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Short Communication

Observation of the growth of a bifurcated tail in the Chilean Marked Gecko, *Garthia gaudichaudii* (Squamata, Phyllodactylidae)

Observación del crecimiento de una cola bifurcada en la salamanqueja del Norte Chico, *Garthia gaudichaudii* (Squamata, Phyllodactylidae)

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ABSTRACT

Many lizards (Superorder Lepidosauria) can regenerate their tail after fully or partially autotomizing it. However, abnormalities in regeneration can sometimes occur, such as the growth of one or more additional tails from wounds produced, for example, by incomplete autotomy. In this work, we describe the growth of an additional tail (i.e., bifurcated tail formation) in the endemic Chilean gecko, *Garthia gaudichaudii*, which reached a total length of 7.1 mm in 48 days of captivity.

Keywords: antipredatory behavior, autotomy, caudal regenerative anomalies, lizard.

RESUMEN

Muchos lagartos (Superorden Lepidosauria) pueden regenerar su cola luego de autotomizarla completa o parcialmente. Sin embargo, a veces pueden ocurrir anomalías en la regeneración como el crecimiento de una o más colas adicionales desde heridas producidas, por ejemplo, por una autotomía incompleta. En este trabajo, describimos en el geco endémico de Chile, *Garthia gaudichaudii*, el crecimiento de una cola adicional (i.e., formación de cola bifurcada) que alcanzó un largo total de 7,1 mm en 48 días de cautiverio.

Palabras clave: anomalías regenerativas caudales, autotomía, comportamiento antidepredatorio, lagartija.

Caudal autotomy is the ability of many lizards (Superorder Lepidosauria) to drop all or part of their tail, usually as a decoy to avoid being captured by a predator (Bateman & Fleming 2009; Emberts *et al.* 2019). In the subsequent spontaneous process of tail regeneration, however, certain anomalies may occur (Barr *et al.* 2020; Henle & Grimm-Seyfarth 2020). Sometimes, the tail is not completely released from the body, leaving an exposed wound at the break point from which a new tail is regenerated (Pheasey *et al.* 2014; Mouadi *et al.* 2021). In other instances, dorsal injuries to the tail, muscle, or adjacent tissue, can cause the appearance of additional tails (Woodland 1920; Das 1932; Lozito & Tuan 2017). However, wounds such as the loss of a single caudal scale, would not cause the development of an extra appendage (Bellairs & Bryant 1985).

Events of caudal regenerative anomalies have been recorded in lizard species that suffer autotomy with intra- and intervertebral rupture patterns (Ananjeva & Danov 1991; Koleska & Jablonski 2015), and can result in tails with two (bifurcated), three (trifurcated; e.g., Pheasey *et al.* 2014), and up to six tails (hexafurcated; Pelegrin & Muniz Leão 2016). Tail bifurcation is the most frequent supernumerary tail phenomenon, having been observed in at least 23 families of lizards (Barr *et al.* 2020; Mouadi *et al.* 2021; Cotoras & Vidal

2023). Nevertheless, most of these records correspond only to anecdotal field observations (Barr *et al.* 2020; Cotoras & Vidal 2023), and few descriptions of the growth of a new additional tail have been reported (e.g., Mouadi *et al.* 2021). Here, we present an observation of formation of a bifurcated tail in the Chilean Marked Gecko, *Garthia gaudichaudii* (Duméril & Bibron 1836).

Garthia gaudichaudii is a relatively small (mean snout vent-length, SVL = 31.8 mm; Reyes-Olivares & Campos-Cifuentes 2019) and nocturnal lizard, that inhabits semiarid coastal environments of central-northern Chile (Demangel 2016). This gecko has a cylindrical tail (mean total length = 26.8 mm; Reyes-Olivares & Campos-Cifuentes 2019), that can be waved in order to communicate with conspecifics (Codoceo 1957; Reyes-Olivares 2021). As other lizards, *G. gaudichaudii* can autotomize its tail when is surprised or captured by a predator (Reyes-Olivares & Campos-Cifuentes 2019). In captivity, a regeneration of a new 19 mm long tail in 48 days, with a regeneration rate of 0.4 mm day^{-1}, has been reported (Reyes-Olivares & Campos-Cifuentes 2019).

On February 13, 2019, during the collection of individuals of *G. gaudichaudii* for an ongoing study carried out in El Panul, Coquimbo Region, Chile (-30.0059° S, -71.3960° W), we found an adult female (SVL = 31.2 mm; total tail length = 22.4 mm) under a stone that partially autotomized its tail when it was manually captured. The tail broke off at 5 mm from the cloaca leaving an exposed wound. The female was transported that same day in a sterile plastic box (10x10x5 cm) to the laboratory of Neuroethology, University of Chile, Santiago, where it was relocated in a new individual plastic box (20x5x15 cm), containing absorbent paper as a substrate, a folded piece of cardboard as shelter (14x5x5 cm), and a 5 ml water container. Water was provided *ad libitum* and the female was fed three times per week with flour beetle larvae (*Tribolium* sp.) dusted with vitamins and calcium (SERA Reptimineral C). The box was placed in an indoor vivarium with continuous ventilation, mimicking conditions recorded in the field site during normal spring days: photoperiod 14:10 h light:dark, and temperatures ranging between 24-30°C.

Female was left undisturbed until when we noticed visually that it had regrown a new tail at the break point (Fig. 1). Since this day, and once a week, it was photographed dorsally and its new tail was measured with a digital calliper (precision 0.01 mm). We calculated tail regeneration rate from the ratio between the final total length of the new branch (mm) and the total number of days in captivity (48 days, or seven weeks) (Vitt 1981). After this time, female was returned in healthy conditions to its original collection point (Fig. 2).

On day 21 after capture, we noticed that a new tail had grown, healing the break point wound of the original tail (Fig. 1). At this point, the original tail was redirected at an angle ~ 150° towards the body of the gecko, while the new tail had a curved shape and grew in caudal direction until day 37 (Fig. 1). Between day 37 and 48, the new tail straightened and redirected its growth to an angle ~ 160° towards the body (Fig. 1). On day 48, the new tail reached a length of 7.1 mm (Figs. 1-2), at a regeneration rate of 0.15 mm day^{-1}.

Tail bifurcation in *G. gaudichaudii* resulted from the generation of a new tail from the wound left by an incomplete autotomy. The new tail grew approximately 7 mm in 48 days under captive conditions. However, its regeneration rate (0.15 mm day^{-1}) was lower than that previously described in other adult female for regeneration of a completely new tail (0.4 mm day^{-1}), even though both individuals were kept captive during the same time and in the same conditions (Reyes-Olivares & Campos-Cifuentes 2019). Incomplete autotomy or caudal wounds are recognized as the main factors causing abnormal tail regeneration in lizards (Barr *et al.* 2020). Nevertheless, potential factors involved in interindividual differences in regeneration rate may also contribute. Probably, the degree of control over energy prioritisation (e.g., trade-offs between growth or reproduction and tail regeneration; Maginnis 2006) or the degree and depth of the wound in the tail (Woodland 1920; Alibardi *et al.* 1988) could explain these dissimilarities.

The occurrence of cases of abnormal tail regeneration in the population studied is null. In three years (2017-2019) of work at the same site, where more than 200 individuals of *G. gaudichaudii* were observed and captured, a case of tail anomaly was never recorded. In fact, tail regeneration is considered a rare phenomenon at the population level. For example, Mouadi *et al.* (2021), observed that only four of 199 individuals (2%) of the gecko *Quedenfeldtia trachyblepharus* (Boettger 1874) had abnormal tails. Moreover, it has been estimated that in general there would be an average 2.75 ± 3.41% of individuals presenting tail abnormalities in natural lizard populations (Barr *et al.* 2020). It is not clear, however, if this low frequency is attributed to the low probability of occurrence of the furcation event (e.g., due to physical limitations, inefficiency of predators) or to the low survival rate of individuals with abnormal tails (by means of negative effects on locomotion, anti-predator tactics and intraspecific communication) (Barr *et al.* 2020). Future research is needed to assess the prevalence as well as the potential costs of abnormal tail regeneration in lizards' populations.

Despite the frequent occurrence of abnormal tail regeneration in lizards (> 180 Lepidosauria species), there are still many related aspects that are poorly understood, such as the formation of a supernumerary tail (Barr *et al.* 2020; Henle & Grimm-Seyfarth 2020; Mouadi *et al.* 2021; Cotoras & Vidal 2023). In this regard, the present report is a contribution to the quantification of the formation time of a bifurcated tail in a lizard.

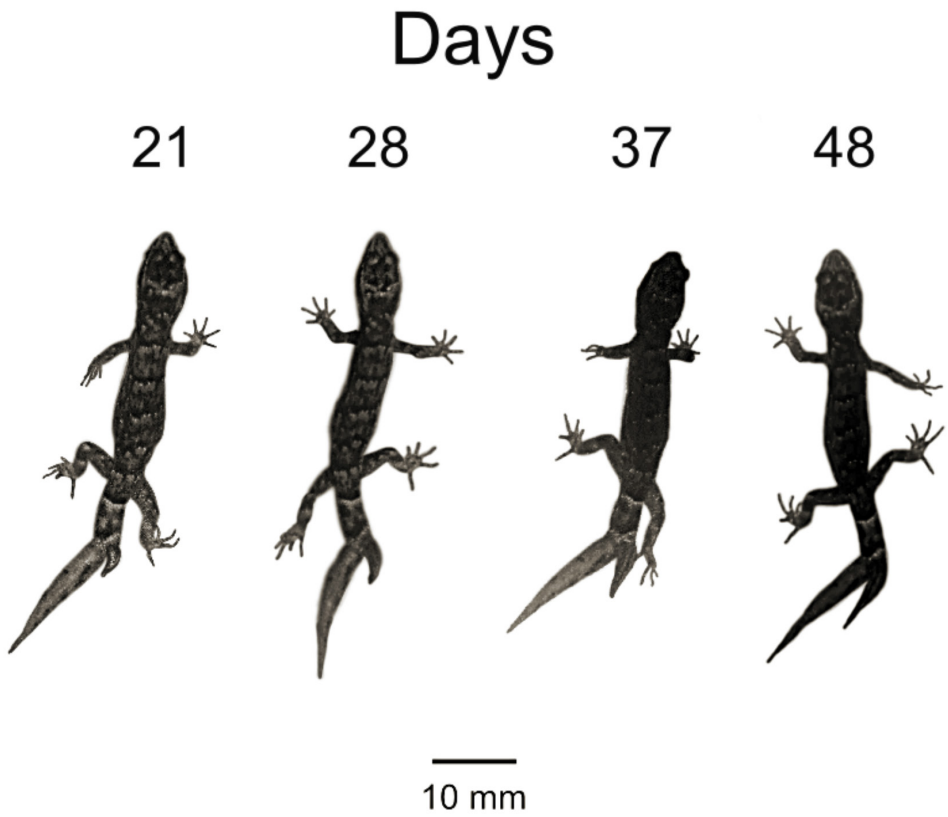

Figure 1. Dorsal photographs of a female *Garthia gaudichaudii* with a growing bifurcated tail (the new tail is on the right). From left to right: 21, 28, 37, and 48 days, after having partially released its tail. / Fotografías dorsales de una hembra de *Garthia gaudichaudii* con una cola bifurcada en crecimiento (la nueva cola es la de la derecha). De izquierda a derecha: 21, 28, 37 y 48 días después de haber soltado parcialmente la cola.

Figure 2. Female of *Garthia gaudichaudii* with its bifurcated tail, returned to its original point of capture in El Panul, Coquimbo Region, Chile. / Hembra de *Garthia gaudichaudii* con cola bifurcada, siendo devuelta a su punto original de captura en El Panul, Región de Coquimbo, Chile.

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REFERENCES

Alibardi, L., Sala, M., Miolo, V. 1988. Morphology and electron microscopy of experimentally produced tail regenerates in lizard. Acta Embryologiae et Morphologiae Experimentalis 9(3): 181-194.

Ananjeva, N.B., Danov, R.A. 1991. A rare case of bifurcated caudal regeneration in the Caucasian agama, *Stellio caucasius*. Amphibia-Reptilia 12(3): 343-349.

Barr, J.I., Somaweera, R., Godfrey, S.S., Gardner, M.G., Bateman, P.W. 2020. When one tail isn't enough: abnormal caudal regeneration in lepidosaurs and its potential ecological impacts. Biological Reviews 95(5): 1479-1496.

Bateman, P.W., Fleming, P.A. 2009. To cut a long tail short: a review of lizard caudal autotomy studies carried out over the last 20 years. Journal of Zoology 277: 1-14.

Bellairs, A., Bryant, S.V. 1985. Autotomy and regeneration in reptiles. In: Gans, C., Billett, F. (Eds) Biology of the Reptilia Vol. 15: 303-410. Wiley, New York.

Codoceo, M. 1957. *Gonatodes gaudichaudi* (Duméril et Bibron). Noticiario Mensual del Museo Nacional de Historia Natural (Chile) 9: 7-8.

Cotoras, D.D., Vidal, M.A. 2023. Tail bifurcation incidence in *Liolaemus* lizards assessed through citizen science and naturalist notes. South American Journal of Herpetology 26: 29-36.

Das, G.M. 1932. Observations on the trifid tails in two specimens of *Hemidactylus flaviviridis*, Ruppell, with a note on the artificial regeneration of double and triple tails of the "Tokhak" lizard, *Gecko verticillatus*, Laurenti. Journal of the Bombay Natural History Society 35: 657-662.

Demangel, D. 2016. Reptiles en Chile. Fauna Nativa Ediciones, Santiago, Chile. 619 pp.

Emberts, Z., Escalante, I., Bateman, P.W. 2019. The ecology and evolution of autotomy. Biological Reviews 94(6): 1881-1896.

Henle, K., Grimm-Seyfarth, A. 2020. Exceptional occurrences of double, triple and quintuple tails in an Australian lizard community, with a review of supernumerary tails in natural populations of reptiles. Salamandra 56: 373-391.

Koleska, D., Jablonski, D. 2015. Tail trifurcation recorded in *Algyroides nigropunctatus* (Duméril & Bibron, 1839). Ecologica Montenegrina 3: 26-28.

Lozito, T.P., Tuan, R.S. 2016. Lizard tail regeneration as an instructive model of enhanced healing capabilities in an adult amniote. Connective Tissue Research 58(2): 145-154.

Maginnis, T.L. 2006. The costs of autotomy and regeneration in animals: a review and framework for future research. Behavioral Ecology 17(5): 857-872.

Mouadi, J., Elbahi, A., Er-rguibi, O., Laghzaoui, E.M., Aglagane, A., Aamiri, A., Aourir, M. 2021. First record of abnormal tail regeneration in the Moroccan endemic gecko *Quedenfeldtia trachyblepharus* (Boettger, 1874) and the family Sphaerodactylidae. Herpetology Notes 14: 959-963.

Pelegrin, N., Muniz Leão, S. 2016. Injured *Salvator merianae* (Teiidae) regenerates six tails in central Argentina. Cuadernos de Herpetología 30(1): 21-23.

Pheasey, H., Smith, P., Atkinson, K. 2014. Natural history notes. *Vanzosaura rubricauda* (Red-tailed Vanzosaur). Bifurcation and Trifurcation. Herpetological Review 45: 138-139.

Reyes-Olivares, C. 2021. Comunicación multimodal en el geco *Garthia gaudichaudii* durante encuentros sociales y con depredadores. PhD Thesis. University of Chile, Santiago, Chile.

Reyes-Olivares, C., Campos-Cifuentes, F. 2019. First report of tail regeneration rate in the endemic Chilean gecko *Garthia gaudichaudii* (Duméril & Bibron 1836) (Squamata, Phyllodactylidae). Boletín Chileno de Herpetología 6: 19-22.

Vitt, L.J. 1981. Tail autotomy and regeneration in the tropical skink, *Mabuya heathi*. Journal of Herpetology 15(4): 454-457.

Woodland, W.N.F. 1920. Some observations on caudal anatomy and regeneration in the gecko (*Hemidactylus flaviviridis*, Riippel), with notes on the tails of *Sphenodon* and *Pygopus*. Quarterly Journal of Microscopical Science 65: 63-100.

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