ between the three groups. There was a significant difference between the three samples (males: n = 118, ECr: $\chi^2_2 = 7.221$, $p = 0.03$; ECl: $\chi^2_2 = 9.771$, $p = 0.008$; females: n = 154, ECr: $\chi^2_2 = 8.649$, $p = 0.01$; ECl: $\chi^2_2 = 15.18$, $p = 0.0005$). If we con-

Table 1. Mean number of ventral scales for three age classes of lizards and results of the discriminant analysis. A: adult sample: 95 females, 65 males; Y: yearling sample: 32 females, 27 males; J: juvenile sample: 27 females, 26 males; U.D.F.C: Unstandardized Canonical Discriminant Function Coefficient; % class: Percent of individuals correctly classified by the discriminant function.

	A		Y		J	
	EC_r	EC_l	EC_r	EC_l	EC_r	EC_l
Mean						
Males	27.8	27.7	28.4	28.5	27.6	27.6
Females	31.6	31.5	31.8	32.2	30.8	31.0
SD						
Males	1.012	.976	1.006	1.051	.902	1.13
Females	1.162	1.050	1.184	1.029	1.55	1.285
F	158 df		57 df		51 df	
	462.2	520.8	139.2	186.1	85.9	105.3
P	$<10^{-5}$	$<10^{-5}$	$<10^{-5}$	$<10^{-5}$	$<10^{-5}$	$<10^{-5}$
U.D.F.C.	.437	.612	.325	.700	.316	.564
Constant	-31.456		-31.193		-25.794	
% class	99.38%		96.61%		96.23%	

Table 2. Percent of correct sex identification for lizards of one group, based on the discriminant function calculated from another group: C: sample from which the discriminant function was calculated; A: sample to which the discriminant function was applied.

C	A	Percentage of individuals correctly sexed	Sample size
Adults	Yearlings	96.9	50
Adults	Juveniles	92.5	53
Yearlings	Adults	89.4	160
Yearlings	Juveniles	83.0	53
Juveniles	Adults	99.4	160
Juveniles	Yearlings	93.2	59

sider only the differences between the juvenile and adult + yearling samples, the distribution of ventral scales did not differ in males (ECr: $Z = -1.569$, $p = 0.117$; ECl: $Z = -1.190$, $p = 0.234$) but did differ in females (ECr: $Z = -2.853$, $p = 0.004$; ECl: $Z = -2.279$, $p = 0.02$).

Testing whether such differences could impair sex determination required us to apply the discriminant function calculated on the basis of one sample to sex individuals of the other two samples. In all cases, the percent of individuals correctly sexed was higher than 83% (table 2). This result allowed us to compute a global discriminant function from the pooled data which gives 97.8% of good discrimination:

$Y = (0.397 \times ECr) + (0.565 \times ECl) - 28.82.$

Discussion

The present method of determining sex in juveniles of the common lizard differs essentially from the methods of Boulenger (1920), Wermuth (1955), and Bauwens and Thoen (1982) in two respects:

1. The number of scales on both sides of the abdominal median line was counted, instead of the number of scale rows. This is certainly a more accurate technique than counting rows because in some places, especially near the collar and the anal plate, scales are not arranged in a clear way.

2. While Boulenger (1920) and Bauwens and Thoen (1982) excluded the last two rows of preanal scales, and Wermuth (1955) included all rows of scales, we only excluded the anal plate. The latter is common to both sides of the abdominal median line, and therefore cannot modify the difference between the numbers of scales of each side.

The way in which ventral scale rows have been counted is often difficult to determine precisely from the original papers. Scales on the ventral surface are not clearly arranged in a linear pattern so that rows are sometimes hard to define, in particular the last two rows. As a consequence, it was very difficult to compare directly the discrimination power of the three methods of counting scales. Ideally, in order to sort out whether the difference in the discrimination power of the methods is due to population differences or due to methodological differences, we should have applied our method to populations of the other authors. However, the 95% of good sex determinations in the present study compared to the 60-75% in Bauwens and Thoen's (1982) work might most probably not be due to differences in methodology but rather to the variation of the ratio of ventral scale numbers between males and females among populations, as already suggested by these authors for their own populations. Indeed, three facts support a similar explanation:

1. A stepwise analysis showed that the inclusion of the second variable (ECI) improved significantly the power of discrimination by only 2%.

2. The number of scales at birth is related to body size (MANOVA, snout-vent length effect: $F_{1,13} = 7.22$ $P = 0.019$).

3. Scale number does not increase with age in *Lacerta vivipara* (data based on individuals marked as hatchling and recaptured later, see Bauwens and Thoen, 1982).

Therefore, it turns out that the difference in the ratio of the number of ventral scales between males and females could reflect a difference in sexual size dimorphism at birth between the two populations.

Discriminating sex at birth using only adult and/or yearling samples imposes additional constraints. In particular, this relies on the hypotheses 1) a mortality rate independent of size (e.g. the number of ventral scales) and 2) no differences in sexual size dimorphism at birth across cohorts if a sample of adults of unknown age is used. Indeed, in the populations studied by Bauwens and Thoen, the distribution of the number of ventral scales was not significantly different between the adult + yearling

and juvenile samples both for males and females. In our study, there was a significant difference between the adult + yearling and juvenile samples in females only. This may suggest that, in our populations but not in the Bauwens and Thoen population, there is either a differential apparent mortality related to size or a difference in sexual size dimorphism at birth across cohorts. However, in the present case, the relatively strong variation in the distribution of the number of scales with age did not alter the discrimination power between sexes.

The discrimination of juveniles' sex based on the counting of ventral scales using only adult lizard poses problems in populations or species for which the difference in sexual sex dimorphism is thus weak and is either cohort-dependent or size-dependent. In this case, the use of juvenile samples taken every year is necessary.

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