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New distribution record, ecology and tail trifurcation of *Cyrtodactylus mamanwa* (Gekkonidae) on Dinagat Islands, Philippines

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Abstract

This study highlights the ecology, natural history, and a new distribution record by providing a unique habitat occurrence record in karst ecosystem and describes a tail anomaly of the endemic Mamanwa Bent-toed Gecko *Cyrtodactylus mamanwa* in the province of Dinagat. The detection of a new population on Unib Island in the southwestern Dinagat extends the previously known distribution of this gekkonid by approximately 100 km south from its known distribution.

Key Words

Dinagat Islands, gekkonid, new island record, reptile, tail abnormality

Introduction

Gekkonidae is one of the most comprehensively studied reptilian families in the Philippines. It is widespread, species-rich, charismatic, and includes many iconic species popular with the general public. Philippine gekkonids are mostly arboreal, ground, and rock dwellers, with a few species demonstrating extraordinary commensal behavior living in close association with humans (Parves and Alam 2015). Mostly nocturnal, they feed on insects and small arthropods and play a vital role in pest control (Newbery and Jones 2007; Tkaczenko et al. 2014; Meiri 2019). They inhabit a range of environments from built-up areas, mixed agricultural plantations, and lowland forests (Siler et al. 2012; Sanguila et al. 2016; Supsup et al. 2016, 2020).

Recent taxonomic revisions and discoveries reveal 55 species of Philippine gekkonids from eight genera: *Cyrtodactylus* (9), *Gehyra* (1), *Gekko* (14), *Hemidactylus* (5), *Hemiphyllodactylus* (2), *Lepidodactylus* (6), *Luperosaurus* (8), and *Pseudogekko* (10) (Taylor 1915; Taylor 1922; Brown and Alcala 1978; Gaulke et al. 2007; Brown et al. 2007, 2011, 2020; Welton et al. 2009; Welton et al. 2010; Wood et al. 2020). The genus *Cyrtodactylus* comprises *C. agusanensis* (eastern Mindanao Island), *C. annulatus* (Mindanao Island and Western Visayas), *C. gubaot* (western Leyte Island), *C. jambagan* (western Mindanao Island), *C. mamanwa* (northern

Dinagat Island), *C. philippinicus* (Northern and Central Philippines), *C. redimiculus* (Palawan Island), *C. sumoroi* (eastern Samar Island) and *C. tautbatorum* in Palawan Island (Welton et al. 2010).

The Mamanwa Bent-toed Gecko *C. mamanwa* is a recently described cryptic species of lizard endemic to the province of Dinagat, split from the *C. agusanensis* complex (Welton et al. 2010). A nocturnal, arboreal, and medium-sized lizard, it occurs in ultramafic habitats (e.g., large boulders, fallen logs on stream banks) from sea level up to 195 m elevation in northeastern Dinagat islands (Welton et al. 2010; Sanguila et al. 2016). Females (maximum snout to vent length, SVL = 92 mm) are larger than males (maximum SVL = 67.5 mm) (Welton et al. 2010). However, its ecology and distribution remain understudied since its discovery.

For most lizards including gekkonids, an intact tail plays a vital role in locomotion, e.g., balance, locomotor performance, ecological flexibility, foraging, predation avoidance, obstacle evasion (Ballinger 1973; Garland and Losos 1994; Iverson et al. 2004; Ofori et al. 2018), storage of nutrients (Daniels 1984), and intraspecific interaction, e.g., courtship, mating, social status, territory defense (Bateman and Fleming 2009; McElroy and Bergmann 2013; Jagnandan et al. 2014). However, their ability to shed the tail and regenerate it does not always function perfectly and may result in unusual tail malformation during regeneration.

Tail anomalies (e.g., bifurcation, trifurcation) have been widely documented. Bifurcation is noted among multiple lizard families: Agamidae (Ofori et al. 2018), Anguidae (Conzendey et al. 2013), Corytophanidae (Cervera and Novelo 2020), Dactyloidae (Najbar and Skawiński 2018; Hoefer and Robinson 2020), Gekkonidae (De Andrade et al. 2015; Gogoi et al. 2018; Maria and Al-Razi 2018; Bhattari et al. 2020), Gymnophtalmidae (Pheasey et al. 2014), Iguanidae (Koleska et al. 2017; Lozano and Siro 2020), Lacertidae (Koleska et al. 2017; Baeckens et al. 2018; Kornilev et al. 2018; Ramadanovic and Zimic 2019; Sorlin et al. 2019), Mabuyidae (Vrcibradic and Niemeyer 2013), Phrynosomatidae (Álvarez et al. 2020), Phyllodactylidae (Filadelfo et al. 2017; Koleska 2018; Tzoras et al. 2020), Polychrotidae (Goin and Goin 1971), Scincidae (Jablonski 2016; Turner et al. 2017; Vergilov and Natchev 2017; Mendes et al. 2019; Magalhães et al. 2020; Miles et al. 2020), Teiidae (Sales and Freire 2019; Da Silva et al. 2019) and Tropiduridae (Passos et al. 2014). However, supernumerary (e.g., tail trifurcation) caudal anomalies were reported only for a few families: Dactyloidae (Camper and Camper 2017), Gymnophtalmidae (Pheasey et al. 2014), Iguanidae (Hayes et al. 2012), Lacertidae (Koleska and Jablonski 2015), Phrynosomatidae (Mata-Silva et al. 2010), Gekkonidae (Crouch 1969) and Teiidae (Trauth et al. 2014; Passos et al. 2016).

In the Philippines, bifurcation was documented only for Gekkonidae [*C. mamanwa* (Welton et al. 2010)] and Scincidae [*Eutropis indeprensa* (Sy and Dalabajan 2018)] from Palawan Island. Herein we present additional knowledge on the ecology, natural history, the distribution, and tail trifurcation anomaly of *C. mamanwa* on Unib Island.

Materials and methods

We conducted a field survey of the herpetofauna at the limestone karst Unib Island (10°01'12.55"N, 125°30'55.90"E, datum WGS 84, 5–120 m elevation), part of the southwestern Dinagat Islands, Barangay Colombus, Municipality of Basilisa, Dinagat Province on 4–15 September 2019. We surveyed 5 transects into each of two habitats (mixed agricultural areas and mature secondary growth forests). Transects were 100 m long by 10 m wide (Heyer et al. 1994; Diesmos 2008; Supsup et al. 2016), marked with luminous ribbon strips placed 10 m apart. We employed visual encounters, opportunistic catching, and microhabitat searches (e.g., limestone crevices, tree trunks, and decaying logs), during daytime (07:30–11:30 h) and night time (18:30–23:30 h). We specifically noted natural history and behavioral observations of *C. mamanwa* during our 10-day sampling (720 person-hours by 6 individuals).

Previous distribution records of *C. mamanwa* were summarized (Welton et al. 2010; Sanguila et al. 2016). All captured individuals were measured using a digital caliper (e.g., SVL), weighed using an electronic weighing scale (± 0.1 g), were identified using published references by Taylor (1922), Welton et al. (2010), Sanguila et al. (2016), and we followed the taxonomic arrangements of The Reptile Database (Uetz et al. 2020). Captured *C. mamanwa* were humanely preserved (euthanized with aqueous chloretone, fixed in 10% buffered formalin and consequently transferred to 70% ethanol), following a standard preservation protocol (Heyer et al. 1994; Simmons 2002) and were deposited in Mindanao State University-Iligan Institute of Technology Natural Science Museum (MSU-IIT NSM).

Results

We documented 51 individuals of *C. mamanwa* in our survey on Unib Island. We observed adults, subadults, and juvenile individuals. We collected 18 adult individuals as voucher specimens (12 males, SVL: 55.5–90.1 mm, mean = 77.01 ± 13.9 SD, weight range: 2.64–11.9 g; 6 females, SVL: 76.5–94.2 mm, mean = 88.7 ± 7.1 SD, weight range: 9.05–12.9 g; vouchers ## 3982–3985, 4019–4023, 4027–4028, 4030–4032, 4038, 4041, 4044, 4049). Specimens from this population were all collected from microhabitats in the proximity of limestone karst outcrops, rock crevices, karst walls and caves, and tree trunks.

This gekkonid displays a variable dorsal color pattern, from canary-yellow to dark-brown depending on the environment it inhabits. It had a distinct red lining with irregular patterns of branching streaks at the cornea and

Figure 1. Tail trifurcation in *Cyrtodactylus mamanwa* on Unib Island. Note the distinct appearance, color, and pattern of the regenerated secondary tail (top), and the supernumerary tail at the tip of the original regenerated tail.

distinctive eyelashes with yellow coloration. The dorsum portrays moderate longitudinal dark bands projecting from the anterior to the posterior (Welton et al. 2010), with hindlimbs and forelimbs forming an asymmetrical stripe extending to its digits. We observed lizards actively foraging and feeding on cockroaches, termites, and small arthropods at night. We located them in limestone outcrops, rock crevices, and tree trunks in mixed agricultural areas and secondary growth forests over limestone karst habitat at night, and found them utilizing cave walls, tree branches, and underneath a decaying log for shelter and refuge during the day.

The individuals we collected were visibly in good physical condition except for one male (MSU-IIT NSM 4020; SVL = 89.1 mm; weight = 11.7 g, Fig. 1), which had an unusual tail trifurcation. The original regenerated tail measured 71 mm. It presented a pronounced asymmetrically forked tail split near the tip of the regenerated autotomized tail (59 mm, posterior to the base of the original regenerated tail), with a distinct pale-greyish color pattern and exhibited a terminated regenerated tail end. The supernumerary tails were of different lengths. The secondary tail axis (bifurcated tail) measured 13.5 mm, forming a 67° angle with the main tail axis while the under-developed offshoot and less noticeable tertiary branch (trifurcated tail extension) measured 2.3 mm and created a 10° angle from the tip of the main tail axis (Fig. 1). The re-grown tail after autotomy varied distinctively from the original tail based on its color pattern and replacement of the bone and cartilage (Fig. 2). This observation suggests complete autotomy with incomplete tail regeneration possibly due to tail development injuries that may have triggered unparalleled growth of secondary tail, and subsequently with the tertiary tail. More than half of the collected specimens had regenerated tails (n = 11, 57.9%). Caudal autotomy was mostly detected in collected males (n = 9, 81.8%) rather than females (n = 2, 25.0%). We used three voucher specimens to represent the whole population documented on Unib Island and present tail features, patterns of sexual dimorphism, and a tail trifurcation anomaly of *C. mamanwa* (MSU-IIT NSM; ## 3982, 4020 and 4021).

Table 1. Distribution records of *Cyrtodactylus mamanwa* on Dinagat Islands, Philippines.

Sites	Locality	Municipality	Coordinates	Elevation	Reference
1	Esperanza	Loreto	10°23'06.0"N, 125°36'50.4"E	48 m	Welton et al. 2010
2	Kawayanan	Loreto	10°21'00.0"N, 125°36'57.6"E	255 m	Sanguila et al. 2016
3	Esperanza	Loreto	10°22'53.8"N, 125°36'57.6"E	5–116 m	Sanguila et al. 2016
4	San Juan	Loreto	10°21'31.0"N, 125°34'48.0"E	26–72 m	Sanguila et al. 2016
5	Santiago	Loreto	10°20'37.0"N, 125°37'04.8"E	No data	Sanguila et al. 2016
6	Columbus	Basilisa	10°01'12.6"N, 125°30'55.9"E	5–120 m	This work

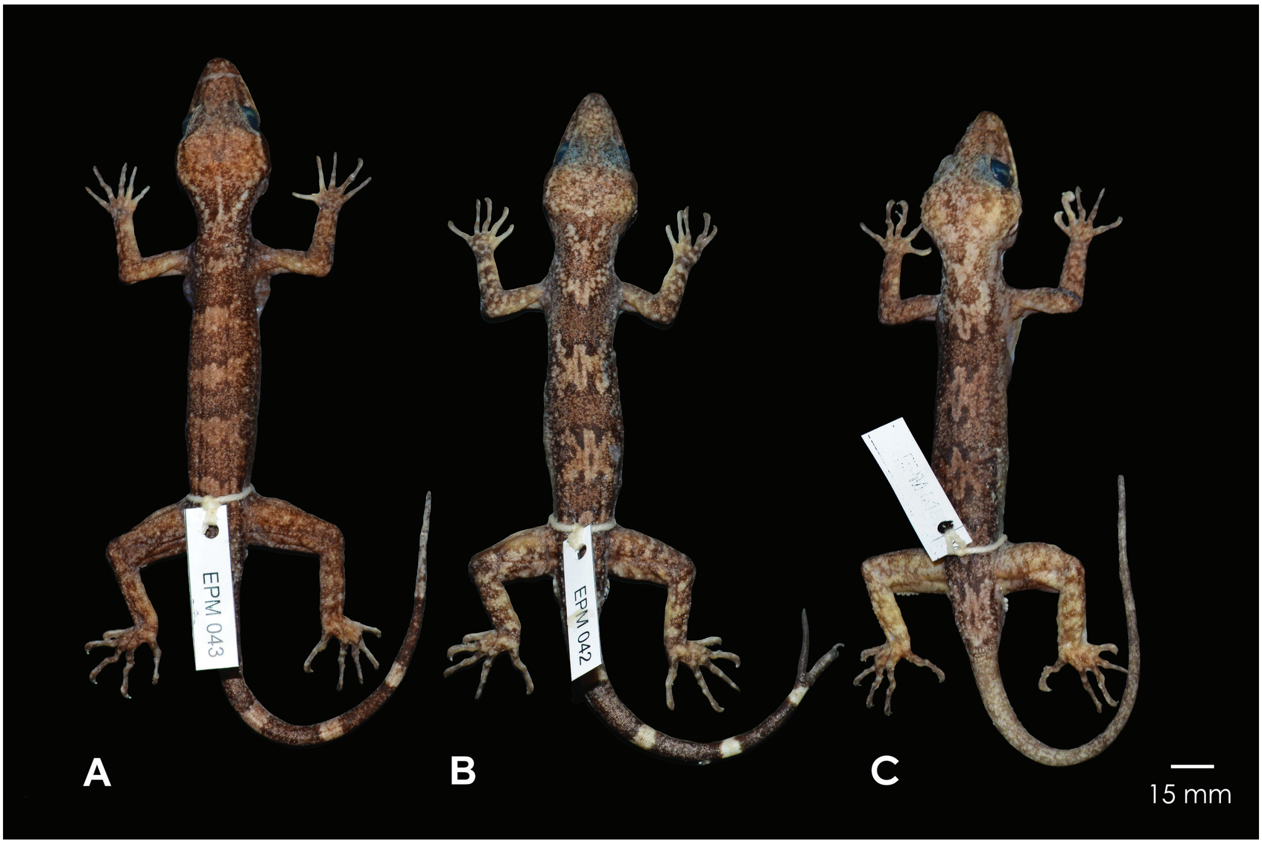

Figure 2. Differences in the morphology of male and female *Cyrtodactylus mamanwa*, emphasizing tail features (**A.** female, Original tail; **B.** male, trifurcated tail; **C.** male, regrown tail) documented on Unib Island.

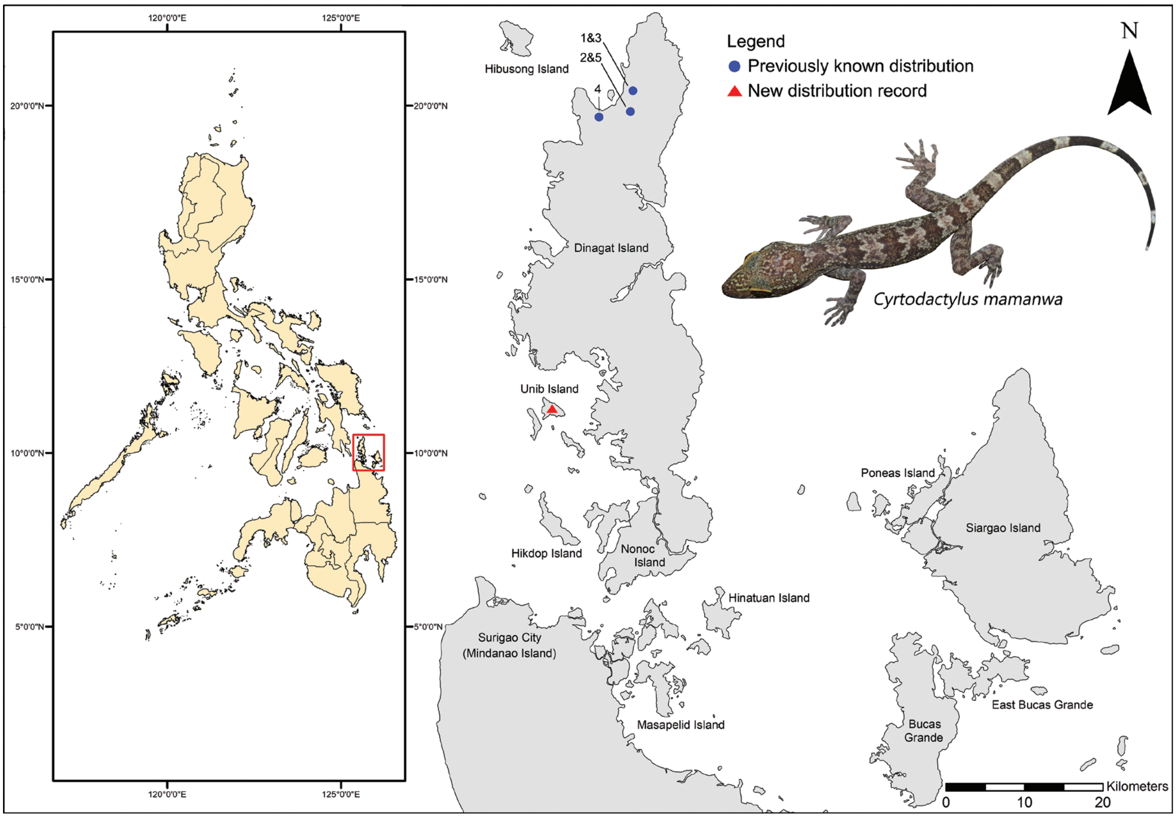

Figure 3. Map of Dinagat Islands with other numerous adjacent islands including Bucas Grande and Siargao (right) within the Philippines (left). Previously known distribution (blue dots) and new distribution record (right triangle) of *Cyrtodactylus mamanwa* in Dinagat Islands. Numbers refer to records presented in Table 1.

Discussion

Cyrtodactylus mamanwa is endemic to the province of Dinagat. Published reports on its distribution are concentrated on the northern part of Dinagat Island (Municipality of Loreto; Sanguila et al. 2016). The detection of a seemingly numerous and healthy population of *C. mamanwa* on the island of Unib, approximately 25 km east of the large Dinagat Island, extends its known distribution by approximately 100 km southwest. It occupies diverse macro- and micro-habitats (e.g., ultramafic forest, forest over limestone or karst).

The present work provides an additional distribution record of *C. mamanwa* from the Dinagat Islands. It is not surprising that the distribution of *C. mamanwa* extends to the southwestern part of Dinagat islands since previous records suggest that it might be present on the neighboring islands of Bucas Grande and Siargao (Welton et al. 2010; Sanguila et al. 2016). However, the population on which we report here illustrates unique habitat occurrence where they are found to inhabit limestone karst ecosystem.

Tropical gekkonids demonstrate a high rate of tail autotomy (Arnold 1984). It is an important defensive strategy of lizards in escaping predators (Gogoi et al. 2018). However, this limits locomotion performance, decreases social status, and reduces mating opportunities (Chapple and Swain 2002; Bateman and Fleming 2009). The individuals we collected that exhibited caudal autotomy might have survived predatory attacks (e.g., birds, snakes) represented by a trifurcated regenerated tail. However, tail malformation may hamper locomotory ability and fitness which attracts putative predatory encounters reducing the survival of the lizards and affects them negatively (Bateman and Fleming 2009; Camper and Camper 2017). We presume that *C. mamanwa* is a natural prey item of predators such as the snakes *Chrysopelea paradisi variabilis*, *Stegonotus muelleri*, *Dendrelaphis marenae*, the birds *Cexy argentatus*, *Halcyon coromanda*, *Penelopides panini* that are present on Unib Island. We have documented a *Chrysopelea paradisi variabilis* preying on *Lepidodactylus herrei* (Maglangit et al. 2021), a closely related gekkonid species to *C. mamanwa*. The higher occurrence of caudal autotomy in males than in females may suggest intraspecific aggression during mating and territorial fights (Iverson et al. 2004; Koleska et al. 2017) and male-male competition over food resources (Koleska 2018). Although the cause of autotomy of these gekkonids is unknown, this species may be a good model for predator-prey interaction studies.

To further understand the process of tail regeneration and the incidence of tail malformations, we encourage herpetologists and biologists to focus on areas of developmental biology (e.g., mechanisms of tail regeneration), histology (e.g., anatomical and histological cause of tail breakage), and physiology (e.g., signals that trigger tail autotomy, effects on fitness and locomotion).

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