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First report of tail regeneration rate in the endemic Chilean gecko *Garthia gaudichaudii* (Duméril & Bibron 1836) (Squamata, Phyllodactylidae)

Primer reporte de tasa de regeneración de cola en el geco endémico de Chile *Garthia gaudichaudii* (Duméril & Bibron 1836) (Squamata, Phyllodactylidae)

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Abstract. Many lizards can regenerate their tail after releasing it in order to escape from a predator, in a process called caudal autotomy. Here, we provide for the first time data on tail regeneration rate in *Garthia gaudichaudii*, an endemic Chilean gecko that uses its tail to communicate in social interactions. For 48 days, and once a week, we photographed and measured in captivity the length of the regenerated tail of a female individual that had autotomized its tail almost completely. At the end of this period, the regenerated tail reached a total length of 19 mm (62.3% of the original tail length). The regeneration rate was 0.4 mm day^{-1}, being higher between the second and fourth week after autotomy (0.75 mm day^{-1}). Tail regeneration in G. gaudichaudii is relatively faster than in other lizards, which suggests that tail loss might negatively affect this species, for example, during social signalling. It will be necessary to evaluate the adaptive value of tail regeneration as well as of tail autotomy in this small gecko.

Keywords: antipredator behaviour, lizards, tail autotomy

Resumen. Muchos lagartos pueden regenerar su cola luego de soltarla para escapar de un depredador, en un proceso llamado autotomía caudal. En este trabajo, entregamos por primera vez antecedentes sobre la tasa de regeneración de cola en *Garthia gaudichaudii*, un geco endémico de Chile que utiliza su cola para comunicarse en interacciones sociales. Durante 48 días, y una vez por semana, se fotografió y midió en cautiverio el largo de la cola regenerada de una hembra que había autotomizado su cola casi por completo. Al final de este periodo, la parte regenerada alcanzó un largo total de 19 mm (62.3% del largo de la cola original). La tasa de regeneración tuvo un valor de 0.4 mm día^{-1}, siendo mayor entre la segunda y cuarta semana después de la autotomía (0.75 mm día^{-1}). La regeneración de cola en G. gaudichaudii es relativamente más rápida que la observada en otros lagartos, lo cual sugiere que el perder la cola podría afectar negativamente a esta especie, por ejemplo, durante la señalización social. Será necesario evaluar el valor adaptativo de la regeneración y autotomía de cola en este pequeño geco.

Palabras clave: conducta antidepredatoria, lagartos, autotomía de cola

Introduction

Autotomy is the ability of some animals to voluntarily shed an appendage (reviewed by Maginnis 2006). Caudal or tail autotomy, is probably the most common and widely known type of autotomy, which is present in most lizard families as an effective defence against predators (Arnold 1984, Clause and Capaldi 2006, Bateman and Fleming 2009, and references therein). Lizards can release their tail when they are captured by a predator, in order to escape away while the predator is being distracted by the spontaneous and vigorous wriggling movement of the released tail (Arnold 1988, Pianka et al. 2003, Pafilis et al. 2005). Most lizards (but not all) can voluntary detach their tails at a specific fracture plane that divide individual vertebrae (Bateman and Fleming 2009, Jacyniak et al. 2017). This kind of autotomy, known as intravertebral autotomy, is triggered by the contractions of various muscle segments that split the fracture plane and break the vertebrae (Arnold 1984, Pianka et al. 2003). Immediately after, a spontaneous tail regeneration process begins, with the formation of a temporary seal of tissue at the tail stub (Jacyniak et al. 2017). The result of regeneration is a new tail that is similar, but not equal, to the original, since it presents an unsegmented cone of cartilage instead of a bony vertebra column with fracture planes (Jacyniak et al. 2017).

Although caudal autotomy has an obvious benefit for lizards, such as significantly increasing the chances of survival in predatory encounters (Daniels et al. 1986, Fox and McCoy 2000, Lin et al. 2017), it can also generate numerous costs (Fox and Rostker 1982, Arnold 1988, Pianka et al. 2003, Bateman and Fleming 2009). More precisely, tail loss can affect energy (McConnachie and Whiting 2003), metabolism (Naya et al. 2007) and various ecological aspects of lizards, such as locomotion performance (Gillis and Higham 2016, Hsieh 2016), reproduction (Martín and Salvador 1993, Fox and McCoy 2000), habitat selection (Martín and Salvador 1992), social status (Fox and Rostker 1982) and social signalling (Fox et al. 1990).

It has been suggested that the regeneration rate and extension of the new tail will depend on the balance between the costs and benefits of losing the tail (Arnold 1984). For example, we might expect a rapid tail regeneration will be more important than body growth or other factors in lizards that have markedly reduced their survival or reproduction following autotomy (Arnold 1984, Bateman and Fleming 2009). Thus, knowledge of the tail regeneration rate can provide an insight into the potential adaptive value of tail regeneration in lizards (Vitt 1981, Arnold 1984, Bateman and Fleming 2009).

Here, we report for first time data about tail regeneration rate in an endemic Chilean gecko, *Garthia gaudichaudii* (Duméril and Bibron 1836). *Garthia gaudichaudii* is a small (snout vent-length (SVL) = 31.8 mm ± 1.9 SD, n = 25, unpublished data) and nocturnal lizard that inhabits semiarid coastal environments of central-northern Chile (Cortés et al. 1994, Demangel 2016). It has a cylindrical tail (length = 26.8 mm ± 6 SD, n = 25, unpublished data) that can be autotomized when it is surprised or captured by a potential predator (Donoso-Barros 1966, Reyes-Olivares C., per. obs.). Also, it can use the tail in social signalling, as males and females show different tail displays when approaching each other (Codoceo 1957, Reyes-Olivares et al. 2018).

Materials and methods

On February 13, 2019, in El Panul, Región de Coquimbo, Chile (30°00' S, 71°23' W), and during the capture of individuals of *G. gaudichaudii*, C. Reyes-Olivares found an adult female that released its autotomized tail almost entirely (88.6 % of the original tail length) when it was surprised under a stone shelter. The autotomized tail was taken with forceps immediately after it stopped moving (approximately five minutes after it was released), measured its length with a calliper (precision 0.01 mm), and stored it in ethanol 99%. The gecko was captured by hand and transported the same day to the laboratory in order to evaluate the regeneration of its tail. It was measured (SVL and tail stub length) and housed individually in a plastic box (20 x 15 x 15 cm). The box had an absorbent paper as substrate, a shelter, and a pot for water. Water was provided ad libitum and the individual was fed three times per week with larvae of flour beetle (*Tribolium sp.*) dusted with vitamins and calcium (SERA reptimineral C). The gecko was placed in separate indoor vivarium with continuous ventilation and conditions mimicking those recorded in the field during normal summer days, photoperiod 14:10 h light: dark, and temperatures ranging between 12 ° and 26 °C. Photoperiod and temperature were provided by halogen lights and humidity by spraying water. The individual was returned, in healthy conditions, to its collection point after 48 days (seven weeks).

The gecko was observed and photographed dorsally at weekly intervals during its entire stay in captivity. Since we noticed that the regenerate tail began to grow (during the second week, see below) we measured it with a digital calliper (precision 0.01 mm) once a week until the last week it remained in captivity. Finally, we calculated the tail regeneration rate from the ratio between the final total length of the regenerated tail and the total number of days (or weeks) of observation (Vitt 1981).

Results

The tail stub and the autotomized tail had a total length of four and 31 mm, respectively. The tail stub did not bleed much immediately after autotomy and a scab was formed on it during the first day. Tail regeneration was evident during the second week after the autotomy, since a pale brown replacement tail emerged (Fig. 1A, B). This color remains until scale differentiation began to occur between the third and fourth week (Fig. 1B). From the fifth week, the regenerated tail turns very similar to the original tail in coloration, shape and scalation (Fig. 1B). At the seventh week, it reached a total length of 19 mm, 62.3% of the original autotomized tail (Fig. 1A, B). The tail regeneration rate was 0.4 mm day^{-1}, or 2.7 mm week^{-1}, although the new tail grew faster in length (0.75 mm day^{-1}) between the second and the fourth week after autotomy (Fig. 1A).

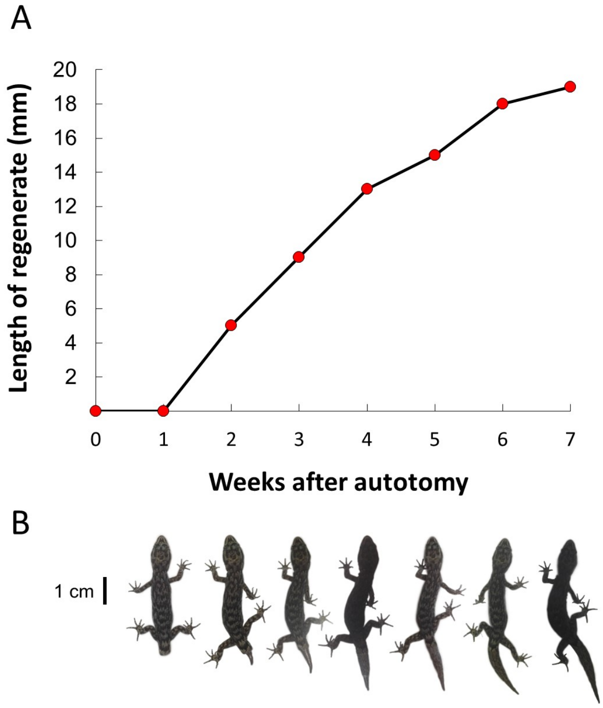

Figure 1: A) Growth in length (mm) of the regenerate tail of an individual of *Garthia gaudichaudii* (SVL = 32.5 mm) after autotomy at week 0. B) Weekly dorsal photographs of the gecko.

Discussion

Tail regeneration rate of lizard is very variable between lizard species (Arnold 1984, Bernardo and Agosta 2005), with values ranging from 0.07 to 1.78 mm day^{-1} (Woodland 1920, Hughes and New 1959, Bryant and Bellairs 1967, Vitt et al. 1977, Vitt 1981, Oppliger and Clobert 1997, Chapple and Swain 2002). Specifically, in geckoes, there are few records of tail regeneration rates, which are similar, or even higher, than that of *G. gaudichaudii*. First, species of the genus *Sphaerodactylus* Wagler 1830 present a tail regeneration rate of 0.47 mm day^{-1} (Hughes and New 1959), whose value is similar to that of *G. gaudichaudii*. In contrast, species such as *Coleonyx variegatus* (Baird 1858), *Hemidactylus flaviviridis* Rüppell 1835, and those of the genus *Thecadactylus* Goldfuss 1820, have higher rates of tail regeneration than *G. gaudichaudii,* with values ranging from 0.7 - 1.12 mm day^{-1} (Gosse 1851, Woodland 1920, Vitt et al. 1977).

Although the tail regeneration rate of *G. gaudichaudii* is one of the lowest observed in geckos, the time that regenerates most of its original tail (seven weeks) is relatively faster than in other species of non-geckonid lizards. The skink *Brasiliscincus heathi* (Schmidt and Inger 1951) regenerates 50% of its original tail only after 10 weeks (Vitt 1981). Moreover, the species *Elgaria multicarinata* (Blainville 1835) and *Plestiodon gilberti* (Van Denburgh 1896) can reach only 30.54 and 30.45 % of their original tail volumes, respectively, after 14 weeks (Vitt et al. 1977). Possibly, the small body size of *G. gaudichaudii* could allow it to regenerate its tail in a shorter total time. The relative rapid tail regeneration of this gecko would suggests, on one hand, that caudal autotomy is an important survival tactic in this species (Fleming and Bateman 2012), and on the other, that to lose the tail could generate potential negative consequences on it, such as affecting social signaling (Fox et al. 1990, Bateman and Fleming 2009). However, we are aware that it is important to assess the tail regeneration in more individuals in order to speculate on the adaptive role of tail autotomy and tail regeneration in *G. gaudichaudii*.

Even though tail autotomy is a highly studied antipredatory mechanism in lizards (McConnachie and Whiting 2003, Clause and Capaldi 2006, Bateman and Fleming 2009), tail regeneration rate has been addressed in relatively few works (Arnold 1984, Bateman and Fleming 2009). In this sense, the present report on the tail regeneration rate in *G. gaudichaudii* constitutes an important contribution to the knowledge of the species, and the first report of tail regeneration in a Chilean lizard.

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