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Natural history of coastal Peruvian solifuges with a redescription of *Chinchippus peruvianus* and an additional new species (Arachnida, Solifugae, Ammotrechidae)

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Abstract.   Two species of *Chinchippus* (Ammotrechidae) were studied in central Peru. Both species are endemic to the hyper-arid coastal desert and appear to derive most of their energy and nutrients from maritime prey, such as intertidal amphipods feeding on beach-cast algae or as arthropod scavengers feeding upon seabird and pinniped carcasses. Data on the spatial distribution of the two species were obtained from analyzing stomach contents of one common predator, the gecko *Phyllodactylus angustidigitus*, and suggest that both species are more abundant in insular than in mainland habitats. We redescribe *Chinchippus peruvianus* Chamberlin 1920, known only from a female specimen and describe the male for the first time while *C. viejaensis* is recognized as new. The new species is distinguished from *C. peruvianus* by its darker coloration, smaller size, and differences in cheliceral dentition.

Keywords: Camel spiders, coastal desert, ecology, Gekkonidae, Peru, *Phyllodactylus angustidigitus*, taxonomy

In the process of investigating the ecology of terrestrial organisms in the coastal desert and guano islands of central Peru, we have come across a series of *Chinchippus peruvianus* Chamberlin 1920 and a closely related species. These solifuges, along with other terrestrial predators, thrive in places that could be defined as a barren land of gravel, sand, and granitic outcrops – a moonscape where arachnids and lizards somehow manage to survive, reproduce, and colonize new habitats. The western coast of South America is among the driest places on Earth (Dietrich & Perron 2006), where arid conditions have persisted for the last 14 million years (Alpers & Brimhall 1988). Facing this hyper-arid ecosystem is one of the world's most productive marine ecosystems, the Peru-Chile cold current (Tarazona & Arntz 2001). The stark contrast in productivity promotes the exchange of energy and nutrients between these two adjacent ecosystems, and marine-derived resources subsidize terrestrial predators along the Peruvian coast (Catenazzi & Donnelly 2007a) and in other coastal deserts (Polis & Hurd 1996). In this study we describe the taxonomy and natural history of the two *Chinchippus* species and explore their distribution in relation to the availability of marine-derived resources.

The genus *Chinchippus* was established by Chamberlin (1920) based on a single female from the Peruvian island of Chincha. He considered it to belong to the African family Daesiidae. Roewer (1934) included *Chinchippus* in the ammotrechid subfamily Saronominae based on the segmentation of legs I, II, and IV and the palpal spination. Muma (1976) tentatively included it with the saronomines although its placement was still based on Chamberlin's sole female. Based on Chamberlin's single female, the genus *Chinchippus* can be recognized by: all the legs having a single tarsal segment, no claws on leg I, stridulating ridges on the mesal

surface of the chelicera, lateral plates of the "rostrum" shorter than the median plates, and a recurved cephalothorax.

METHODS

One of us (AC) conducted fieldwork at the Paracas National Reserve (PNR; 13°51′S, 76°16′W), ~19 km S of the Chinchas islands, in the Peruvian Region of Ica (Fig. 1). This reserve protects 335,000 ha of coastal waters and subtropical Peruvian coastal desert, including a variety of arid and hyper-arid terrestrial habitats. The PNR includes the Paracas Peninsula, which forms the southern edge of Paracas Bay, and the islands of Sangayán and La Vieja. The coastal topography is extremely heterogeneous and includes sandy, gravel, pebble and boulder beaches; cliffs; wind-shaped landforms; and uplifted ancient beaches. The climate is characteristic of the arid coastal desert of Peru and northern Chile and receives less than 2 mm of rain per year (Craig & Psuty 1968). Temperatures are mild and range between an average high of 22.9° C in February to an average low of 16.3°C in August (Environmental Resources Management 2002).

Using the methods of Muma (1951), Brookhart & Muma (1981, 1987), Muma & Brookhart (1988), and Brookhart & Cushing (2004), we measured total length; length of palpus, leg I, leg IV; length and width of chelicera and propeltidium; width of base of fixed finger; and length and width of female genital operculum using Spot Basic™ with an Olympus SZX12 microscope at 25× magnification. All measurements are in millimeters. Ratios used previously by Brookhart & Cushing (2002, 2004) were computed. These ratios are as follows: A/CP: the sum of the lengths of palpus, leg I, and leg IV divided by the sum of length of chelicera and propeltidium indicating length of appendages in relation to body size. Long-legged species have larger A/CP ratios. Because there is no fondal notch, the cheliceral width/fixed finger width ratio is used to indicate whether the fixed cheliceral finger of the male is thin or robust in relation to the size of the chelicera. Genital operculum length/genital operculum width represents the

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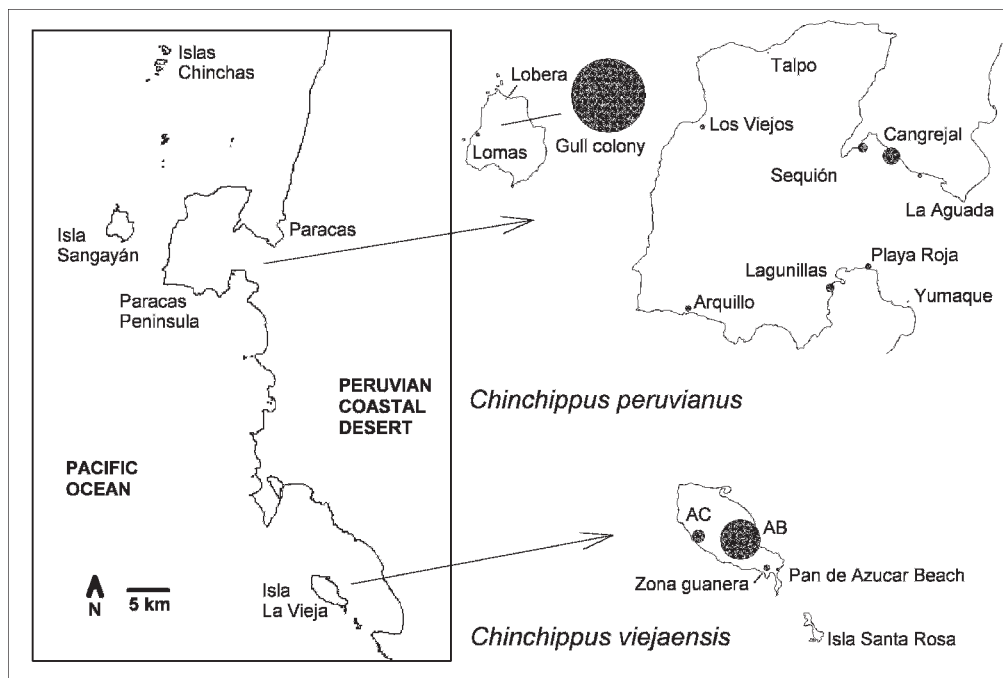
Figure 1.—Map of study localities and spatial variation in the frequency of occurrence of *Chinchippus peruvianus* and *C. viejaensis* in stomach contents of the gecko *Phyllodactylus angustidigitus* at Isla Sangayán (3 sites), the Paracas Peninsula (10 sites) and Isla La Vieja (4 sites), central Peru. The diameter of circles represents frequency of occurrence ranging from 0% (Yumaque, Paracas Peninsula) to 100% (gull colony, Isla Sangayán).

relative size of the female genital operculum in terms of length and width. Species determinations were based on a combination of color comparisons, the shape and dentition patterns of the male chelicerae, palpal setation, and color patterns of the propeltidium, palpus, and legs. The shape of the female chelicerae and the female genital operculum margin were observed using the method of Brookhart & Cushing (2004). Cheliceral dentition patterns were based on the method of Maury (1982) in which, for example, PT-1-2-AT indicates one primary tooth, two intermediate teeth, and one anterior tooth.

Collections from which material was borrowed or deposited include the Museum of Comparative Zoology at Harvard University, Cambridge, Massachusetts, USA (MCZ); the Museo de Historia Natural, Universidad Nacional Mayor de San Marcos, Lima, Peru (MUSM); and the Denver Museum of Nature and Science, Denver, Colorado, USA (DMNS).

We collected solifuges by using pitfall traps or by opportunistically collecting during nocturnal walks. We used pitfall traps consisting of plastic cups 9 cm in diameter and 10 cm deep filled with a mix of water and detergent along the southern end of Paracas Bay between 6–9 January and 6–11 April 2003. During the January trapping, a series of three pitfall traps were placed near sandy/muddy beaches in coastal dunes and the adjacent desert at 5, 10, and 15 m distance from shore. During the April trapping, we placed pitfall traps near shelly beaches along transects at 0, 0.1, 1, 10 and 100 m from shore. We installed three transects, each one composed of three lines of pitfall traps. In addition to pitfall trapping, we also counted and measured solifuges in 90 1-m^2 plots in the

intertidal zone in March 2003. Count data of the March and April trapping period were reported by Catenazzi & Donnelly (2007a). Here we report count data from the January trapping, as well as solifuge size-distribution data from the March trapping along the shelly beach. Means are reported ± SE and statistical tests are considered significant at $P < 0.05$.

We include anecdotal observations on predators, prey, and behavior of solifuges observed in the field. Some of these observations were captured in photographs and video and are available online at http://acatenazzi.googlepages.com/chinchippus.

We relied upon stomach content examinations of the gecko *Phyllodactylus angustidigitus* Dixon & Huey 1970, a common and ubiquitous reptile in the coastal desert, to better understand the distribution of solifuges in the coastal desert of the Paracas Peninsula and the islands of Sangayán and La Vieja. These geckos feed opportunistically on any live terrestrial arthropod of appropriate size, including beach hoppers, centipedes, arachnids, and insects (Catenazzi & Donnelly 2007a), and do not masticate their prey, facilitating the task of identifying prey remains in the stomachs. Stomach contents were obtained by inserting a small catheter through the esophagus and by flushing the geckos' stomachs with water (Catenazzi & Donnelly 2007a). Stomach contents ($n = 814$) were collected from Isla La Vieja (4 sites), Isla Sangayán (3 sites), and the Paracas Peninsula (10 sites). We considered whole prey items only to calculate frequency of occurrence of *Chinchippus* prey with respect to number of geckos sampled and with respect to total number of prey items in all pooled stomach contents.
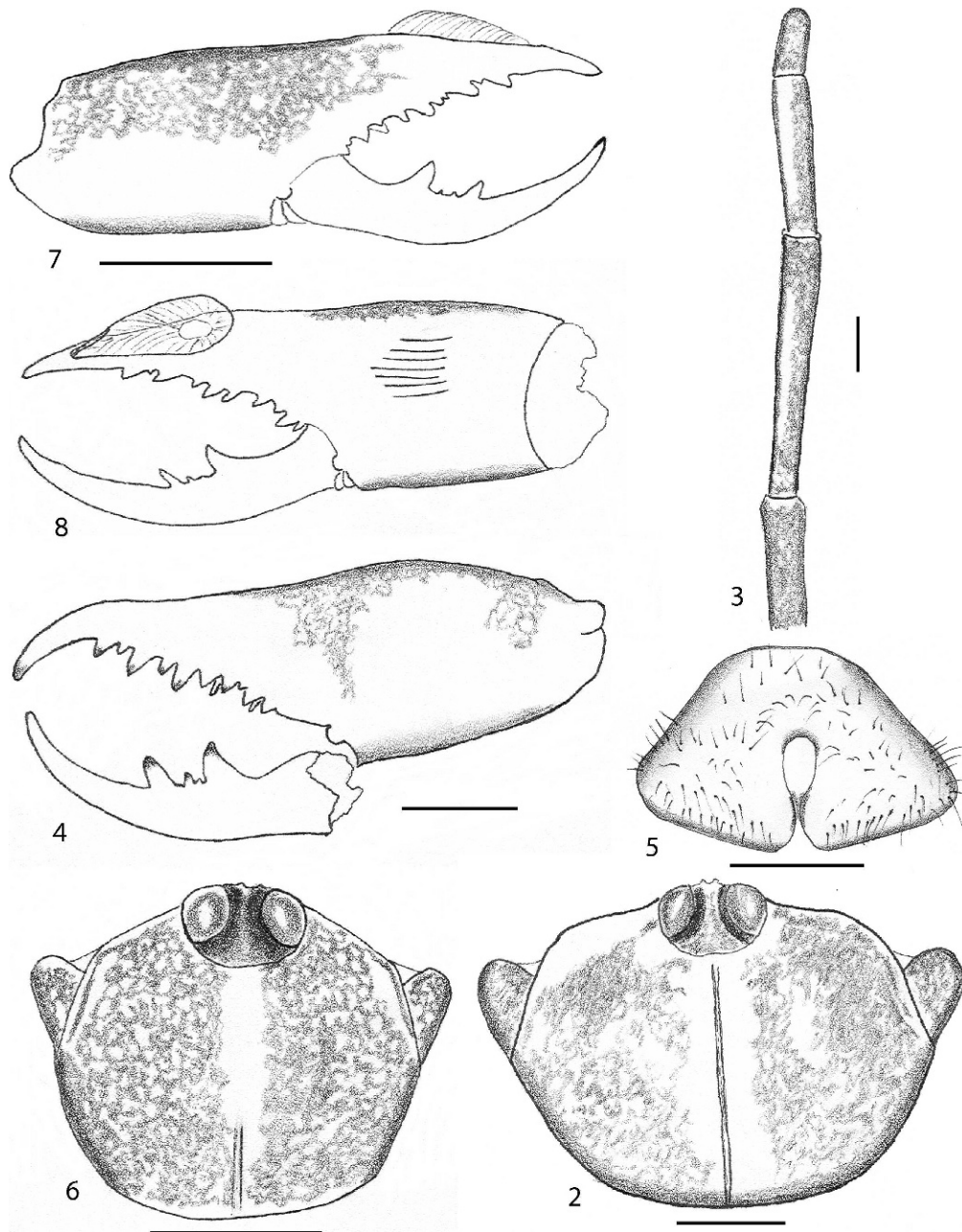
Figures 2–8.—*Chinchippus peruvianus*. 2–5. Female holotype, Peru: Ica: Islas Chinchas, 26 October 1919, R. C. Murphy (MCZ 519): 2. Propeltidium, dorsal; 3. Palp, dorsal ; 4. Right chelicera, ectal; 5. Genital operculum, ventral. 6–8. Male, Peru, Cangrejal, 25 March 2003, A. Catenazzi: 6. Propeltidium, dorsal; 7. Right chelicera, ectal; 8. Right chelicera, mesal. Scale bars = 1 mm.

TAXONOMY

Family Ammotrechidae Roewer 1934
Subfamily Saronominae Roewer 1934
Genus *Chinchippus* Chamberlin 1920
Chinchippus peruvianus Chamberlin 1920
(Figs. 2–8)

Chinchippus peruvianus Chamberlin 1920:36–37.

Material examined.—*Type:* PERU: *Ica Region*: female holotype, Islas Chinchas (13°37′37″S, 76°23′21″W), 26 October 1919, R.C. Murphy (MCZ 519).

Other material: PERU: *Ica*: Paracas Bay: 2 ♀ (1 from the stomach content of *Phyllodactylus angustidigitus*), Cangrejal (13°51′03″S, 76°17′08″W, 1 m elev.), 3 March 2003, A. Catenazzi (DMNS); 2 ♂ same data except 25 March 2003, A. Catenazzi (DMNS); 2 ♀, La Aguada (13°51′44″S, 76°16′15″W, 2 m elev.), 7 January 2003, A. Catenazzi (DMNS); 1 ♂, Museo de Paracas Julio C. Tello (13°52′00″S, 76°16′26″W, 13 m elev.), 25 March 2003, A. Catenazzi (DMNS).

Diagnosis.—*Chinchippus peruvianus* is larger and lighter than *C. viejaensis* and differs by cheliceral dentition (compare Figs. 7 and 11).

Figure 9.—Habitus of *Chinchippus viejaensis*. Male (left), female (right).

Description.—*Female holotype*: Color: Overall color as described by Chamberlin (1920): chelicera mottled violet-brown; propeltidium violet-brown with a pale creamy light ovate area highlighted by a lighter median band extending from eye tubercle to posterior end of propeltidium; eye tubercle dark (Fig. 2); mesapeltidium, metapeltidium white; abdomen creamy yellow with a median mottled violet-brown stripe dorsally and creamy grey laterally and dorsally; palp darker on tarsus and femur, metatarsus and tibia pale to white, coxa creamy yellow (Fig. 3). Legs II, III, IV light, violet-brown on tarsus, metatarsus, and apical parts of the tibia, darker on distal end of tibia as in femur, coxa creamy white. Leg I creamy white except for femur, which is a light violet; malleoli white.

Chelicera: fondal teeth graded III, I, IV, II; Fixed finger teeth arranged 1-PT-1-MT-1-AT; movable finger teeth arranged PT-1-2-AT (Fig. 4; however, Chamberlin illustrates PT-1-AT). Six to seven stidulatory ridges on the meso dorsal aspect of the chelicerae.

Palp: tarsus/metatarsus ratio 3:1.

Legs: leg IV tarsus with ventral paired setae arranged 2-2-2-2-2-1.

Abdomen: genital operculum: clavate with anterior arms thick, median edge recurved forming a deep central cavity accessing the genital opening, posterior edge straight (Fig. 5).

Male: Color: color pattern, including appendages, the same as in the female except the median pale stripe extends only from the posterior third of the propeltidium towards the ocular tubercle (Fig. 6); chelicera mottled dorsally and ectally coalescing anteriorly (Fig. 7); pale ventrally; malleoli white.

Chelicera: fondal teeth graded I-III-II-IV ectally and I, III, II mesally; fixed finger teeth arranged PT-1-2-MT-1-AT; movable finger teeth arranged PT-1-2-AT (Figs. 7, 8). Flagellum a broadly elliptical structure attached to the fixed finger above the primary tooth, slightly to the dorsal edge. The attachment appears to be a concave structure. No setae or fringes are seen on the edges of the flagella. It bears some resemblance to the flagella of *Saronomus capensis* (Kraepelin 1899) (Maury 1982:127–130, figs. 1–8). Six to seven stridulatory ridges on the mesal dorsal aspect of the chelicerae (Fig. 8).

Palpus: tarsal/metatarsal ratio of 3.4:1 (Fig. 3).

Legs: all legs with a single tarsal segment; leg I with no claw and slightly enlarged (bulbous) tarsus; leg IV with ventral spination of 2-2-2-2-2-1.

Dimensions.—*Female holotype*: total length 10.0, cheliceral length 5.0, cheliceral width 1.7, propeltidium length 1.75, propeltidium width 3.15, palpus length 10.0, first leg length 8.0, fourth leg length unknown (damaged). Ratios: A/CP (cannot be computed), genital operculum length/width 0.5.

Females (n = 4): total length 12.0–16.0, cheliceral length 4.4–4.85, cheliceral width 1.37–1.65, propeltidium length 1.8–2.2, palpus length 12.0–16.0, first leg length 10.0–11.0, fourth leg length 16.0–20.0. Ratios: A/CP 7.26–7.48.

Males (n = 3): total length 12.5–13.5, cheliceral length 2.5–2.7, cheliceral width 0.88–0.99, propeltidium length 1.7–1.75, propeltidium width 1.8–2.2, palpus length 12.5–13.5, first leg length 9.0, fourth leg length 17.0–19.0. Ratios: A/CP 10.3–11.7.

Chinchippus viejaensis new species
(Figs. 9–14)

Material examined.—*Types*: PERU: *Ica Region*: male holotype, Isla La Vieja, Reserva Nacional de Paracas,
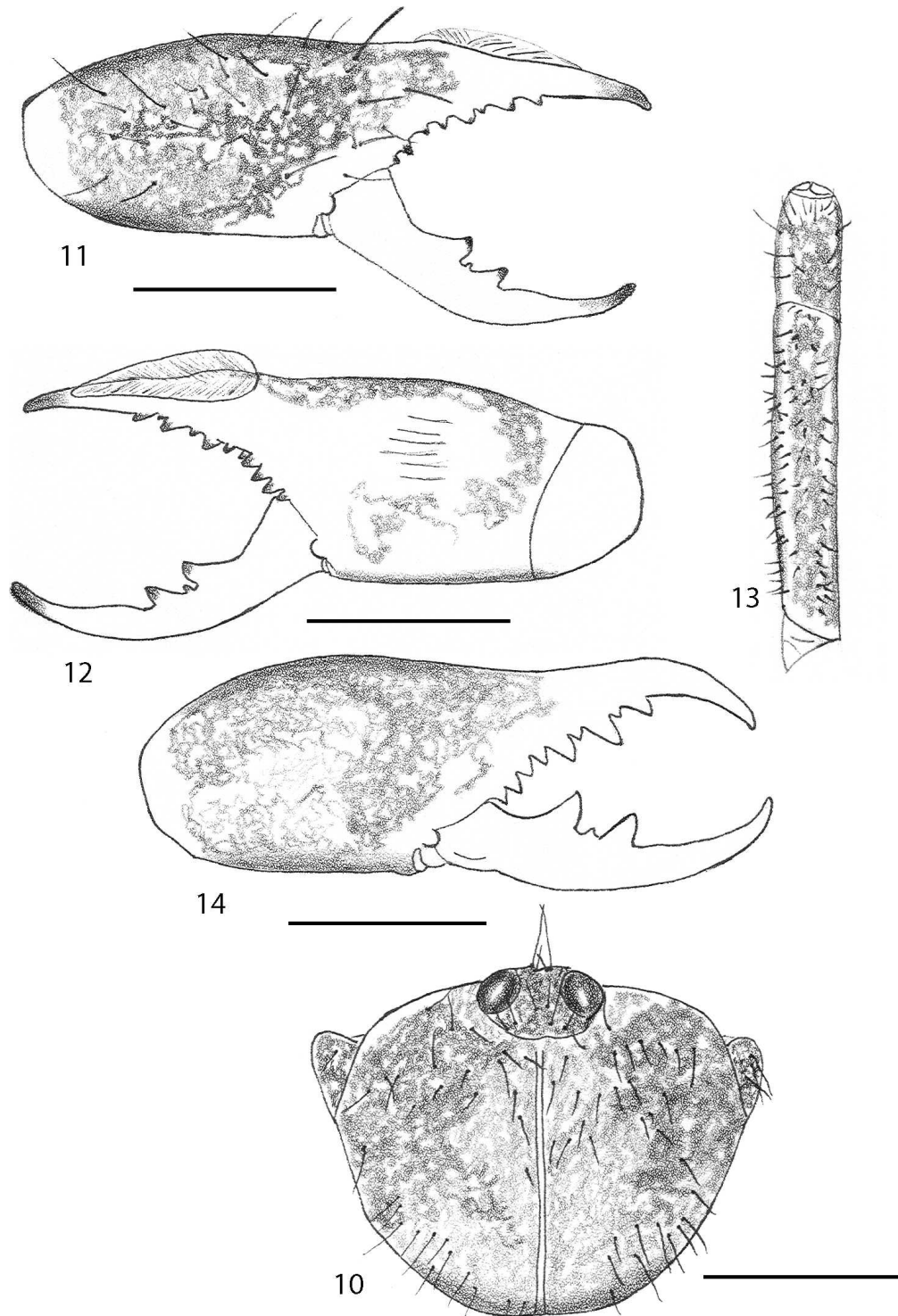
Figures 10–14.—*Chinchippus viejaensis*. Male holotype and female allotype, Peru: Isla La Vieja, 15 September 2003, A. Catenazzi. 10–13. Male holotype: 10. Propeltidium, dorsal; 11. Right chelicera, ectal; 12. Right chelicera, mesal; 13. Palpal tarsus, metatarsus, dorsal. 14. Female allotype, right chelicera, ectal. Scale bars = 1 mm.

14°26′28.4″S, 76°12′28.4″W, 230 m, 15 September 2003, A. Catenazzi (DMNS). Allotype female collected with holotype (MUSM).

Etymology.—Named for the type locality, Isla La Vieja, Peru.

Diagnosis.—This species can be differentiated from *C. peruvianus* by its darker coloration, smaller size, and differences in cheliceral dentition (compare Figs. 7 and 11).

Description.—*Male holotype*: Color: pale mottled violet to dark violet-brown overall; palpal tarsus, metatarsus, tibia, and

Table 1.—Average number of *Chinchippus peruvianus* captured per pitfall trap near sandy and muddy beaches at Paracas Bay between 6–9 January 2003. Position = distance from the mean high tide level. Traps = number of pitfall traps. No males were captured in pitfall traps.

Position	Traps	Females	Immatures
5 m	27	0.11 ± 0.06	0.04 ± 0.04
10 m	27	0.07 ± 0.05	—
15 m	27	0.07 ± 0.05	0.04 ± 0.04
Total	81	0.09 ± 0.03	0.02 ± 0.02

apical two thirds of the femur dark violet-brown dorsally, creamy white ventrally; legs I and II dusky brown and violet-brown at the tibia-femur; legs III and IV violet-brown dorsally on tibia, fibula, and apical portion of tarsus; propeltidium darker violet-brown with a very pale ovate area and a median thin, pale stripe extending from eye tubercle to the posterior of the propeltidium (Figs. 9, 10); chelicerae mottled violet-brown (Figs. 9, 11); abdomen with dorsal violet-brown patches on each sternite dorsally (Fig. 9); malleoli white.

Chelicera: fondal teeth three of equal size, fixed finger dentition 1-P-M-1-A, movable finger dentition P-1-A. Six to seven stridulatory ridges found on posterior mesal surface of chelicerae (Figs. 11, 12). Flagellum of *C. viejaensis* similar to *C. peruvianus* with a slightly narrow anterior opening and perhaps a more medial attachment above the primary tooth. No setae or fringe is visible. The cheliceral dentition pattern shows some similarity to *Ammotrechula gervaisii* (Pocock 1895) (Roewer 1934:600) but has no mesal tooth and no fringed flagellum. Palpus: metatarsus/tarsus ratio 3:1; no spine-like setae (Fig. 13).

Legs: leg I with no claw; leg IV with 2-2-1 spine-like setae on the ventral aspect of the tarsus and 2-2-1-1 on the metatarsus.

Female allotype: Color: very similar to the male with the abdominal tergites a lighter color (Fig. 9). The median pale ovate area of the propeltidium is lighter in the female. Leg III femur creamy white.

Chelicera: fixed finger dentition P-1-M-1-A; movable finger P-1-A; fondal teeth III, I, II, IV ectally and mesally; 5–6 stridulatory ridges on the dorsal mesal aspect (Fig. 12).

Palps: metatarsi/tarsi ratio of 2.5:1.

Legs: leg IV with 2-2-1 spine-like setal pattern on ventral aspect of the tarsus and 2-2-1-1 on the metatarsus.

Abdomen: genital operculum similar to *C. peruvianus* with a deep central cavity forming the entrance to the genital orifice.

Dimensions.—*Male holotype*: length 10.0, cheliceral length 2.35, cheliceral width 0.97, propeltidium length 1.54, propeltidium width 2.02, palpus length 10.0, first leg length 7.0, fourth leg length 8.0. Ratios: A/CP 6.84. *Female allotype*: total length 11.0, cheliceral length 2.75, cheliceral width 1.04, propeltidium length 1.51, propeltidium width 2.27, palpal length 7.0, first leg length 6.0, fourth leg length 6.5. Ratios: A/CP 5.64.

TAXONOMIC REMARKS

Previous to this study, *Chinchippus* was a monotypic genus based on a single female specimen. The identification of the associated male and a second species supports Chamberlin's (1920) erection of this genus. These two species are in the subfamily Saronominae based on tarsal segmentation of the
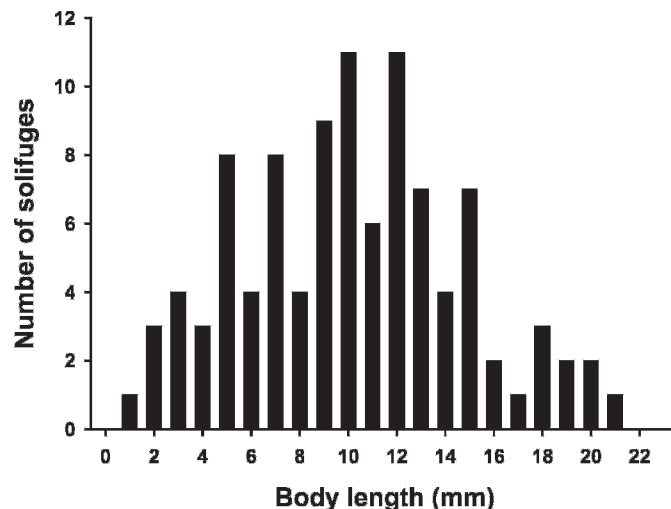

Figure 15.—Size distribution of *Chinchippus peruvianus* (*n* = 101 individuals) at Cangrejal, Paracas Bay, Peru between 26–28 March 2003.

4th leg and the flagellar structure. These characters differentiate the species in the Saronominae from all species currently placed in the Ammotrechinae. The genital opercula of the two species of *Chinchippus* are very similar and differ from other members of the subfamily Saronominae or Ammotrechinae.

ECOLOGICAL RESULTS AND DISCUSSION

Chinchippus peruvianus.—Murphy (1925) collected the holotype in a building of the Compañia Administradora del Guano on the Islas Chinchas and reported that individuals hunt for invertebrates attracted to a light source at night. We made most of our collections and observations on the natural history of *C. peruvianus* at the Paracas Peninsula and on Isla Sangayán. The species appeared to be extremely abundant along a 2 km stretch of shelly beach near the southern end of Paracas Bay (Catenazzi & Donnelly 2007a, b), where individuals could easily be found by lifting rocks, empty shells, and dried marine wrack near shore. At Isla Sangayán, we observed *C. peruvianus* under rocks and carcasses of South American sea lions (*Otaria flavescens* Péron 1816).

Results of the January pitfall trapping near sandy/muddy beaches of Paracas Bay (Table 1) suggest that *C. peruvianus* was more frequent along shelly beaches (see results in Catenazzi & Donnelly 2007a) than it was along sandy or muddy beaches (see below for data from gecko stomach content analyses in support of this hypothesis). Body length distribution for individuals captured on shelly beaches during March 2003 (Fig. 15) averaged 9.4 ± 0.4 mm for the population including immatures (*n* = 101); the maximum body length was 20.2 mm for a female.

Chinchippus peruvianus was found in stomach contents of *P. angustigitus* from most sites in the Paracas Peninsula and from all sites on Isla Sangayán (Tables 2, 3; Fig. 1). Note that the site with 100% frequency of occurrence of *C. peruvianus* (gull colony on Sangayán) was based on the stomach contents of only three geckos. At the Paracas Peninsula, near-shore sites along Paracas Bay and Lagunillas Bay had the highest frequencies of occurrence, possibly because of the large amount of beach-cast macro-algae supporting abundant

Table 2.—Spatial variation in the frequency of occurrence of *Chinchippus peruvianus* in stomach contents of the gecko *Phyllodactylus angustidigitus* in 10 sites of the Paracas Peninsula, Peru between March and December 2003. See Fig. 1 for site locations. Geckos = number of stomach contents examined; Occurrence = frequency of *C. peruvianus* in the geckos' stomach contents; Prey items = number of all prey items in the geckos' stomach contents; Frequency = frequency of *C. peruvianus* relative to the number of prey items.

Site	Geckos	Occurrence	Prey items	Frequency
Paracas Peninsula				
Cangrejal	127	22.8% (29)	607	5.8% (35)
La Aguada	43	4.7% (2)	383	0.5% (2)
Sequión	33	12.1% (4)	218	1.8% (4)
Yumaque	17	— (0)	81	— (0)
Talpo	41	— (0)	171	— (0)
Lagunillas	41	9.8% (4)	235	2.1% (5)
Playa roja	24	8.3% (2)	166	1.2% (2)
Los Viejos (beach)	54	— (0)	421	— (0)
Los Viejos (desert)	38	5.3% (2)	96	2.1% (2)
Arquillo	18	5.6% (1)	123	0.8% (1)
Isla Sangayán				
Lobera	178	1.1% (2)	1408	0.2% (3)
Gull colony	3	100.0% (3)	65	20.0% (13)
Lomas	27	3.7% (1)	164	0.6% (1)
Total	644	7.8% (50)	4138	1.6% (68)

populations of intertidal arthropods and/or because these beaches were easily accessible to both solifuges and geckos. Frequencies of occurrence were low at coastal sites near cliffs (Arquillo, Yumaque, Playa Roja) or sites that are exposed to the ocean (Los Viejos, Talpo), similarly to distribution patterns found in *P. angustidigitus* geckos (Catenazzi & Donnelly, unpublished data). *Chinchippus peruvianus* readily excavates burrows in fine sand when disturbed. The burrowing behavior included biting, raking, and plowing sand at irregular intervals. However, *C. peruvianus* was also found in pebble beaches and in coarse soil where other microhabitats replace burrows (e.g., dried macroalgae, sea lion and seabird carcasses; A. Catenazzi pers. obs.).

Other species of South American solifuges seem to be associated with vegetation cover and soil characteristics: for example Xavier & Rocha (2001) detected a preference of *Mummucia mauryi* Rocha (in Xavier & Rocha 2001) for areas covered by *Opuntia inamoena* (Cactaceae) during the dry season, whereas Rocha & Carvalho (2006) and Martins et al. (2004) noted that white sandy soils where solifuges can easily excavate their burrows may facilitate colonization by *Mummucia taiete* Rocha & Carvalho 2006 and *M. coaraciandu*

Pinto-da-Rocha & Rocha 2004 respectively. In the case of *C. peruvianus* (as well as *C. viejaensis*, see below), vegetation cover is unlikely to explain distribution patterns because it is extremely scarce and absent at most sites. Island and coastal habitats colonized by the two *Chinchippus* also differ widely in soil types (A. Catenazzi, pers. obs.; see habitat descriptions). The higher frequency of occurrence of these solifuges in places that receive marine-derived energy and nutrients, such as beaches with stranded marine macroalgae colonized by arthropods or insular seabird colonies with arthropod scavengers and ectoparasites suggests that food availability in the hyper-arid Peruvian coastal desert may explain distribution patterns.

Seasonal activity can be inferred from results of the geckos' stomach contents, by assuming that the feeding preference of geckos did not vary seasonally. Solifuges at Paracas Bay were most frequent in the geckos' stomachs during the austral summer (Table 3), and their frequency of occurrence with respect to the total number of prey items from March to December 2003 (including data from December 2004) followed a polynomial curve ($y = 0.42x^2 - 6.8x + 27.7$, $R = 0.81$) with a minimum predicted value for August (0.3%

Table 3.—Seasonal variation in the frequency of occurrence of *Chinchippus peruvianus* in stomach contents of the gecko *Phyllodactylus angustidigitus* at Paracas Bay, Peru during March–December 2003. See Fig. 1 for site location and Table 2 for table headings; * includes 15 stomach contents collected in December 2004.

Month	Geckos	Occurrence	Prey items	Frequency
March	12	25.0% (3)	40	10.0% (4)
April	35	20.0% (7)	130	7.7% (10)
May	43	18.6% (8)	176	5.7% (10)
June	27	18.5% (5)	188	2.7% (5)
July	9	—(0)	35	— (0)
August	16	6.3% (1)	143	0.7% (1)
September	3	— (0)	89	— (0)
October	8	25.0% (2)	65	3.1% (2)
November	13	— (0)	112	— (0)
December*	19	26.3% (5)	55	9.1% (5)
Total	170	18.2% (31)	990	3.7% (37)

Table 4.—Spatial variation in the frequency of occurrence of *Chinchippus viejaensis* in stomach contents of the gecko *Phyllodactylus angustidigitus* in four sites of Isla La Vieja, Peru. See Fig. 1 for site locations and Table 2 for table headings.

Site	Geckos	Occurrence	Prey items	Frequency
AB	22	54.5% (12)	449	3.6% (16)
AC	19	15.8% (3)	96	3.1% (3)
Pan de Azúcar				
Beach	36	2.8% (1)	224	0.4% (1)
Zona guanera	14	7.1% (1)	182	0.5% (1)
Total	91	18.7% (17)	951	2.2% (21)

frequency of occurrence). This seasonal activity contrasts with the phenology described by Martins et al. (2004) for *M. coaraciandu* in the Brazilian Cerrado, where surface activity based on pitfall traps was negatively correlated with monthly temperature. However, higher temperatures in the Cerrado were associated with higher rainfall, which could also influence solifuge activity. Rainfall in Paracas is negligible throughout the year, but average night temperatures can be low in the austral winter and could limit solifuge activity.

The diet of *C. peruvianus* is dependent upon marine sources of energy and nutrients. In the case of supratidal populations, such as those in Paracas Bay (Tables 3 and 4), solifuges rely on intertidal algivores for their diet (Catenazzi & Donnelly 2007a). The beach hopper *Transorchestia chiliensis* (Amphipoda, Talitridae) was the most common prey item based on field observations (5 out of 10 feeding events). Analyses of stable carbon isotopes also suggested that these beach hoppers were an important prey item for *C. peruvianus* (Catenazzi & Donnelly 2007a, b).

Insular solifuge populations likely feed on ectoparasites and other arthropods found in detritus or on the carcasses of seabirds and pinnipeds because the Islas Chinchas (type locality of *C. peruvianus*) are entirely devoid of vegetation, and Isla Sangayán has scant vegetation that occupies a tiny fraction of the island (the site Lomas in Fig. 1); both islands are mostly cliff-bound. For solifuge populations near the *Otaria flavescens* colony on Isla Sangayán (site Lobera in Fig. 1), arthropod scavengers of pinniped carcasses are likely to be important dietary items, as suggested by the high carbon and nitrogen stable isotope values (albeit only two individuals were analyzed, with $\delta^{13}C = -14.64‰$ and 14.89‰ and $\delta^{15}N = 24.33‰$ and 25.58‰; A. Catenazzi, unpubl. data). Nitrogen isotopic values increase on average by 3.4‰ for each trophic interaction and therefore can be used to estimate the trophic position of an organism (Post 2002). Nitrogen isotopic values of *O. flavescens* on Sangayán average $17.44 \pm 0.35‰$ (Catenazzi & Donnelly 2008); therefore, isotopic values of *C. peruvianus* are consistent with the idea that solifuges feed on scavengers of *O. flavescens*; (i.e., that they are two trophic positions above *O. flavescens*).

Natural predators of *C. peruvianus* at the Paracas Peninsula and Sangayán include, in addition to *P. angustidigitus*, the scorpion *Brachistosternus ehrenbergii* (Gervais 1841), the spider *Odo* sp. (Zoridae), as well as conspecific individuals. Cannibalism is likely to be common, because these solifuges occur at high density in the first meters from shore. We observed cannibalism in the field on two occasions, and all captive encounters of pairs of *C. peruvianus* resulted in one individual devouring the other one.

The tsunami that followed a 7.8 magnitude earthquake on 15 August 2007 modified the coastal landscape in Paracas Bay. High waves removed many of the supralitoral dunes where *C. peruvianus* specimens had been collected for this study. It is possible that the flooding of the supratidal areas caused a decline in local populations because Catenazzi & Donnelly (2007a) noted that most *C. peruvianus* are found in the supratidal zone within 1 m from the high mean tide level. However, *C. peruvianus* could recolonize supratidal areas from sections of beach that were protected from the tsunami by a steeper slope of the beach and/or by the presence of rocks and other topographic features.

Chinchippus viejaensis.—This species has only been collected from Isla La Vieja (also called Isla Independencia) in central Peru. This island (area 60.86 ha) is located in Independencia Bay, approximately 6 km west of the mainland and 1.6 km north of a smaller island, Santa Rosa (Fig. 1). Both La Vieja and Santa Rosa are guano islands where hundreds of thousands of seabirds, mainly guanay cormorants (*Phalacrocorax bougainvillii* Lesson 1837) and Peruvian boobies (*Sula variegata* Tschudi 1843), used to congregate. At the time of our visits between July and November 2003, La Vieja did not have any breeding colony of these two guano bird species. However, the upper parts of the island were interspersed with nests of kelp gulls (*Larus dominicanus* Lichtenstein 1823) and Peruvian diving-petrels (*Pelecanoides garnotii* Lesson 1828). Most specimens of *Chinchippus viejaensis* were collected in pitfall traps and stomach contents of the gecko *P. angustidigitus* from a small ridge on the southern slope of the island (type locality, site AB on Fig. 1). The slope measures ~12° and is exposed towards the south. The ground is covered with coarse pebbles (16–32 mm grain size) interspersed with a few granitic outcrops. No plants grow along the ridge or neighboring areas; however, a thin lichen crust covered some rocks along the top of the ridge. Predominant winds carry ocean aerosols and moisture towards the ridge, which may explain the presence of lichens in an otherwise unproductive environment. During our November visit, we observed many nests of kelp gulls; most nests had been built between rocks along the ridge.

Based on our observations, we can document predation of this solifuge by *P. angustidigitus* only. *Chinchippus viejaensis* was found in 18.7% of the gecko stomach contents from the entire island, and in 54.5% (12 in 22) of the stomach contents collected at the AB site (Fig. 1, Table 4). Additional sampling locations (Fig. 1) included the western slope of the island (site AC), the beach near Pan de Azúcar, and the guano area north of Pan de Azúcar. Site AC is similar to site AB in being a barren slope with granitic outcrops and seabird nests. However, this slope is steeper (19°) and exposed to the west. The ground is composed of fine to medium pebbles with some large rocks and several granitic outcrops. Subterranean nests of Peruvian diving-petrels occupy areas of very fine pebbles and coarse sand, whereas nests of kelp gulls (much less frequent than at the AB site) are located among rocks in the granitic outcrops, along with very few plants of *Solanum murphyi* I.M. Johnst. (four plants within a 2.25-ha quadrant plot). The beach near Pan de Azúcar is made of coarse pebbles

Table 5.—Seasonal variation in the frequency of occurrence of *Chinchippus viejaensis* in stomach contents of the gecko *Phyllodactylus angustidigitus* at Isla La Vieja, Peru. See Fig. 1 for location and Table 2 for table headings.

Month	Geckos	Occurrence	Prey items	Frequency
July	35	14.3% (5)	403	1.2% (5)
September	38	18.4% (7)	376	2.4% (9)
November	18	27.8% (7)	172	4.1% (7)
Total	91	18.7% (17)	951	2.2% (21)

frequently littered with marine wrack including kelp and crustacean carcasses. The ground adjacent to the beach is a gentle slope that abuts on a shallow depression to the northwest of Pan de Azúcar beach. Much of this slope had been used by guanay cormorants and Peruvian boobies for nesting ground because at the time of our visit, the ground was covered with ~30 cm of guano. Similarly, guano birds once occupied the guano area to the north of the mentioned shallow depression.

It is likely that invertebrates feeding upon seabirds or consuming detritus associated with seabird activity (e.g., regurgitates, feathers, guano, etc.) are important prey items for this solifuge species because the extreme aridity and scant primary productivity of the island supports very few herbivores. In support of this hypothesis, the occurrence and frequency of *C. viejaensis* in the gecko stomach contents almost doubled at the onset of the breeding season of kelp gulls in November (Table 5).

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