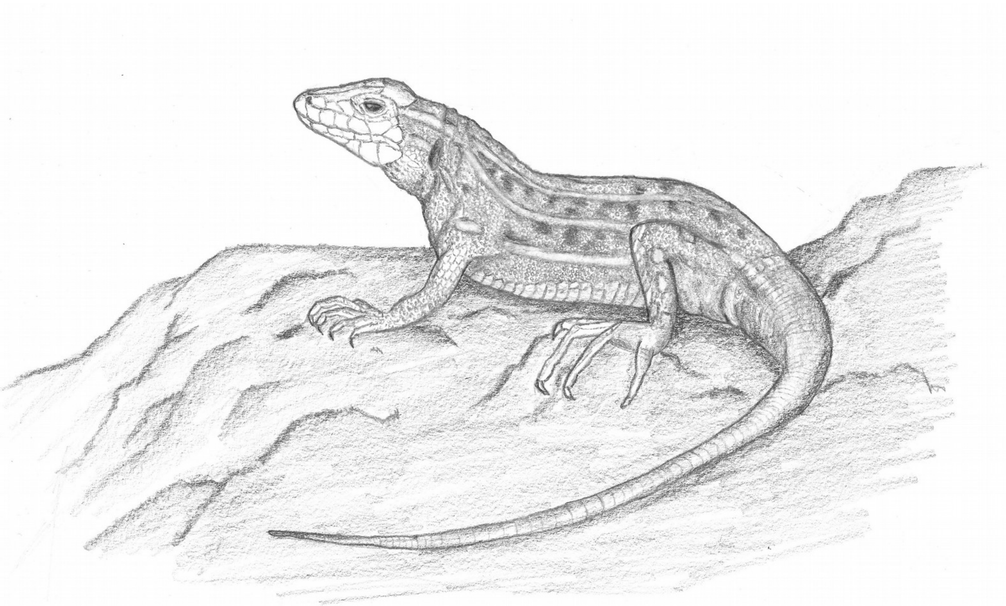
Capítulo III

Body growth and its implications in population dynamics of *Acanthodactylus erythrurus* (Schinz, 1834) in the Eastern Iberian peninsula

Robby M. Drechsler & Juan S. Monrós



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Body growth and its implications in population dynamics of *Acanthodactylus erythrurus* (Schinz, 1834) in the Eastern Iberian peninsula

Robby Marcel Drechsler*[1] & Juan Salvador Monrós[1]

[1]Cavanilles Institute of Biodiversity and Evolutionary Biology, University of Valencia, c/ Catedrático José Beltrán Martínez 2, 46980 Paterna, Valencia, Spain

*Corresponding author; email: robbymar@uv.es

Abstract

We calculated growth rate for the spiny-footed lizard (*Acanthodactylus erythrurus*) inhabiting coastal eastern Spain from long-term mark-recapture data. Growth curves differ between sexes, with males growing faster than females and achieving larger size maximums. In this population each sex reaches maturity at about 300 days of age, approximately 34% faster than males, and 28% faster than females studied in a population further south and west in Iberia. Our logarithmic growth model has an accuracy of 96.8% and high statistical significance ($r = 0.96$ for males and $r = 0.97$ for females). Although both the exponential curve of "best fit" for growth estimated for males ($r = 0.81$), and the linear curve of "best fit" estimated for females ($r = 0.77$) in a population from Cádiz (Busack & Jaksic, 1982) are also significant. The overlap between growth curves and the general data cloud of the population showed that at the end of the year the proportion of individuals younger than one year was 80% and the proportion of individuals older than one year was 20%. Our data, in agreement with calculated maximum life spans for males (1.9 years) and females (2.1 years) in Cádiz, suggest a life span of approximately two years for both sexes. Females seem to reproduce only in a unique season in their lives, at this locality, as in Cádiz (Busack & Klosterman, 1987) they likely lay only one clutch, whereas females in Morocco (Bons, 1962) may produce two.

Keywords: *Acanthodactylus erythrurus, growth rates, population dynamics, Spain*

Introduction

A species' growth pattern is closely related to its life history (Case, 1978) and influences both functional age of reproductive maturity and species longevity (Tinkle, 1969). Because of this it is an important factor to be considered in ecology and population dynamics.

Body size and age in reptiles are positively correlated (Halliday & Verrel, 1986) and there is still important information lacking regard to growth patterns and lifespan, age of sexual maturity, differing growth models or variability within different populations of the same species. There are only two reliable methods for estimating age of an individual available today: skeletochronology and mark-recapture (Halliday & Verrel, 1986), but with the advance of molecular techniques, age may eventually be estimated accurately by studying telomeres (Hatase et al., 2008). Skeletochronology is effective for long-lived species (e.g. turtles; Avens & Snover, 2013), but is error prone for species with short life cycles (e.g. Eden et al., 2007). The mark-recapture method is most reliable for these species (e.g. Znari & Brown, 1999), but to use it reliably, long-term population monitoring is required.

The dominant species in the study area is the spiny-footed lizard *Acanthodactylus erythurus* (Schinz, 1834), a relatively large, insectivorous species with Mediterranean distribution. It has a remarkable preference for open and arid habitats, what makes that in the Iberian peninsula it is especially abundant in coastal dune environments (Pérez-Mellado, 1982). *A. erythrurus* is one of the cases where there are still unknowns regarding the relation between growth and population dynamics, what can also be perceived in the information compilation of the species done by Belliure (2015).

Therefore, we proposed this study with the objective of describing in detail the growth pattern of *A. erythrurus* from a coastal population in the East of the Iberian peninsula. Moreover, assessing the implications it has on ecological parameters like population dynamics. All in the context of improving the knowledge regarding these characteristics in order to favour future conservation plans for this species.

Materials and methods

Study area

The study area is situated in the East of the Iberian peninsula, at about 10 km south Valencia city and it is part of the Albufera de Valencia Natural Park (39°20'29”N 0°18'43”W). It is formed by a coastal line of about 10 km length (N-S) and 1 km wide (E-W).

The sampling site presents a typical Mediterranean vegetation. Adjacent to the shore, mobile dunes with a variable degree of maturity and a vegetation formed mainly by different grass and bush species (generally less than 1 m tall) like *Ammophila arenaria*, *Helichrysum stoechas*, *Euphorbia paralias*, *Medicago marina* or *Rhamnus alaternus*, among others. Then, further away from the coast line, also an area of fixed dunes with a forest vegetation mainly formed by Aleppo pine (*Pinus halepensis*) and a dense undergrowth of species like *Smilax aspera*, *Asparagus officinalis*, *Chamaerops humilis* or *Pistacia lentiscus.*

Methods

Samplings were carried out between April and October (both included) of 2015 and 2017. In the first year we did two samplings every two weeks, while in 2017 we intensified the sampling effort to four times a week. That means a total of 131 sampling days.

Each sampling consisted in a random track census with two hours of duration, where we recorded all seen individuals of *A. erythrurus*, distinguishing age class and sex, when possible. We began sampling two to three hours after sunrise. In parallel to the countings, we captured every individual possible by hand or looping (Fitzgerald, 2012), stopping the census timer during the duration of each capture try.

We put all captured individuals in individualized cloth bags for the posterior measurement. Once we finished the sampling we processed the captured individuals, recording sex, age class and other observations. Then we measured the basic biometry (snout-vent length [SVL], total length [TL] and weight) (similar to other studies like Sacchi et al., 2007). Finally, we marked each individual with an unique code of amputated phalanges, a method commonly used for marking lizards (e.g. Perry et al., 2011). Once finished the measuring we released each individual near the point of capture.

Data analysis

For the abundance estimation we standardized the countings by the duration time of each census, obtaining abundance values in individuals/hour. Then, we grouped the data by months, calculating the mean and standard error in each case.

For the growth curve estimation we used biometric data of recaptures (45 individuals with 116 datasets). We calculated the growth rate for each recapture by dividing the increment in SVL by the number of elapsed days (eg. Haenel & John-Alder, 2002). Then, we grouped the obtained values by intervals of 10 mm SVL (of the individual), calculating the mean value of growth rate for each interval. Afterwards, we drew a tendency line, which equation allowed us to assign a growth rate value (in mm/day) to every value of SVL. The inverse value of the growth rate (in days/mm) allowed us to estimate the theoretical time an individual needs to grow from 30 mm SVL to 31 mm, from 31 mm to 32 mm and so on. The representation of this increment in size in relation to time is the growth curve. We applied this procedure separately for each sex. In order to evaluate the precision of our model we carried out an intensive sampling in April 2018, obtaining a total of 20 recaptures of different sizes and sexes.

For the study of age composition of the population in a certain moment of the year, we estimated the highest value of SVL individuals hatched in summer are able to reach (according to our model). In order to obtain this value, we drew the growth curve on the largest individual of each sex at the end of October that according to our model hatched in the previous summer. We set the initial point of the growth curves on the first day we observed hatchlings in the field (13th of July). According to this model, individuals situated over the maximum line in spring and summer of the following year are too big to have hatched the previous year and, thus, can be considered second year individuals.

Results

The analysis of the censuses showed that juveniles of *A. erythrurus* hatch from July to October. The maximum in hatchings occurs in August (Fig. 1). The calculation of the growth rate shows that the relation between the size of an individual (*SVL*, in mm) and its theoretical growth rate (*GR*, in mm/day) is expressed by the following formula for each sex:

Males ($R^2 = 0.995$):

$$GR = 5.28 \cdot 10^{-5} \cdot SVL^2 - 0.01 \cdot SVL + 0.46$$

Females ($R^2 = 0.998$):

$$GR = 4.86 \cdot 10^{-5} \cdot SVL^2 - 0.01 \cdot SVL + 0.48$$

The application of these formula for each value of SVL in intervals of 1 mm allowed the estimation of the number of days an individual needs to reach a certain size (Table 1). The representation of these values allowed us to draw the growth curves, which adjust to the following logarithmic formula, where *SVL* is the size of an individual (in mm) and *t* is time (in days):

Males ($R^2 = 0{,}923$):

$$SVL = 9{,}65 \cdot \ln(t) + 3{,}34$$

Females ($R^2 = 0{,}937$):

$$SVL = 7{,}50 \cdot \ln(t) + 10{,}61$$

The testing of the model showed a precision of 93.9% comparing the predicted and the real, observed, values. Nevertheless, it also showed quite high error values (~16%) in individuals which passed the hibernation during the initial phase of their growth, that means individuals which hatched late (from the middle of September) the previous year. Supposing that the growth during hibernation is null or negligible, we subtracted effective growth days in each of these individuals until the error of the model respect the real value was minimal. This showed a mean duration of the hibernation of 117 ± 23 days. Considering this and correcting the effective days of growth in the mentioned individuals, the error of the prediction went down to 3.2% in these cases and the precision of the general model went up to 96.8%.

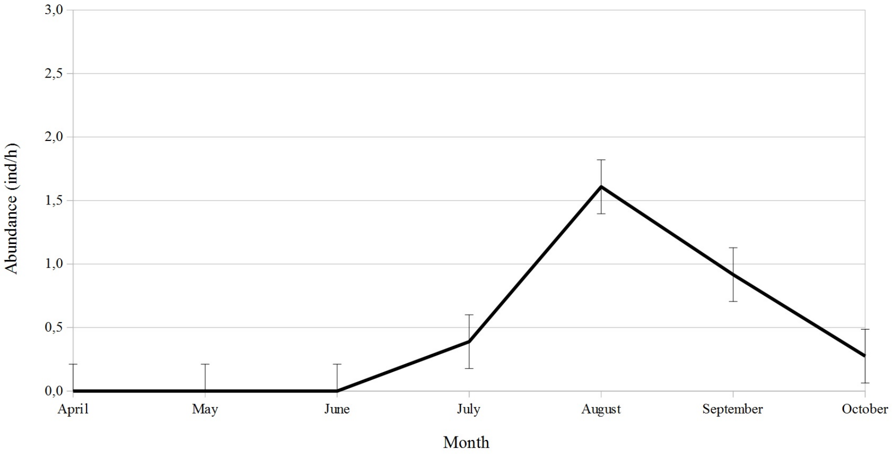

Figure 1: Representation of the mean and standard error of the variation in hatchling abundance (in individuals/hour) during the year.

Table 1: Estimated age in days according to our growth model in intervals of 1 mm SVL, considering an initial SVL of 30 mm.

SVL (mm)	Estimated age (days)		SVL (mm)	Estimated age (days)	
	Males	Females		Males	Females
31	5	5	54	188	240
32	10	10	55	201	264
33	15	16	56	215	292
34	20	21	57	230	324
35	26	27	58	246	363
36	32	33	59	263	412
37	38	40	60	281	476
38	44	47	61	300	571
39	50	54	62	321	742
40	57	61	63	344	1639
41	64	69	64	368	-
42	71	77	65	395	-
43	78	86	66	423	-
44	86	95	67	455	-
45	94	105	68	490	-
46	103	116	69	528	-
47	112	127	70	572	-
48	121	139	71	620	-
49	131	153	72	676	-
50	141	167	73	740	-
51	152	183	74	815	-
52	163	200	75	905	-
53	175	219	76	1015	-

The overlap of the growth curves with the data cloud of all captures (Fig. 2) allowed us to estimate the age class composition of the population during the year (Fig. 3). We can remark from this representation the disappearance of second year individuals in September, what can be a hint to the lifespan. Moreover, the proportion of individuals younger than one year at the end of the activity period is over 80%. Therefore, the proportion of second year individuals at the beginning of the year is about 20%.

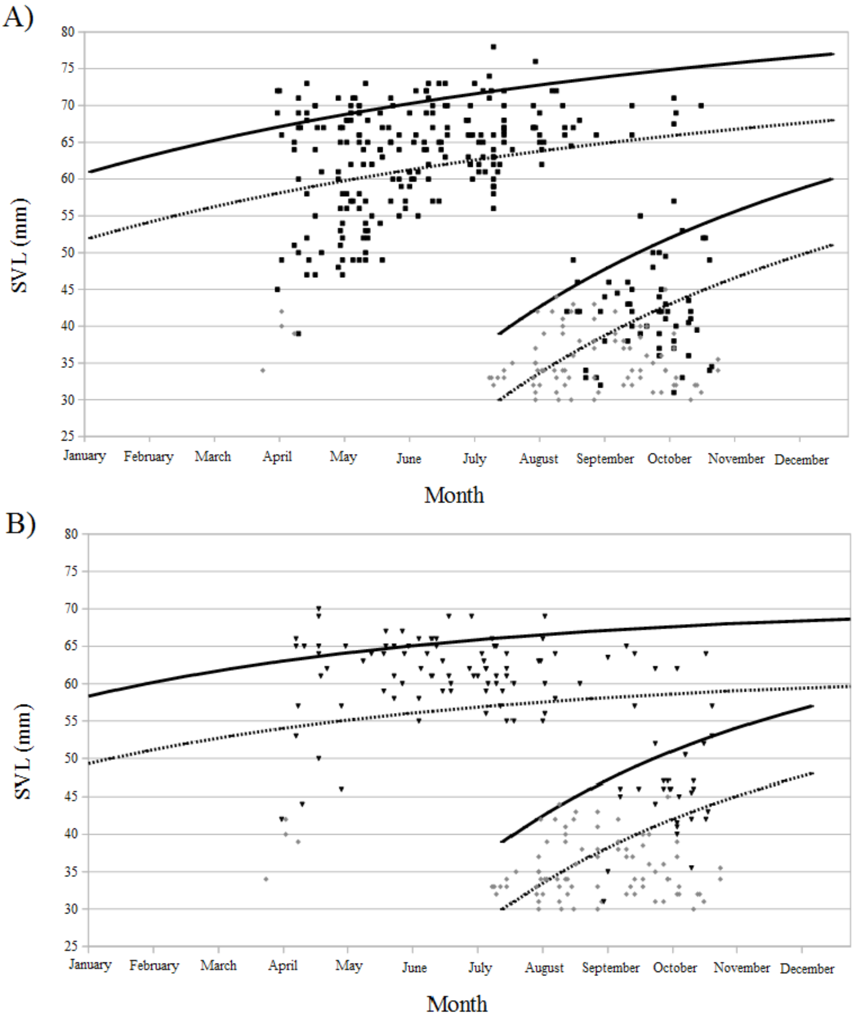

Figure 2: Overlap between the growth curves and the general data cloud obtained during the samplings. We represent the mean curve (dotted line) and the maximum curve (continuous line) for each sex: males (A) and females (B). In the data cloud we distinguish males (black squares), females (black triangles) and individuals with unknown sex (grey diamonds).

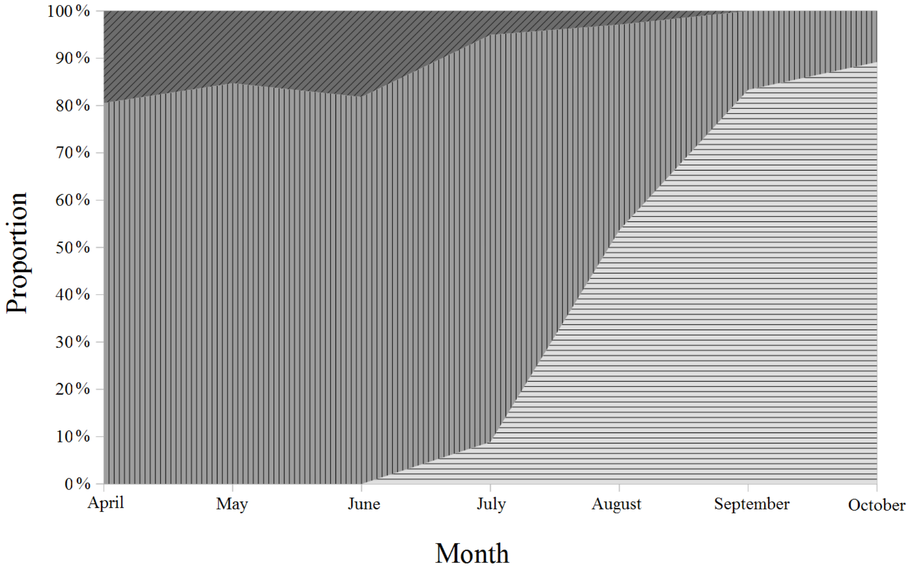

Figure 3: Representation of the variation of age class proportions in the population during the year, according to our growth model. We distinguish the proportion of present year individuals (clear area with horizontal lines); first year individuals (intermediate dark area with vertical lines) and second year individuals (dark area with diagonal lines).

Discussion

The beginning (13th of July) and maximum (August) of the appearance of hatchlings coincide with the observed in other populations (Pollo & Pérez-Mellado, 1990). Therefore, the temporal calibration of our growth curve model is valid and applicable or comparable to other populations. In previous studies it was described that juveniles hatch with a size between 28 and 31 mm (Pérez-Quintero, 1996; Belliure, 2015). Thus, also the consideration to use the minimum observed SVL in the field (30 mm) as the initial point of the model is valid.

There is only one previous study where growth rates of *A. erythrurus* were estimated (Busack & Jaksic, 1982). This study was carried out in a region in South Spain, about 273km South and 534km West of our study site. Climate data from both sites are quite similar, ours being a bit drier, hence we do not expect great differences in the general performance of the species. Our recorded growth rates are considerably higher than the ones described in Busack & Jaksic (1982). The authors estimated growth rates of 0.06 mm/day for males and 0.05 mm/day for females. However, this calculation has a high error margin as they calculated the growth rate for a large size interval (from hatching to sexual maturity) using preserved individuals. Our study allows a much finer evaluation of growth. In addition, in the cited study the authors hypothesize an exponential growth curve for males and a lineal one for females. Although both curves were significant ($r = 0.81$ for males and $r = 0.77$ for females) (Busack & Jaksic, 1982), our results show that the growth rate varies while the individual is growing. Smaller individuals have considerably higher growth rates (around 0.2 mm/day) than larger ones. This results in a logarithmic type of growth curve, with a high slope at the beginning, which gets flatter as time passes. This is also reflected by the higher statistical significance of our model ($r = 0.96$ for males and $r = 0.97$ for females).

This type of growth curve is very common. Back in 1938 the so called Bertalanfy Equation was described (Von Bertalanfy, 1938), or its more generalized version from Richards (1959), and it has already been applied to reptiles (Shine & Charnov, 1992). However, as Busack & Jaksic (1982), we found a sexual dimorphism, presenting males higher growth rates than females. This is also consistent with the fact that adult males tend to be larger than females (Castilla, Barbadillo & Bauwens, 1992; Barbadillo & Bauwens, 1997).

Previously it was described that *A. erythrurus* reaches sexual maturity at an age of about 1.5 years (Busack & Jaksic, 1982; Seva, 1982). Considering that males reach sexual maturity at 60 mm SVL (Seva, 1982), and females at 55 mm SVL (minimum size we observed a gravid female), according to our model, in our population both sexes reach sexual maturity after about 300 days. That means a considerably shorter time than previously described, approximately 34% faster than males, and 28% faster than females studied in Cádiz (Busack & Jaksic, 1982). In fact, the very first hatchlings could be able to reproduce the following year. Nevertheless, endocrinological studies of the population should be carried out in order to evaluate the exact moment when each sex reaches sexual maturity, moreover considering the quite large variability in sizes of reproductive maturity described in different populations of this species (Belliure, 2015).

The results we recorded regarding population dynamics are very interesting. The maximum value that according to our model an individual hatched in summer is able to reach at the end of the year suggests that more than 80% of the population is renewed every year. That means only 20% of the individuals reach the second winter. This, in combination with the described in the previous paragraph, could mean that there is an important selective pressure on the moment of hatching. In Busack & Jaksic (1982), although the authors estimated higher annual survival rates (around 55%), the estimated lifespan is approximately two years. Our model is coherent with this, given that second year individuals disappear exactly two years after the maximum of hatchings in the present year. Although, we have to remark that from that point the growth rate is so low that our model is not able to distinguish one year individuals and older.

This has also repercussions on the reproductive strategy *A. erythrurus* follows. The almost entire annual renovation of the population indicates that this species follows a strategy based on a single reproduction. That means, the majority of females only reproduces in a unique season in their lives, being able to lay up to two clutches. Although the number of clutches is variable between different populations (Bons, 1962; Busack &

Klosterman, 1987; Castilla, Barbadillo & Bauwens, 1992; Carretero & Llorente, 1995). Some females reach the second year. These females would act as a “reproductive reserve” if one year results to be very unfavourable. If this theory shows to be correct, it would mean that *A. erythrurus* is a much more fragile species than previously thought, as a single reproduction leads to a higher susceptibility to unfavourable conditions and, in consequence, increases the risk of extinction (e.g. Jonsson & Ebenman, 2001; Jeppson & Forslund, 2012). In fact, we found one case of a female which in 2017 was gravid and in 2018 was recaptured with the typical red coloured tail indicating heat, evidencing that she participates in a second reproductive event. This hypothesis is coherent with the recorded data, as the proportion of females in second year individuals (58%) is considerably higher than the general mean adult sex ratio of the population (35%) (unpublished data). This may also indicate that lifespan for females is longer than for males.

In conclusion, this is the first work which describes in detail the growth of *A. erythrurus* and, in addition, analyses the repercussion it has on population dynamics and reproductive ecology of the species. In fact, we obtained interesting results, which show that some data previously described should be revised or profiled. Our results and analyses will be of great importance when elaborating future managing and conservation protocols for this species.

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