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TAIL FURCATION IN TWO COMMON NEOTROPICAL LIZARDS: *CTENOSAURA SIMILIS* (GRAY, 1831) AND *GONATODES ALBOGULARIS* (DUMÉRIL & BIBRON, 1836)

BIFURCACIÓN DE LA COLA EN DOS LAGARTIJAS NEOTROPICALES COMUNES: *CTENOSAURA SIMILIS* (GRAY, 1831) Y *GONATODES ALBOGULARIS* (DUMÉRIL & BIBRON, 1836)

José Manuel Mora[1,2*], Lucía I. López[3] & Luis A. Cruz[4]
[1]*Carrera de Gestión Ecoturística, Sede Central Universidad Técnica Nacional, Alajuela, Costa Rica.*
[2]*Department of Biology and Museum of Vertebrate Biology, Portland State University, Portland, Oregon, USA.*
[3]*Unidad de Ciencias Básicas y Carrera de Tecnología de Alimentos, Sede Atenas, Universidad Técnica Nacional, Costa Rica.*
[4]*Green Zion New Forest, Guatuso, Alajuela, Costa Rica.*
**Correspondence: josemora07@gmail.com*

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Resumen.– La autotomía es un mecanismo de defensa en las lagartijas, seguido de la regeneración de la cola. La pérdida de la cola desencadena un proceso regenerativo epimórfico espontáneo, que resulta en un reemplazo completamente funcional. Sin embargo, la regeneración caudal no siempre es perfecta y, a veces, puede dar lugar a anomalías como colas adicionales. Descubrimos dos lagartijas con colas divididas en Costa Rica. El 7 septiembre 2021, a las 14:10 h, encontramos una *Ctenosaura similis*, Iguanidae, con una cola trifurcada en el Pacífico Central. En este caso dos colas regeneradas surgieron de la original para formar una trifurcación. El 6 junio 2013, a las 10:00 h, encontramos una *Gonatodes albogularis*, Sphaerodactylidae, con dos colas en las tierras bajas del norte. La cola de esta hembra era doble, con dos colas que emergían juntas sin una distinción clara. Aquí presentamos estos dos casos y los comparamos con otros casos reportados.

Palabras clave.– Autotomía, Iguanidae, pérdida de apéndices, regeneración, reptiles, Spherodactylidae.

Abstract.– Autotomy is a defense mechanism in lizards, followed by subsequent tail regeneration. Tail loss triggers a spontaneous epimorphic regenerative process, resulting in a fully functional replacement. However, caudal regeneration isn't always flawless and can sometimes lead to abnormalities like extra tails. By chance, we discovered two lizards with furcated tails in Costa Rica. On 07 September 2021, at 14:10 h, we encountered a female ctenosaur, *Ctenosaura similis*, Iguanidae, with a trifurcated tail in the Central Pacific region. In this case, two regenerated tails emerged from the original, forming a trifurcation. On June 6, 2013, around 10:00 h, we found an adult female Yellow-headed Gecko, *Gonatodes albogularis*, Sphaerodactylidae, with two tails in the northern lowlands. The tail of this female was double, with two tails emerging together without a clear distinction. Here, we present these two cases and compare them with other reported instances.

Keywords.– Appendage loss, autotomy, Iguanidae, regeneration, reptiles, Spherodactylidae.

Tail autotomy, or self-amputation of the tail, is one of the most dramatic escape mechanisms in lizards (Pianka & Vitt, 2003). When faced with a predator, a lizard voluntarily detaches its tail at a specific fracture plane in the vertebrae (Pelegrin & Muniz Leão, 2016). This detachment is achieved through powerful muscle contractions (Vitt & Caldwell, 2014), and the severed tail begins to thrash violently, driven by anaerobic metabolism, continuing to thrash for an extended period (Pianka & Vitt, 2003). The thrashing tail distracts the predator, giving the lizard time to escape to safety (Arnold, 1988), while the predator is left with only an expendable part of the lizard's body (Vitt & Caldwell, 2014).

Although appendage regeneration in reptiles is typically limited, tail replacement is possible, especially in lizards that undergo autotomy (Alibardi, 2017a, b; Mora et al., 2020). After

a successful autotomous escape, tail regeneration becomes a crucial step (Clause & Capaldi, 2006). Tail loss triggers a spontaneous epimorphic regenerative process, resulting in the formation of a fully functional, though structurally different, replacement (Gilbert et al., 2013). Regenerated tails can vary in size, being smaller, similar to, or larger than the original (Vitt & Caldwell, 2014). Additionally, instead of regenerating vertebrae, the new tail forms a cartilaginous rod (Lozito & Tuan, 2017; Bassett et al., 2021). Despite these differences, tail regeneration is essential, as this appendage serves important functions such as prehensility, visual displays, aggressive interactions, energy storage, locomotor performance, and defense against predators (Liang et al., 2024).

Typically, the new tail replaces the autotomized tail, but complications can arise (Hoefer & Robinson, 2020). Regeneration malformations, often called multi-furcations, can range from simple bifurcations to more complex forms like hexafurcations (Hoefer & Robinson, 2020; Bassett et al., 2021). Abnormal tail regeneration or furcations have been documented (Barr et al., 2020; Henle & Grimm-Seyfarth, 2020), but recent data lists 250 lizard species from 25 families, with 91 % exhibiting bifurcated tails (Baum & Kaiser, 2024).

Some members of the Iguanidae family, like *Iguana iguana*, can autotomize their tails during early development but are believed to lose this ability as they age (Etheridge, 1967). *Ctenosaura similis* (Gray, 1831), as currently recognized, is a large, locally abundant iguana with a head lacking a crest and a cylindrical tail characterized by whorls of distinctly enlarged, heavily keeled spiny scales separated by rows of smaller scales (Mora, 2010). Adult males reach a standard length of 489 mm, while females measure up to 400 mm, with total lengths of 1,300 mm and 800 mm, respectively (Leenders, 2019). It ranges from the Isthmus of Tehuantepec in Mexico southward to central Panama on the Pacific slope, with several isolated populations along the Atlantic slope, from sea level to 1,320 m a.s.l. (Mora, 2010).

Geckos are among the lizards with a high capacity for autotomy (Pianka & Vitt, 2003). The Yellow-headed Gecko, *Gonatodes albogularis* (Duméril & Bibron, 1836), can reach a total length of up to 113 mm, with no sexual dimorphism in size; its moderately long tail makes up 50 to 58% of its total length (Savage, 2002). It is a common lowland lizard, found from southern Mexico and Central America to northern South America, at elevations ranging from 2 to 1,000 m a.s.l. (Leenders, 2019). This lizard is often observed on palms, strangler figs, or other trees with deeply creviced bark (Leenders, 2019), but it also inhabits pastures, roadside fences, fallen logs, trash piles, and human-made structures (Savage, 2002). There are few reports of tail defects in Costa Rican lizards. Here, we report two cases that could be considered extreme: a female Yellow-headed Gecko with two tails and a female ctenosaur with a trifurcated long tail.

During a casual walk in the lowlands of the Central Pacific region of Costa Rica, we observed a ctenosaur with an abnormal tail. The ctenosaur was basking on rocks in the garden of the Tropical Height condominium in Playa Hermosa, Puntarenas Province, Costa Rica (9° 34' 57" N, 84° 36' 34" W; 41 m a.s.l.). Additionally, during a personal birdwatching tour, we found a Yellow-headed Gecko with two tails on a wall at Green Zion New Forest, Guatuso, Alajuela Province, Costa Rica (10° 37' 58" N, 84° 47' 02" W; 130 m a.s.l.).

On September 7, 2021, at 14:10 h, we found a female ctenosaur with a trifurcated tail (Fig. 1). The tail appeared to be of normal length relative to its snout-vent length (SVL), but about halfway down, it split into two branches. It seems that the tail was injured, with the distal portion preserved beyond the breakage point, where the second branch began. This left branch was thinner and slightly shorter than the right section, lacking the typical alternating light and dark ring coloration and the characteristic whorls of heavily keeled spiny scales. The right section, forming the main tail, displayed both the ring coloration and normal whorls of spiny scales. However, a little further beyond the halfway point, this section had another branch similar to the previous one, with a branch emerging to the left. This second left branch resembled the first one, being shorter and ending in a hook-like inward bend. The right section, continuing as the main tail, had a single coloration at the end and appeared to be a regenerated portion. This represents regeneration from an already regenerating tail, resulting in multiple tails (Barr et al., 2020).

On 06 June 2013, at around 10:00 h, we found an adult female Yellow-headed Gecko with two tails (Fig. 1). The tail was double, with both tails emerging together from the back of the gecko's spine, without a clear distinction between them. The left section was slightly thinner than the right, but the lengths of both tails were similar and comparable to a normal tail, representing 50 to 58 % of the total length for individuals of this species (Savage, 2002). This appears to be a case of regeneration from the original tail (Barr et al., 2020).

The reported cases of tail malformations in the ctenosaur and Yellow-headed Gecko are rare occurrences in Costa Rica. Although a bifurcated tail has previously been documented in a male Yellow-headed Gecko, this case involved only a short

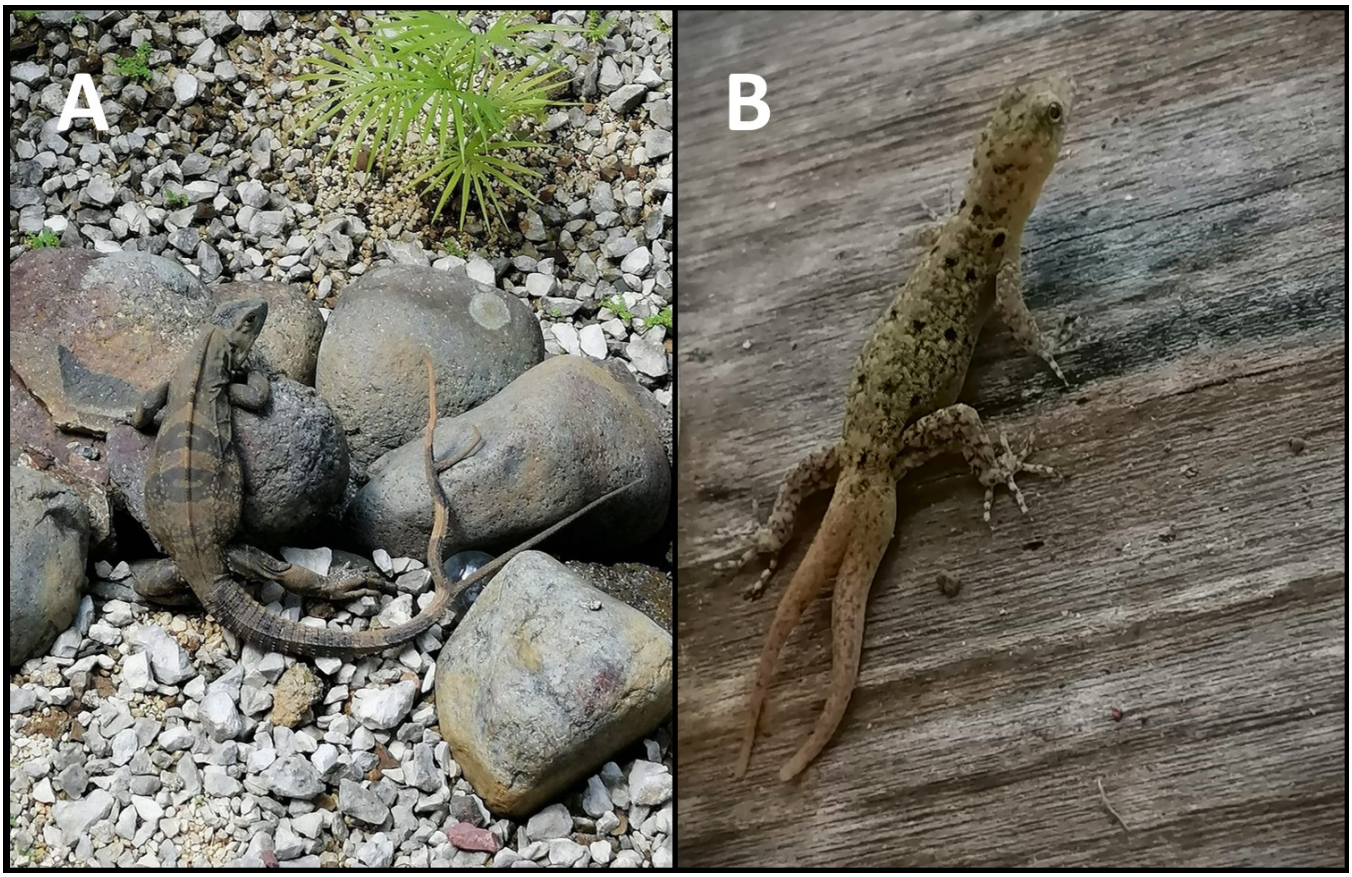

Figura 1. A. Hembra de garrobo, *Ctenosaura similis*, con cola trifurcada, de la región del Pacífico Central de Costa Rica. B. Hembra de geco cabeza amarilla, *Gonatodes albogularis*, con dos colas, de las tierras bajas del norte de Costa Rica.

Figure 1. A. Female ctenosaur, *Ctenosaura similis*, with a trifurcated tail, from the Central Pacific region of Costa Rica. B. Female Yellow-headed Gecko, *Gonatodes albogularis*, with two tails, from the northern lowlands of Costa Rica.

bifurcation at the end of the tail (López & Mora, 2021). In contrast, significant tail alterations in ctenosaurs have not been reported, despite their abundance, especially in the lowlands of the central and northern Pacific regions of Costa Rica (Mora, 2010). The only other documented case of tail malformation in a Ctenosaur is from *Ctenosaura palearis* Stejneger, 1899, in Guatemala, which exhibited a trifurcated tail with three newly regenerated sections (Ariano-Sánchez & Gil-Escobedo, 2016).

Tail malformations in lizards are relatively common, often manifesting as tail bifurcation (Kolenda et al., 2017; Baum & Kaiser, 2024). These anomalies frequently occur during the regeneration process following autotomy (López & Mora, 2021). The female Yellow-headed Gecko in our study may have experienced complete autotomy of the tail in the past, as suggested by the color pattern changes in the two new tails. However, such autotomy would have had to occur near the base of the tail, which is unusual, though complete tail loss is possible (Reyes-Olivares et al., 2023). It is plausible that the gecko was attacked near the base but managed to escape. We hypothesize that the double tail resulted from a complete caudal autotomy rather than another condition, as both tails originated from the same base. It is possible that the initial tail was autotomized, triggering the regeneration process, but a subsequent injury at the same site initiated a second regeneration process, leading to an additional regenerated tail. This condition is somewhat similar to the case observed in a Green Iguana, *Iguana iguana*, in Colombia (Arango-Lozano & Patiño-Siro, 2020).

In some cases, a tail may break but remain partially attached, leading to a regenerated tail with multiple tips (Pheasey et al., 2014). This can occur due to prior injuries (Lynn, 1950) or mechanical damage preventing the tail from fully detaching (Arnold, 1994), allowing additional tails to form during the regeneration of the affected area (e.g., Gogliath et al., 2012; Pheasey et al., 2014; Mouadi et al., 2021). Injuries to the dorsal tail,

muscles, or adjacent tissues can also result in the development of extra tails (Lozito & Tuan, 2017; Reyes-Olivares et al., 2023). This may explain the trifurcated tail observed in the female ctenosaur, although no distinct break point was visible. It's possible that the tail sustained two injuries either simultaneously or at different times but largely remained attached. Each injury site might have continued to grow normally while simultaneously initiating regeneration, leading to the development of an additional tail at each injury point (Yadollahvandmiandoab et al., 2022). In iguanids, tail breakage often results from intraspecific aggression due to overcrowding, sexual aggression during mating, or unsuccessful predation attempts (Hayes et al., 2012; Arrivillaga & Brown, 2020).

Lizards undergoing caudal autotomy face both short- and long-term costs related to the physical loss of the tail and the energy required for regeneration (Barr et al., 2021). Tail furcation can adversely affect an animal's fitness, as the tail plays a crucial role in locomotion and influences activities such as mating, foraging, and escaping from predators (Passos et al., 2014; López & Mora, 2021; Vishnu & Ramesh, 2021). Further investigation into the potential consequences of supernumerary tails in lizards is warranted (Perpignani & Alvarez, 2023).

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