

Differences of growth in three relict populations of *Lacerta viridis* (Laurenti, 1768)

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Abstract

Growth patterns were studied in a 5-year study in three relict populations of *Lacerta viridis* in north-eastern Germany. Measured snout-vent lengths were adjusted to the logistic growth curve step by step for each age class separately. Growth curves were computed for each population, discriminating between both sexes. Significant increments were found for years 1-3 in population 1, for years 1-4 in population 3 but only for years 1-2 in population 2. The exact date of maximum growth is shifting towards the end of the season in higher ages. Significant differences were only found concerning individuals from population 1 in their first activity season. These are reaching maximum growth speed about two weeks later than individuals from other populations. Only in population 2 and only in the first year of activity a higher growth of females had to be considered as significant. Differences of growth patterns in and between populations are the result of adaptation to varying ecological conditions. In this context food supply, microclimate, length of activity season, parasite load, injuries and social status of the individual have to be mentioned. As of weather conditions and habitat structure many of the mentioned factors show high variation. Additionally interpretation of SVL data becomes very problematic, if no basic knowledge of life history parameters exists. Therefore final statements about the nature of influencing factors and their interference require more common garden, replacement and/or breeding experiments. The differences should make every field herpetologists suspicious in assigning individuals to a certain age class by their SVL only.

Introduction

In contrast to the huge number of studies using dissected animals, there are only a few longitudinal investigations of growth patterns of European lizard species. This is not surprising because repeated catching of free ranging animals with known age is very time consuming whilst observation capacity is usually very limited.

Nevertheless, measures of snout-vent-length (SVL) are often directly used to discriminate between groups of different age or reproductive commitment (e. g. Rahmel & Meyer 1988). Nevertheless growth rates and their variations should be influenced by life history as well as by habitat quality. Sometimes they are regarded to provide an index of food availability. But at least in temperate regions growth parameters should also reflect the amount of time, activity is possible in a given habitat. This should be true for field populations of the European green Lizard (*Lacerta viridis*/*Lacerta bilineata*), too. From this species we have exact growth data from to terrarium investiga-

tions by Rykena (1976). Unfortunately, from the field only few measurements of SVL are known (Mertens & Schnurre 1949). Using capture-recapture data only Peters (1970) was able to gain sufficient data to describe mean SVL's for different age classes in a relict population in north-eastern Germany.

In the following the results of a five-year study on three similar relict populations of *Lacerta viridis* will be presented in brief. The aim is to describe basic growth patterns in field populations of *Lacerta viridis* and to present some ideas about the factors influencing growth in field populations. Knowing this "input data" is important with respect to species protection measures as well as to theory building and modelling of lizard populations.

Study area and methods

Snout-vent lengths of *Lacerta viridis* were measured between 1994 and 1998 in three relict populations located in Brandenburg (north-eastern Germany). The detailed structure of the habitats are described elsewhere (Elbing 2000)

Habitat 1: Extended mosaic of poor, slow growing pine plantation and sparsely covered or bare sand patches.

Habitat 2: Linear edge between pine forest and open heath. There are only few plant species, but habitat is richly structured by wood-piles and trenches.

Habitat 3: Linear dam beside a railway track. Vegetation is dry and fallow. The neighbouring areas are covered with pine forest.

I only used data of animals for which hatching years were known (1992-1998). Raw data were adjusted to fit a logistic growth curve, which describes growth independently from the final snout-vent length (Ricklefs 1968, Andrews 1982). The curve was adjusted step by step for each age class (year of activity) separately using the formula:

$$W = D + (A - D) / (1 + \text{Exp}(-K * (T - t)))$$

with:

W = SVL at time T

A = SVL at the end of the season

D = SVL at the beginning of the season

K = growth constant

T = Age in days (output as "C" in months)

The single curves were "summarised" by using the final value of year n as starting value for year n+1. The model allows a detailed description of growth by calculating parameters A, D, C and K as well as their 95%-confidence interval. Besides the last mentioned parameter K data was calculated for each age separately (A1-A4, D1-D4, C1-C4). Mention, that A1 is the absolute SVL after the first year; whilst A2-A5 are

representing the yearly increments of growth. In the results, only D1 (estimated hatching size) will be shown separately, as D2 was set as A1, D3 as A1+A2, D4=A1+A2+A3 etc. Possible differences between sexes are covered by introduction of additional female parameters A1F, A2F, A3F and A4F. Variations are considered to be statistically significant if 95% Confidence intervals are not overlapping or if an esti-

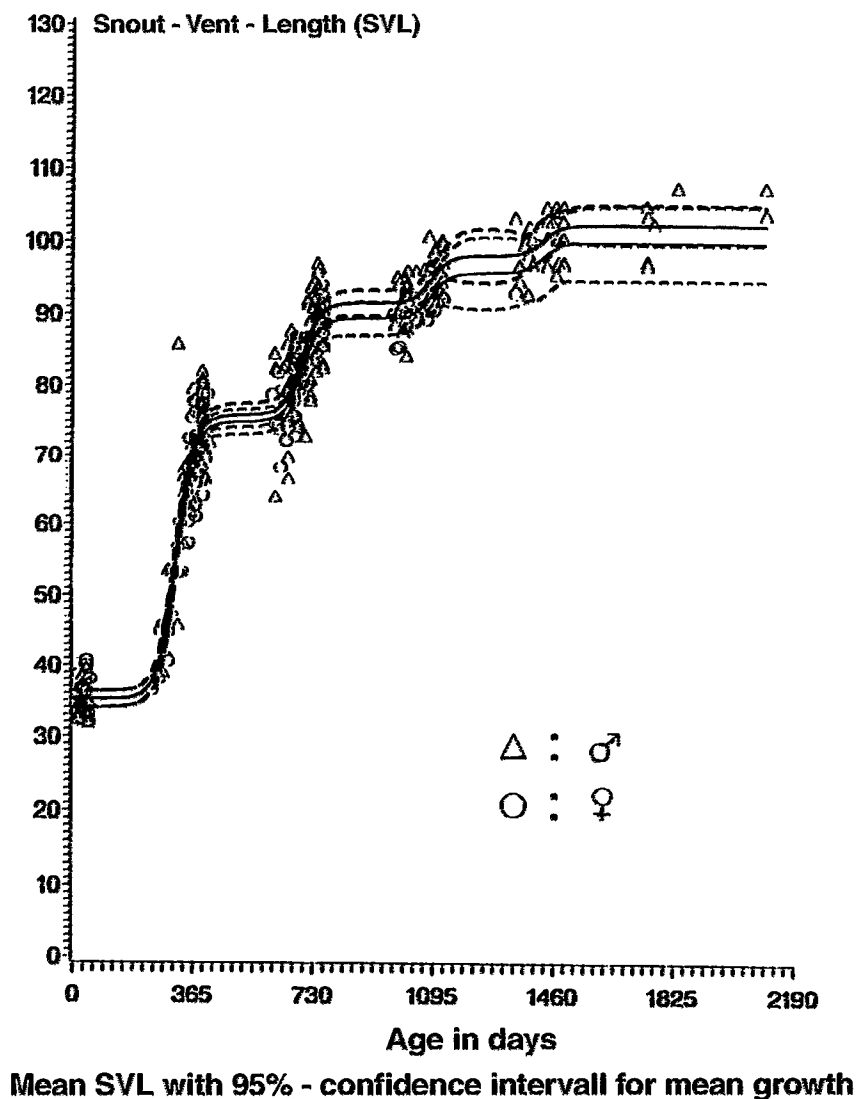


Figure 1:Growth curve after stepwise adjustment of measured Snout-vent-lengths to logistic growth curve. The curve of population 3 (n=349 measurements) is given as an example to elucidate the general pattern ("stair" character with decreasing increments in higher ages) of the estimated growth curves. The solid lines represent the estimated growth curves, dashed lines are reflecting to standard deviation.

mated parameter (including its 95%-Confidence interval) is different from 0. Computing was done using the PROC NLIN procedure from SAS. As an example, figure 1 shows the resulting growth curve of population 3.

Results

Growth curves were computed separately for each population, discriminating between both sexes. First it was differentiated between autotomised individuals and those with original tails, too. But as no significant differences were found (95%-confidence intervals showed wide overlappings), there is no necessity to discuss them separately.

Population 1

SVL of hatchlings in this population was roughly 34,0 mm and within their first complete activity season juveniles grew up to 77,5 mm (Table 1). The mean growth increment during the second year was 19,6 mm whilst growth in the third year was around

Parameter	estimation (\pm sx)	lower limit	upper limit
A1	74,5 (\pm 1,5)	71,5	77,6
A2	19,6 (\pm 2,4)	14,8	24,4
A3	8,8 (\pm 4,4)	0,1	17,5
D1	34,0 (\pm 1,6)	31,0	37,1
C1	11,0 (\pm 0,2)	10,6	11,3
C2	23,3 (\pm 0,4)	22,6	24,1
C3	35,6 (\pm 2,1)	31,5	39,6
K	1,3 (\pm 0,2)	0,9	1,7
A1F	1,2 (\pm 1,4)	-1,6	3,9
A2F	0,6 (\pm 2,9)	-5,1	6,3
A3F	0,0 (\pm 5,4)	-10,7	10,7

Table 1: Growth parameters of population 1 after adjustment of SVL-data (n=145) to logistic model. Parameter estimate (\pm standard deviation) are given as well as lower and upper limit of 95%-confidence interval. For detailed definition of parameters see method. Parameters A and D are given in mm, C is given in months whilst growing constant K is dimensionless. Indices are referring to Ages (1 = first Year 2 = second year etc.). Due to poor raw data it was not possible to compute values for the 4th year.

9,0 mm. Exact date of maximum growth rate shifted from mid July in the first activity season (15.8. + ca. 11 months) to end of July (15.8. + ca. 35,6 months). Females appeared to have higher SVL than males in the first two years, but the difference was not significant. The growth constant k was estimated to be 1,6.

Population 2

Growth parameters computed for population 2 are given in Table 2. Hatchling SVL was 35,0 mm and SVL at the end of the first activity season was 87,9 mm in males and 90,5 mm in females. This sex-specific difference was significant only in the first year. The increment during the second activity season was 15,8 mm, which corre-

Parameter	estimation \pm sx	lower limit	upper limit
A1	87,9 (\pm 1,4)	85,7	90,2
A2	15,8 (\pm 1,7)	12,4	19,1
A3	4,5 (\pm 3,1)	-1,6	10,6
A4	4,5 (\pm 4,3)	-4,0	13,0
D1	35,0 (\pm 1,4)	32,2	37,8
C1	10,4 (\pm 0,1)	10,2	10,6
C2	23,2 (\pm 0,3)	22,5	23,8
C3	36,6 (\pm 1,5)	33,6	39,6
C4	47,3 (\pm 2,4)	42,6	51,9
K	1,1 (\pm 0,1)	1,0	1,3
A1F	2,6 (\pm 1,5)	0,5	4,9
A2F	0,0 (\pm 2,1)	-4,0	4,0
A3F	0,0 (\pm 2,4)	-6,6	6,6
A4F	0,0 (\pm 4,8)	-9,4	9,4

Table 2: Growth parameters of population 2 after adjustment of SVL-data ($n=204$) to the logistic model. Parameter estimate (\pm standard deviation) are given as well as lower and upper limit of 95%-confidence interval. For detailed definition of parameters see method. Parameters A and D are given in mm, C is given in months whilst growing constant K is dimensionless. Indices are referring to Ages (1 = first Year 2 = second year etc.)

sponds to a final SVL of 103,7 mm. During the following seasons some individuals grew remarkable, which nevertheless was not significant at the population level. The estimated date of maximum growth shifted from mid June in the first activity season to the end of August in the fifth activity season. The growth constant k was estimated as 1,1.

Population 3:

Hatchling size was estimated as 35,2 mm for this population (Table 3). Within their first year of activity juveniles grew as large as 75,0 mm. The growth increments within the following 3 years are statistically significant, reaching values of 14,6 mm (2nd year), 6,4 mm (3rd year) and 4,2 mm (4th year). The date of maximum growth shifted from mid June (1st year) to the beginning of August (4th year). Females seem to have

parameter	Estimation (\pm sx)	lower limit	upper limit
A1	75,0 (\pm 0,9)	73,2	76,8
A2	14,6 (\pm 1,4)	11,8	17,4
A3	6,4 (\pm 2,8)	0,8	11,9
A4	4,2 (\pm 2,1)	0,2	8,2
D1	35,2 (\pm 0,6)	34,0	36,3
C1	10,4 (\pm 0,1)	10,2	10,6
C2	23,1 (\pm 0,3)	22,6	23,6
C3	36,2 (\pm 0,9)	34,5	37,9
C4	47,4 (\pm 2,0)	43,4	51,4
K	1,1 (\pm 0,1)	1,0	1,3
A1F	1,0 (\pm 0,9)	-0,8	2,7
A2F	1,2 (\pm 1,7)	-2,1	4,5
A3F	0,2 (\pm 2,8)	-5,3	5,7

Table 3: Growth parameters of population 3 after adjustment of SVL-data ($n=349$) to the logistic model. Parameter estimate (\pm standard deviation) are given as well as lower and upper limit of 95%-confidence interval. For definition of parameters see method. Parameters A and D are given in mm, C is given in months whilst growing constant K is dimensionless. Indices are referring to Ages (1 = first Year 2 = second year etc.)

higher SVL, but this difference was not significant. The growth constant k is estimated to be 1,1.

The results can be summarised as follows:

There was no significant difference between SVL of hatchlings from different populations.

Significant increments were found for 1st-3rd year growth in population 1, for 1st-4th year growth in population 3 but only for 1st-2nd year growth in population 2.

The estimated date of maximum growth shifts towards the end of the season in older ages. Significant differences among populations in the timing of maximum growth rate were only found concerning individuals from population 1 in their first activity season. These are reaching maximum growth rate about two weeks later than individuals from other populations.

Growth constant shows a very wide 95%-confidence interval. Only estimations of population 2 and 3 are similar. Estimations of k for population 1 shows substantial variation (although confidence intervals show partly overlapping: Population 1: 0,9-1,7 versus Population 2 & 3: 1,0-1,3).

With only one exception (one year old animals in population 2) there were no significant differences in growth patterns between males and females.

Discussion

Like in other reptiles (Andrews 1982) growth of green lizards is discontinuous. This is one reason for the decrease in the seasonal increment in higher ages ($A_{x+1}-A_x$) and the shift in the dates of the maximum growth rate (C_x). The main factor for reduced growth is maturation (Peters 1963, Rykena 1976). An adult lizard taking part in reproduction is forced to direct more resources into reproductive output (eggs, sperms, sexual behaviour) rather than into own growth. This leads to an distinct reduction of growth during reproductive period and a delay of maximum growth rate (C_x). This pattern is not only true for green lizards, but for other reptiles, too (Moll & Legler 1971 in Andrews 1982).

Significant sex-specific differences in growth of SVL were not found in this study as well as in Peters (1970) and Rykena (1976). The only exception is the group of one year old animals in population 2, in which females have higher SVL than males. This can be explained by the fact that females enter their second hibernation about 14 days later than males, resulting in a prolonged activity (=growing) season. Shifts in activity seasons between populations can be used to explain the delay of maximum growth rate in population 1, which corresponds with a delay in spring activities in this population (Elbing 2000).

SVL of hatchlings and the general pattern of growth curves are similar in all three populations, but there are some qualitative and quantitative differences. The dynamics of

growth in the first two years is high in population 2, which corresponds with growth data from Rykena (1976). She found that under terrarium conditions green lizards grow very fast in their first 200 days of activity (Field conditions: About 360 calendar days). Growth dynamics remain high for the next 100 days of activity (Field conditions: Up to late spring of 3rd calendar year) and shows distinct decrease for the following 200 activity days (Field conditions: Summer of 4th calendar year). After 500 days Rykena (1976) found hardly any growth in green lizards. In contrast, lizards from population 1 and 3 showed significant growth even in their 3rd and 4th year of life (means 4th to 5th calendar year). The growth dynamics of population 1 are similar to those given by Peters (1970) for another relict population of green lizards. According to him the SVL at the end of the activity season are about 62-78 mm (one year old animals), 85-95 mm (three year old animals) 90-100 mm (four year old animals). He stresses that individual variability is high, so that SVL in higher age classes are widely overlapping. The increased width of 95%-confidence interval for older ages is indicating, that the same is true for the three populations investigated in this study.

General growth patterns are interacting with various other parameters of general ecological conditions and life history. In the ecological context food supply, microclimate, length of activity season, parasite load, injuries and social status of the individual (Andrews 1982, Sorci et al. 1996, Adolph & Porter 1996) have to be mentioned. As of weather conditions and habitat structure many of the mentioned factors show high variation. Although it is quite impossible to investigate all possible influence factors under field conditions and to interpret the single results and their interdependence, some of the differences between the three populations are not surprising: Take for example the quite low growth rate in population 3: The habitat is sunny, diverse and richer than the other two study areas. Nevertheless growth rates are not the highest – obviously because these population shows the highest overall social costs and the highest relative reproductive effort (Elbing 2000).

Population 1, inhabits a shady habitat with comparatively poor resources (Elbing 2000) and therefore shows low growth rates. In contrast growth rate in population 2, inhabiting a sunny and more diverse habitat (Elbing 2000) are higher. This fast growth enables early maturation. In Population 2 individuals are usually taking part in reproduction after the second hibernation, whilst in population 1 no lizard seem to reproduce before their fourth spring. Both patterns may have advantages. For short-lived individuals like those in population 2 (mean life expectancy: ~ 4 years; Elbing 2000), early reproduction is more important than for long-lived animals like in population 1 (mean life expectancy: >>5 years).

These few examples show, that interpretation of SVL data is not easy if – like in many dissection studies – there is no basic knowledge on ecological and life history parameters and their variability. At least the results of this study should make every researcher suspicious in assigning individuals to a certain age class by their SVL only.

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