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Geographic range extension for the critically endangered leaf-toed gecko *Phyllodactylus sentosus* Dixon and Huey, 1970 in Peru, and notes on its natural history and conservation status

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Abstract. Here we provide the first record of *Phyllodactylus sentosus* out of Lima city. This new record extends the known species distribution *ca.* 318 km (straight line) south-southeastern from the southernmost record at Pachacamac, in the city of Lima. This new record also increases the area of occurrence of the species to 1300 km². All specimens were found near or inside crevices surrounded by dry vegetation on a riverbed. We recorded the air and substrate temperature and the relative humidity during the period of activity of the individuals of *P. sentosus*, which reached its peak between 21:00 and 22:00 hours. We report the presence of the snake, *Bothrops pictus,* and other potential predators in the area. Moreover, we present a brief morphological description and describe the variation of the collected specimens. Additionally, we report a new record of *P. sentosus* in the city of Lima. Finally, we discuss on the basis of our new information, about its ecology and conservation status.

Keywords. Costal desert, endemic, Ica, Nasca, *Phyllodactylus kofordi*, restricted, San Fernando, terminal lamellae.

Introduction

The leaf-toed gecko *Phyllodactylus sentosus* is the only terrestrial reptile from Peru identified as Critically Endangered according to the Peruvian Wildlife Red List (Supreme Decree N°004-2014-MINAGRI, 2014) and the International Union for Conservation of Nature "Red List of Threatened species" (IUCN, 2016). This species was described on the basis of six specimens collected in Lima city in the 70s decade (Dixon and Huey, 1970). Since its description, *P. sentosus* individuals have been found in other sites (nine localities), all of them restricted to the city of Lima, between the basins of the rivers Chillón and Lurín (Figure 1) (Cossios and Icochea, 2006; Pérez et al., 2013; Olivera et al., 2017).

Phyllodactylus sentosus is a small species of gecko (SVL < 60 mm) with a low reproductive rate (Dixon and Huey, 1970) that inhabits coastal areas with dry soil or sand with scattered rocks and no vegetation (Pérez and Balta, 2016). Within Lima city, this species can only be found at very small areas primarily located at archeological sites (Cossios and Icochea, 2006). The natural history and ecology of this species remains understudied especially in habitats without human interference.

In a recent biological inventory at the San Fernando National Reserve (Ica department), we recorded a population of *P. sentosus*. This finding represents the first record of this species out of Lima city and a considerable range extension. Additionally, we describe a new type of habitat, present some natural history observations, review the differences with *P. kofordi*, report a new locality for this species inside of Lima city, and discuss about the conservation status for this species.

Material and methods

The expedition to San Fernando National Reserve was carried out during the winter season from 30 June to 13 July 2016. We conducted herpetological surveys during the day, in search of diurnal reptiles, and during the night in search of snakes and particularly geckos, using an extensive species inventory technique (Scott,

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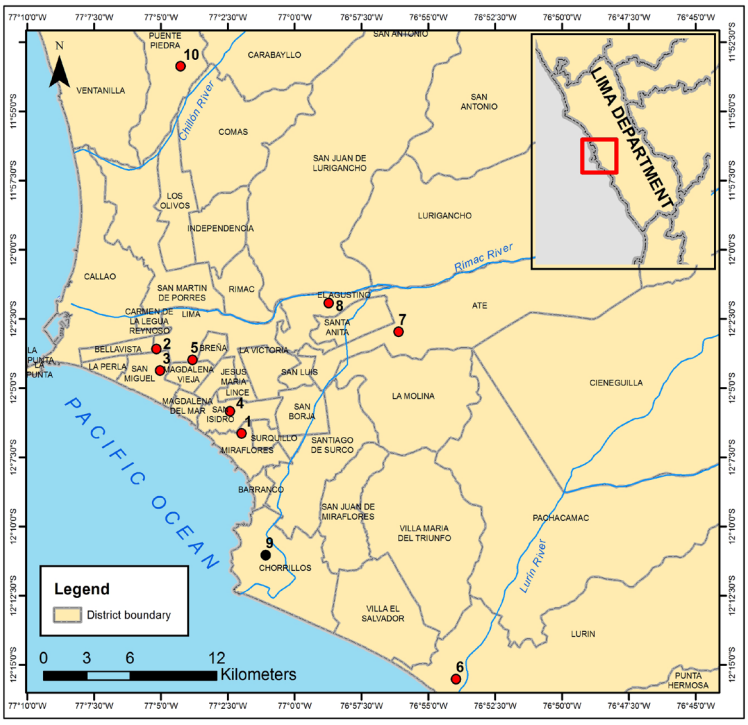

Figure 1. Previously known distribution of *Phyllodactylus sentosus* within the city of Lima. Red dots represent previously known localities taken from Cossios and Icochea (2006), Pérez et al. (2013), and Olivera et al. (2017), and black dot represents the new record inside the city. Names of the localities: (1) Pucllana, (2) Universidad Nacional Mayor de San Marcos, (3) Parque de las Leyendas, (4) Huallamarca, (5) Mateo Salado, (6) Pachacamac, (7) Puruchuco, (8) La Atarjea, and (9) Instituto Nacional de Salud, Chorrillos, and (10) Tambo Inga.

1994). Total sampling effort was 31 person-hours over three nights (30 June to 2 July 2016) with a mean of 5.3 person-hours by night. Individuals of *Phyllodactylus sentosus* were collected by night, during surveys conducted between 20:30 and 03:30 hours. Individuals of *P. sentosus* were collected, as voucher specimens, and euthanized with a lethal dose of the narcotic T61®. Tissue samples were taken from the liver and the specimens were fixed over 24 hours in 10% formalin, stored in 70% ethanol, and finally deposited in the herpetological collection of the Centro de Ornitología y Biodiversidad (CORBIDI), Lima, Peru. Snout-vent length (SVL) was taken with a digital caliper, tail length (TL) and total length (TTL) with a ruler, both to the nearest 0.01 mm. Sex of specimens was determined by checking the presence of hemipenes, when these could be everted to the time of injection of fomaline at the base of tail or by dissecting and directly checking the gonads, when no hemipenis was everted. Morphological characters used to identify the species followed Dixon and Huey (1970). Examined specimens are given in Appendix I. Air temperature and relative humidity were taken with a termohigrometer Radioshack HTC-2 and the temperature of the substrate with a thermometer HI 98501-1 Hanna®. The updated distribution range was estimated from the geometric convex hull polygon that results from the union of all localities. This method is currently being used to evaluate and compare the extension range of threatened species (IUCN, 2001). The polygon was calculated from Minimum Bounding Geometry routine in Arc Tool Box (ESRI 2010).

Results

Eleven individuals of *Phyllodactylus sentosus* (CORBIDI: 17601-02, 17604, 17606-07, 17608-11, 17613, 17615) were recorded and collected by night at the Ica River (14.8159°S, 75.5482°W, 14 m a.s.l.),

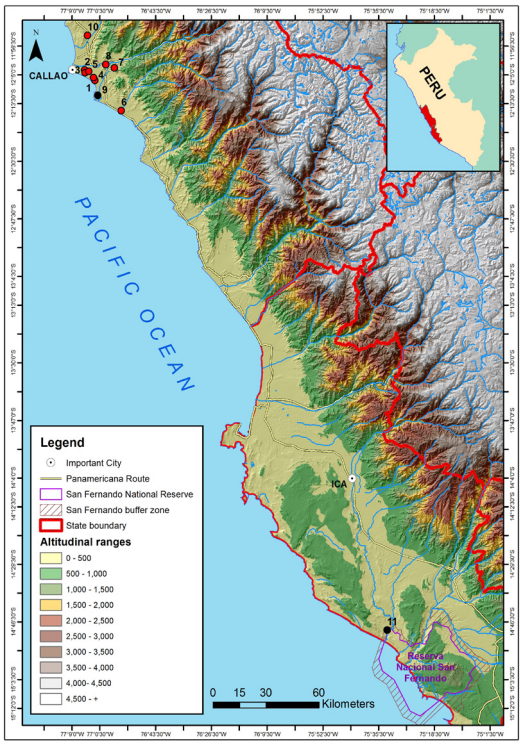

Figure 2. Distributional range of *Phyllodactylus sentosus,* previously known localities (red dots) and new records (black dots). Names of the localities: (1) Pucllana, (2) Universidad Nacional Mayor de San Marcos, (3) Parque de las Leyendas, (4) Huallamarca, (5) Mateo Salado, (6) Pachacamac, (7) Puruchuco, (8) La Atarjea, (9) Instituto Nacional de Salud, Chorrillos, (10) Tambo Inga, and (11) Ica River (San Fernando National Reserve). Previously known localities for *P. sentosus* taken from Cossios & Icochea (2006), Pérez et al. (2013), and Olivera et al. (2017).

at San Fernando National Reserve, Nasca province, Ica department, Peru. These specimens represent the first record of *P. sentosus* out of Lima city and a range extension of approximately of 318 km south-southeast (straight line) from the nearest locality, the archeological sites of Pachacamac (Figure 2). Consequently, the area of occurrence of *P. sentosus* is extended to 1300 km².

All specimens were found near or inside crevices surrounded by dry vegetation, *Tamarix* trees, shrubs, and dunes on the edge of the riverbed (Figure 3). These crevices originated naturally as the soil desiccates during the hottest and driest summer seasons. The size of the crevices in the area varied between 15 and 40 cm of length and 7 to 15 cm of width. Four individuals were found inside the crevices and seven near them. These individuals out of the crevices, when threatened, ran into the crevices seeking for a cover. Active individuals were registered from 20:30 to 03:00 hours. Six individuals (54.5%) were recorded between 21:00 and 22:00, three individuals (27.2%) were registered around 00:00, one (9%) at 01:43, and one (9%) at 03:10. Air temperature during the active hours of *P. sentosus* was between 16.3°C and 18.2°C, substrate temperature on the ground was between 18.1°C and 21.4°C, and relative humidity was between 78% and 90%. Several sheds of *Bothrops pictus* were found inside crevices that were also used by *P. sentosus* individuals as den and a juvenile specimen of this snake was collected near those crevices. We identified the sheds as belonging to *B. pictus* due to the presence of strongly keeled dorsal scales. Because no other coastal snakes in central and southern Peru have keeled scales.

All the specimens collected at San Fernando agree with the diagnostic characters and general description given for *Phyllodactylus sentosus* by Dixon and Huey (1970). Table 1 includes morphological characters of the specimens collected in this study and those ones of the type series of *P. sentosus* given by Dixon and Huey (1970). The specimens from San Fernando can be distinguished from all species of *Phyllodactylus*, except *P. kofordi*, by having large tubercles on dorsum, thigh, tibia, forearms, and tail (Dixon and Huey, 1970). However, *P. sentosus* can be readily distinguished from *P. kofordi* by having very small terminal lamellae and rounded scales in the middle of ventral surface of tail (Dixon and Huey, 1970; Figure 4A, C); whereas in *P. kofordi*, terminal lamellae are expanded and scales in the middle of ventral surface of tail are enlarged and polygonal (Dixon and Huey, 1970; Figure 4B, D).

Most of the collected specimens have similar overall color pattern to that described by Dixon and Huey (1970) for *Phyllodactylus sentosus.* However, some individuals from San Fernando have a slightly different dorsal pattern and coloration (Figure 5). In one juvenile specimen (CORBIDI 17607), dorsal background color was cinnamon sprinkled with cream and dark brown tubercles, some arranged in faint transversal bands (Figure 5A). Other juveniles were brownish cream with cream and dark brown tubercles arranged in conspicuous transversal bands (e.g. CORBIDI 17602; Figure 5B). Dorsal background color is paler in adult specimens and the transversal bands of tubercles can be conspicuous or faint (e.g. CORBIDI 17609; Figure 5C), except in one adult female (CORBIDI 17601) with brownish gray dorsum without any colored tubercle not

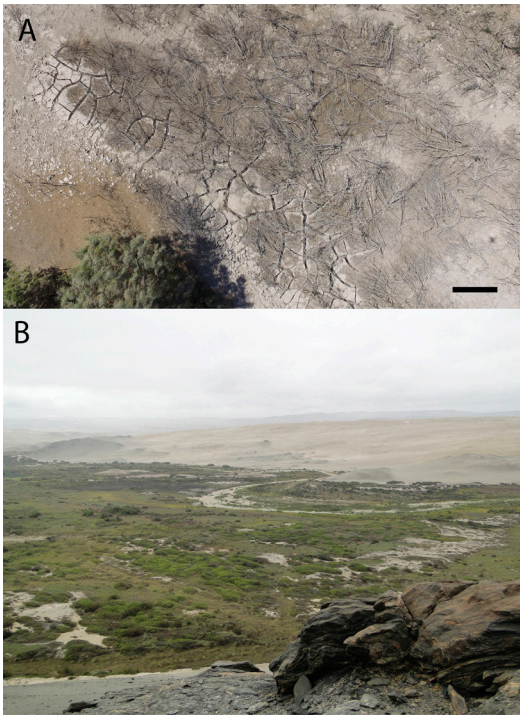

Figure 3. The habitat of *Phyllodactylus sentosus* at the Ica River, San Fernando National Reserve. (A) An aerial view of the crevices that *P. sentosus* individuals use as dens (scale bar = 1 m); (B) the general landscape of the Ica Valley where the specimens were collected.

even on the tail (Figure 5D). Most specimens, except that female individual (CORBIDI 17601), have a brown lateral stripe along the side of the head and conspicuous cream and dark brown intermixed transversal bands on the tail. Specimens with complete tail have 13 to 17 dark brown transversal bands on it. Ventral coloration is gray in all specimens.

Additionally, while revising material for comparison (see Appendix I), we found another specimen of *Phyllodactylus sentosus* in the herpetological collection of CORBIDI (collected in 2013). An adult male (CORBIDI 14138) collected in a small archeological remnant at the Instituto Nacional de Salud at Chorrillos district (12.1841°S, 77.0182°W, 40 m a.s.l.), Lima province, Lima department, Peru (Figures 1-2). The specimen was collected by workers of the Instituto Nacional de Salud and there is no additional data. This record increases to ten the known localities for *P. sentosus* within Lima city (Figure 1).

Discussion

The knowledge about the critically threatened gecko *Phyllodactylus sentosus* is still very poor. After its description in 1970 the major data compilation about its distribution was presented by Cossios and Icochea (2006). Some years later, this species was recorded in other locations inside Lima city (Pérez et al., 2013; Olivera et al., 2017). Pérez and Balta (2016) summarized information about its habitat, ecology and conservation status. According to Pérez and Balta (2016), *P. sentosus* inhabits areas with substrate such as dry soil or sand with some rocks and without vegetation, a kind of habitat that can only be found at archeological sites in a city like Lima. Despite the conservation status of *P. sentosus* and the fact that it was only known from

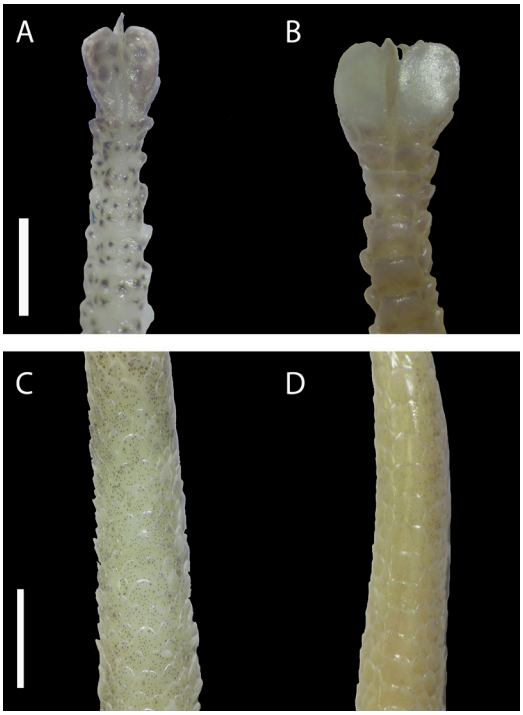

Figure 4. Key characters used to distinguish *Phyllodactylus sentosus* from *P. kofordi*. (A) Fourth finger of *P. sentosus* (CORBIDI 17611) showing reduced terminal lamellae; (B) Fourth finger of *P. kofordi* (CORBIDI 14200) showing expanded terminal lamellae; (C) ventral view of *P. sentosus* tail (CORBIDI 17601), showing rounded scales in the middle of ventral surface of tail; (D) ventral view of *P. kofodi* tail (CORBIDI 3514), showing enlarged polygonal scales in the middle of ventral surface of tail. Scale bar = 3 mm.

Table 1. Morphological characters and measurements (in mm) of *Phyllodactylus sentosus*, range followed by mean in parenthesis. Data presented in the column "Ica River" correspond to the specimens of the range extension. Column "CORBIDI 14138" corresponds to the specimen from Chorrillos, Lima (see text). Column "Dixon and Huey 1970" gives the data of the original description.

CHARACTER AND MEASUREMENTS	Ica River / n = 11	CORBIDI 14138 / n = 1	Dixon and Huey 1970 / n = 6
Scales across chin inmediately following postentals	6-8 (7.9)	8	6-8 (7.3)
Internasals scales	2-3 (2.5)	3	2 (n = 1)
Scales bordering posterior edge of internasals	5-6 (5.9)	6	5-7 (6.3)
Scales across snout at level of third labial	16-18 (17.3)	19	16-18 (16.5)
Midorbital scales	11-14 (12.9)	12	13-14 (13.3)
Scales along line from nostril to eye	9-10 (9.8)	9	9-10 (9.3)
Supralabial scales	5-7 (6.2)	7	-
Infralabial scales	5-6 (5.9)	5	-
Scales around midbody	46-52 (49.6)	52	-
Scales across venter	18-19 (18.5)	19	18-21 (19.3)
Scales along venter	47-54 (50.2) (n = 10)	50	47-55 (50.3)
Fourth finger lamellae	11-12 (11.2)	12	11 (n = 1)
Fourth toe lamellae	11-13 (12.3)	13	12-13 (12.5)
Enlarged rows of dorsal tubercles	15-17 (16)	15	14-16 (15)
Paravertebral tubercles	27-30 (28.3)	28	26-31 (28.8)
Enlarged rows of tubercles at base of tail	7-9 (7.7) (n = 9)	8	6-8 (n = 4)
Body bands	7-8 (7.4) (n = 10)	7	8-10 (9)
Tail bands	13-17 (16.8) (n = 6)	9	13-14 (n = 2)
Maximum SVL Males (mm)	47.7 (n = 2)	-	49-56 (52.5) (n = 2)
Maximum SVL Females (mm)	52.8 (n = 5)	-	39-50 (44.5) (n = 2)
TL	32.6-51.4 (44.1) (n = 7)	38.7	46.3 (n = 1)
TL / TTL	51.2-54.7 (n = 7)	47.3	45-50

the city of Lima—the capital of Peru— there is scarce information about its ecology and natural history unlike other species of gecko as *P. delsolari, P. pachamama, P. thompsoni* and *Phyllopezus maranjonensis*, species that have been described during the last eleven years and inhabit remoter places (Koch et al., 2006; Venegas et al., 2007; Aurich et al., 2011; Koch and Beraun, 2011; Aurich et al., 2015).

Given that our study was conducted in a natural environment, our records on the habitat of *P. sentosus* are completely different from that one described by Pérez and Balta (2016). At archeological sites, the species uses as refuge the archeological remains and the trash left by people in the area such as: rocky debris, mud bricks, crevices on mud walls, the interstices between mud bricks and garbage heaps (Cossios and Icochea, 2006; Pérez et al., 2013; Olivera et al., 2017; P.J. Venegas pers. observ.). Probably, before the urbanization of Lima, this species occupied a wider variety of microhabitats and refuges, not related to archeological remains. The time of our specimens were found suggest that the peak of activity of *Phyllodactylus sentosus* is between 21:00 and 22:00 hours, a similar pattern has been reported to other geckos, like *P. angustidigitus* and *P. gerrhopygus* at the desert of Ica (Pérez and Balta, 2011).

Pérez and Balta (2016), consider that introduced predators like domestic cats and rats are one of the major threats for *P. sentosus* at the archeological sites. At the Ica River in Nasca the potential predator of *P. sentosus* is the venomous snake *Bothrops pictus* that also uses crevices on the dry soil as dens. This nocturnal species is endemic from Peru, it inhabits the costal desert and foothills (Campbell and Lamar 2004). Other potential predators in our study site, observed several times during the night surveys, are the Andean fox *(Pseudalopex culpaeus)* and the borrowing owl *(Athene*

Figure 5. Variation of *Phyllodactylus sentosus* specimens from the Ica River at San Fernando National Reserve. Dorsolateral views of: (A) CORBIDI 17607, juvenile, SVL 31 mm ; (B) CORBIDI 17602, juvenile, SVL 33 mm ; (C) CORBIDI 17609, adult male, SVL 47 mm ; (D) CORBIDI 17601,adult female, SVL 47 mm.

cunicularia). We also recorded many rats (*Rattus rattus*) at the patches of *Tamarix* trees and one domestic cat around the area where the geckos were observed.

As pointed out by Pérez and Balta (2013), *P. sentosus* is a species with poor dispersal ability, mainly given that the asphalt, buildings and runways of Lima city may prevent its dispersal. The morphological features of a terrestrial gecko like *P. sentosus*, e.g., very small terminal lamellas on fingers and toes, limit its capability to live inside houses or buildings as opposite to climber species of *Phyllodactylus* with expanded terminal lamellas, such as *P. reissii* (Dixon and Huey, 1970). In fact, the latter species is considered as introduced in Lima city, as it is native from northern Peru and Ecuador, where it is very common in towns and can be found moving through the walls and roofs of human constructions (Tello, 1998). Currently, *P. reissii* is widely distributed through the districts of Lima city (P.J. Venegas pers. observ.). There are two specimens of *P. reissii* from La Molina and Surco districts in the herpetological collection of CORBIDI (see Appendix). Additionally, individuals of *P. reissi* have been found inside of houses in Lima city and mistakenly identified as *P. sentosus* by non-specialists (L.Ríos pers. observ.).

According to Pérez and Balta (2016), *Phyllodactylus sentosus* is listed as Critically Endangered B2ab (ii,iii,iv,v) because it has an estimated area of occupancy (based on the availability of suitable habitat) of less than 8 km², it occurs as a severely fragmented population, and there is a continuing decline in the quality of its habitat, the number of individuals, and likely in its area of occupancy as a result from pressures on the species and its remaining microhabitat. Our record from the Ica river at San Fernando National Reserve, extends the area of occurrence of *P. sentosus* to 1300 km², as a consequence this species can no longer be considered a Critically Endangered species (<100 km²) according with the criteria B1 of IUCN (2001). The new presented information suggests that the conservation status of *P. sentosus* should be changed to Endangered following the B1ab (ii,iii,iv,v) criteria. However, it is essential to confirm if *P. sentosus* occurs along the coast between Lima and Nasca, and these should be supported by voucher specimens. Until new information about *P. sentosus* distribution is collected, we prefer to be cautious and avoid the negative consequences that could bring to the species a premature change in their conservation status.

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Appendix I.

Phyllodactylus kofordi: PERU: *Lambayeque*: Cerro Huacrupe (05º49'46.7"S, 79°57'5.8"W), 161 m a.s.l., CORBIDI 03588-91; *Piura*: Sechura: Manglares de San Pedro (05°30'48.4''S, 80°53'33.4"W), 0 m a.s.l., CORBIDI 03510-17; Huancabamba: San Jacinto del Tocto (5º43'32.20"S, 79º43'17.60"W), 316 m a.s.l., CORBIDI 14199-202, CORBIDI 14207-09.

Phyllodactylus reissii: PERU: *Lima*: La Molina: Calle Los Agrologos, 200 m a.s.l., CORBIDI 12506; Surco: Calle Santa Rita, 120 m a.s.l., CORBIDI 12813.