

# Discovering insect species based on photographs only: The case of a nameless species of the genus *Scaria* (Orthoptera: Tetrigidae)

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## Abstract

A heated debate on whether a new species should be described without a physical specimen, i.e., by designating a photographed specimen to serve as a holotype, has been ongoing for a long time. Herewith, without nomenclatural actions, a new species of the Batrachidein pygmy grasshoppers belonging to the genus *Scaria* Bolívar, 1887 is identified from the Andean rainforest in Peru. This species is clearly different from all its congeners by morphology and coloration. Two individuals of this peculiar species are known only from the photographs found on iNaturalist. The species has not been observed since 2008 when the photographs were taken. A short historical overview of the topic is given, illustrating the pros and cons of photograph-based species description. The concepts of names, holotypes, research effort, and conservation are discussed and related to the problem at hand. The current state of the taxonomic community's beliefs regarding this issue is reflected by the authors' three unsuccessful attempts to name this new species.

## Keywords

Amazon, conservation, new species, Orthoptera, Peruvian Yungas, photography-based taxonomy, pygmy grasshopper, the ICZN

## Introduction

Describing species from photographs or illustrations is not a common practice, but it has been done a number of times (Fricke and Kacher 1982, Welch et al. 1986, Jonkers and Roersma 1990, Wallach and Jones 1992, Jones et al. 2005, Sinha et al. 2005, Robb et al. 2013, Cheng et al. 2015, Marshall and Evenhuis 2015, Ingrisch et al. 2016, Lonsdale and Marshall 2016, Nardelli 2016). Most of the names based on photographs are valid, but exceptions do exist (for an extensive historical overview of this practice, see Krell and Marshall (2017)). Some of these publications have sparked a debate about the validity of describing species in this way. The following paragraphs provide a brief overview of the current state of the debate. Some authors (Timm and Ramey 2005,

Santos et al. 2016) have implied that the International Code of Zoological Nomenclature (ICZN 1999) prohibits naming a species without a physical holotype, which is not correct (see Discussion).

While Marshall and Evenhuis (2015) agree that collecting specimens is “highly desirable” as it allows for consideration of their internal morphology, microscopic and genetic characters and preservation of data for future access, they argue that, in certain cases, the specimens cannot be preserved and are getting harder to come by due to rigorous restrictions on collecting and transporting biological material, finally concluding that “collecting specimens is highly desirable, but it is indeed no longer required” because there is a growing number of high-quality photographs of taxa made by “digital collectors.” A prediction is made that “this situation will inevitably force the biodiversity community to adapt to growing numbers of new taxa recognized without benefit of dead, preserved type specimens” (Marshall and Evenhuis 2015). Löbl et al. (2016) consider such a practice dangerous, as it promotes quick capturing of visual data instead of careful observation. They fear that works describing taxa based on an incomplete set of characters (i.e., photographs) may encourage non-experts to try to publish their works, harming the whole field of taxonomy as a result. These fears are considered unfounded by Shatalkin and Galinskaya (2017), as there are indeed very rigid requirements (ICZN 1999) for describing species from photographic evidence. Marshall and Evenhuis (2015) cite Minter et al. (2014) in claiming that “collecting specimens is no longer required to describe a species...” The work in question, though, presents a limited set of examples (birds, amphibians, and plants) where scientists played a role in the extinction of those animals and suggests using alternative means of sampling endangered species through high-resolution photography, audio recording, and nonlethal sampling. The case has never been made for insects, and Marshall and Evenhuis (2015) themselves agree that such a case would be difficult to make. Whether the cases illustrated by Minter et al. (2014) even represent the issue was called into question by Krell and Wheeler (2014), but this is beyond the scope of our paper. Löbl et

al. (2016) suggested publishing information about the existence of a new species without naming it. This is certainly possible but effectively discouraged due to the difficulty of finding a journal that would publish such a finding (Amorim et al. 2016). Having exhausted all the alternatives, we do exactly that.

Amorim et al. (2016) also suggest that, while being a fine addition to the process of describing a species, photographic evidence cannot replace the usual process of “collecting, preparing, comparing, describing, and delimiting species, that allows identifications (which are always hypotheses) to be double-checked.” We agree with this view but also feel the need to claim that there are and should be certain exceptions where blindly following this protocol could rob the scientific community of valuable knowledge. The immense administrative complexity of establishing a new species based on photographs has prevented us from doing so. An example to illustrate how photography-based taxonomy may introduce chaos is *Presbytis johnaspinalli* Nardelli, 2015, a new monkey species in the subfamily Colobinae, described from pictures of caged animals found on the Internet (Nardelli 2015). The morphological characters provided were not sufficient to clearly differentiate it from similar species, and some (Nijman 2015) have even suggested that the monkeys were bleached by the traders who were trying to make them more visually appealing. Nardelli (2016) responded to the criticism, defending his claims, but the status of *Presbytis johnaspinalli* remains unclear. In the case of *Scaria* sp., it is clear that this is a hitherto unknown species.

In this paper, we describe an unnamed species of a pygmy grasshopper (family Tetrigidae, subfamily Batrachideinae Bolívar, 1887), belonging to the tribe Batrachideini and genus *Scaria* Bolívar, 1887 (according to Cigliano et al. 2020) based on two photographs posted on the iNaturalist website by one of the authors (Roberto Sindaco; <https://www.inaturalist.org/observations/9968031>) and three previously unpublished photographs taken by Roberto Sindaco at the same time as the original two. The photographs, taken in August 2008 in Peru (Fig. 1), were posted in 2018, and the specimens photographed were identified by the senior author as a new species belonging to the subfamily Batrachideinae. Since the photographs were posted, no one has described the species, nor has there been another recorded sighting of it. Differences in morphology observed from the five photographs may be sufficient to propose a new species within the genus *Scaria* Bolívar, 1887. Despite that, we decide not to establish one. The taxonomic community does not accept photography-based taxonomy for reasons developed above. This is proven by rejections of this very manuscript when the naming of the species was included. Thus, this study aims to report an interesting unknown *Scaria* without nomenclatural actions. The specimens of the unnamed species were found in Peru (Bongará Province, Department of Amazonas, Peru), which is a part of the Neotropical biogeographic region. This area is home to an astonishing number of animal and plant species (Elton 1973), owing such diversity to favorable environmental factors and long evolutionary history (Condon 2008). Considering these facts, it is clear that there is a wealth of species

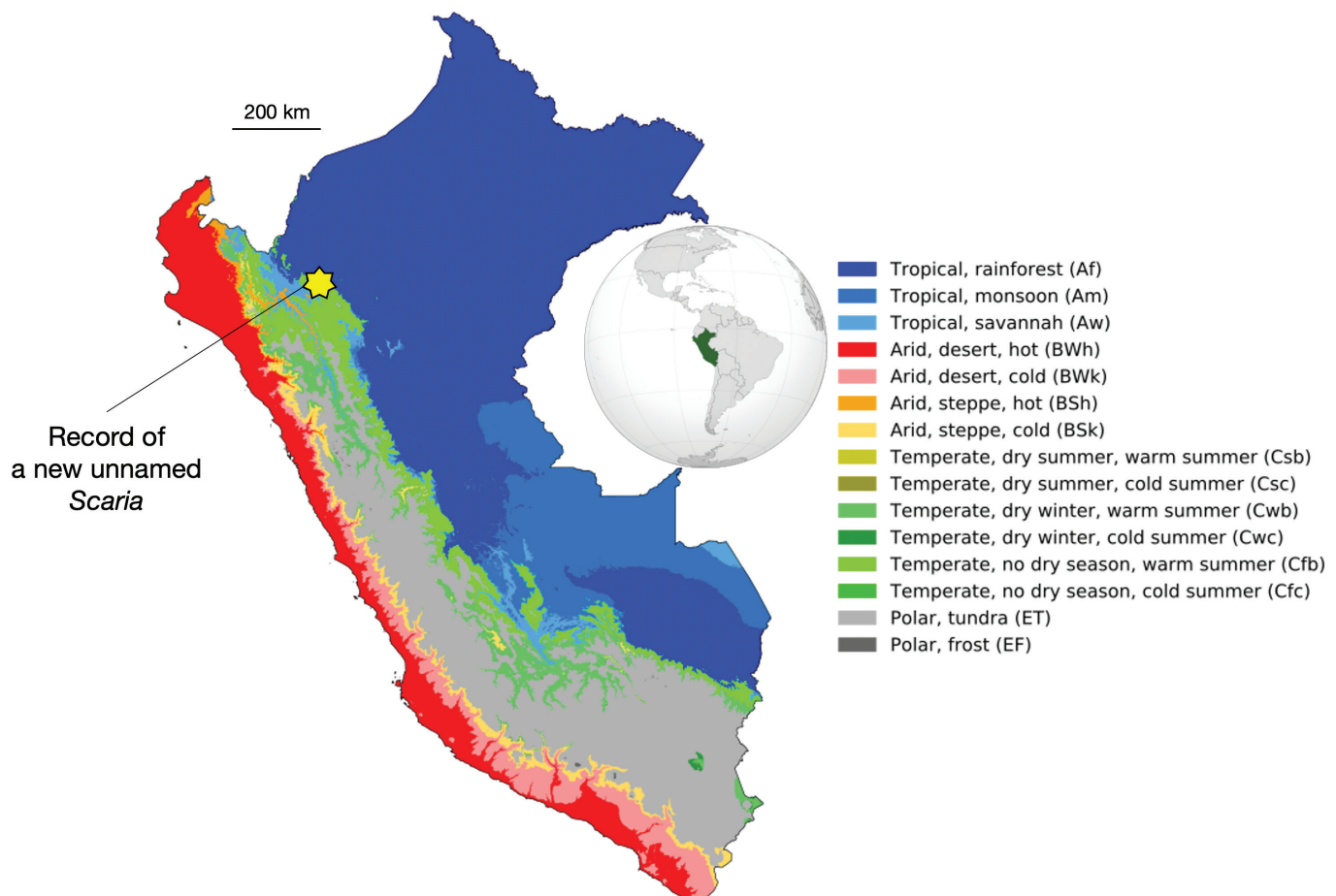


Fig. 1. Position of the only known locality of *Scaria* sp. Peroles near Yambrasbamba, marked with a star on the map of Peru with annotated Köppen-Geiger climate classification. Adapted from Beck et al. (2018).

unknown to science that are waiting to be described. Unfortunately, this impossible task (due to its sheer volume) is becoming even more discouraging due to the ongoing destruction of the entire region (Kehoe 2019). Drastic measures should be taken to reduce our negative impact on the environment because stable ecology is not only the playground of taxonomists, but also the cornerstone of the sustainability of life itself (Brown 1997, Kehoe 2019). The problem of declining biodiversity (Leather 2017, Forister et al. 2019) is only growing more significant, and cases such as this will keep happening. The unwillingness of the taxonomic community to discuss this issue and arrive at a set of rules that will apply to everybody equally is a major obstacle for scientists who find themselves in possession of publishable material in this field. With this paper, we hope to take a step towards an eventual solution.

## Materials and methods

**Locality information.**—The unnamed *Scaria* species is, for now, known only from a single locality in Peru. Peroles, near Yambasbamba and 1905 m above sea level [5.670300°S, 77.918900°W], is one of the northernmost rainforests of the Peruvian Yungas and connects Amazon and Andes, a peculiar region where mosaics of unique rainforests reach extremely high altitudes. This ecoregion is considered to be in an almost critically endangered state (Beck 2018, WWF 2020). Although the locality is very close to two protected areas—the Cordillera Colan Natural Sanctuary and the Alto Mayo protected forest—the area is severely deforested and looks like a mosaic of patches of forest alternating with deforested areas for grazing cattle. This forest is known for hosting the critically endangered yellow-tailed woolly monkey (*Oreonax flavicauda* (Humboldt, 1812)), one of “The World’s 25 Most Endangered Primates” (Shanee et al. 2019).

**Taxonomy.**—Taxonomy follows Orthoptera Species File (OSF; Cigliano et al. 2020), while nomenclature is in accordance with the International Code of the Zoological Nomenclature (ICZN 1999). Systematics of the genus *Scaria* follows Cadena-Castañeda et al. (2019), who divided it by means of a cladistic analysis into three species groups—groups *S. hamata* (De Geer, 1773), *S. lineata* Bolívar 1887, *S. producta* Hancock, 1907—and *S. laeta* Günther, 1940 without assignment to any species group.

**Comparative material examined.**—Materials of *Scaria* species identified by Cadena-Castañeda et al. (2019) for which photographs were available and which were used by us for comparison with the new species are included in Table 1. Museum collections acronyms used are as follows: **ANSP**—The Academy of Natural Sciences of Drexel University, Philadelphia, Pennsylvania, USA; **BYUC**—Monte L. Bean Life Science Museum, Brigham Young University, Provo, Utah, USA; **CAUD**—Colección de Artrópodos y otros Invertebrados de la Universidad Distrital Francisco José de Caldas, Bogotá, Colombia; **INPA**—Coleção de Invertebrados do Instituto Nacional de Pesquisas da Amazônia, Manaus, Brazil; **JSC**—Collection Josip Skejo, Zagreb, Croatia; **MNCN**—Museo Natural de Ciencias Naturales, Madrid, Spain; **MRSNT**—Museo Regionale di Scienze Naturali di Torino, Torino, Italy; **NMW**—Naturhistorisches Museum Wien, Vienna, Austria; **SMDT**—Staatliches Museum für Tierkunde, Dresden, Germany; **UFAM**—Coleção Zoológica Prof. Paulo Bührnheim, Universidade Federal do Amazonas, Manaus, Brasil.

**Morphological terminology.**—Terminology of morphological characters follows Rehn (1904), Grant (1962), and Tumbrinck

(2014). Batrachideinae is a subfamily with well-defined synapomorphies: 1) antennae usually more than 20 antennomeres, 2) anterior and mid femora with dorsal furrow, 3) female’s spermatheca with two diverticula, 4) square-shaped paranota, 5) frontomedial projection in the form of a spine, 6) fastigium of the vertex continuously and uniformly curved and marginally projected above the compound eyes, and 7) (usually) maculated tegmina. These characters are taxonomically reliable and have already been thoroughly discussed by several authors who have also listed exceptions (Bolívar 1887, Rehn 1904, Grant 1962, Tumbrinck 2014, Tumbrinck and Skejo 2017). Division of the genus *Scaria* into four species groups was supported by differences in the I) morphology of pronotum, II) male and female terminalia, III) head morphology, IV) general appearance of the anterior spine of pronotum, and V) body coloration. Key for identification of the species groups of genera *Scaria* was given in Cadena-Castañeda et al. (2019). Cadena-Castañeda et al. (2019) state that characters such as postocular stripe and tegmina maculation might represent homoplastic characters but are still useful in the identification key.

**Artificial intelligence (AI) enhancement of photographs.**—An AI service (letsenhance.io) was used to enhance the photographs from iNaturalist. We used the “smart enhance” setting with 2× upscaling. These enhanced photographs were used to discern small details, in combination with the original photographs, in order to avoid any potential visual artifacts in the upscaled photographs (Fig. 2). AI photography enhancement has proven to be a very useful tool in our case. We would like to note that it should be used with a measure of precaution, as the tool is not perfect, and visual artifacts in the upscaled photographs may appear. These problems are easily noted and avoided by people with experience with, in this case, animal morphology and anatomy.

## Results

### Taxonomy

Family Tetrigidae Rambur, 1838  
Subfamily Batrachideinae Bolívar, 1887  
Tribe Batrachideini Bolívar, 1887

Genus *Scaria* Bolívar, 1887

**Type species.**—*Scaria hamata* (De Geer, 1773).

**Composition and distribution.**—With this unnamed species, genus *Scaria* currently includes 13 species. All the species inhabit South America, with only one species (*S. fasciata*) reaching central America (e.g., Panama and Nicaragua) (Hancock 1907, Cadena-Castañeda et al. 2019). The genus is currently divided into four species groups (see Table 1). Members of *Scaria* inhabit the Amazon rainforest and its vicinity.

**Generic identification of the unnamed species.**—Grant (1956) listed three characters as differentiable between *Scaria* and newly established *Rehndium* Grant, 1956: 1) morphology of female subgenital plate, 2) smaller body size of *Rehndium* members, and 3) frontal costa more protrusive in *Rehndium* than in *Scaria*. Cadena-Castañeda et al. (2019) added a few more characters, among them 4) *Scaria* is generally slenderer than *Rehndium*; 5) tegmina of *Scaria* members are black, while they are brown in all other



**Table 1.** Material of *Scaria* species examined and organized by species groups by Cadena-Castañeda et al. (2019) containing brief information on the distribution.

Species	Material examined	Distribution
<b><i>Scaria (hamata)</i> group</b>		
<i>S. boliviana</i> Bruner, 1920	(1) NT: 1♀ Bolivia: La Paz: Nor Yungas, Yolosa (S16.24, W67.74) 1260 m a.s.l., 13.XII.2008. leg. S.M. Clark (BYUC); (2) 1♂ Bolivia: La Paz: Nor Yungas, Pacallo, (S16.21, W 67.79) 29.IV. 2005. leg. S.M. Clark & R.L. Johnson (BYUC)	Bolivia (La Paz, Santa Cruz)
<i>S. granti</i> Cadena-Castañeda, Mendes & Silva, 2019	HT: 1♂ Brasil: Acre: Bujari, Floresta Estadual Antimary (S9.33, W68.32) 27.VII. 2016. leg. J.A. Rafael (INPA)	Brazil (Acre state: Bujari, Floresta Estadual Antimary)
<i>S. hamata</i> (De Geer, 1773)	(1) NT: 1♂ Brasil: Amazonas: Universidade Federal do Amazonas (UFAM) (S3.09, W59.97) 03.II.1979. leg. J.A. Rafael (INPA); (2) 1♀ Ecuador: Zamora-Chinchi, Río Zamora valley, El Pangui, Maralí (S3.71, W78.55) 900 m a.s.l. 29.XII. 2009. leg. H. Braun, det. J. Skejo (JSC)	Brazil (Amazonas state); Ecuador
<i>S. jonasi</i> Cadena-Castañeda, Mendes & Silva, 2019	HT: 1♂ Brasil: Amazonas: Tefé (S3.33, W64.69) 01.–05.XI.2016. leg. J.A. Oliveira & D.M.M. Mendes (INPA)	Brazil (Amazonas state, Tefé)
<i>S. rafaelli</i> Cadena-Castañeda, Mendes & Silva, 2019	(1) 1♂ Brasil (Cadena-Castañeda et al. 2019, fig. 24); (2) 1♀ Brasil (Cadena-Castañeda et al. 2019, fig. 25)	Brazil (Amazonas state and Rondônia state)
<b><i>Scaria (lineata)</i> group</b>		
<i>S. fasciata</i> Hancock, 1907	(1) 1♀ Ecuador: Cachabi, leg. Rosenberg (ANSP) (photographic record (Cadena-Castañeda et al. 2019, fig. 13)); (2) 1♀ Colombia: Chocó: Bahía Solano (N6.21, W77.40) (photographic record (Cadena-Castañeda et al. 2019, fig. 33)); (3) 1♂ (photographic record (Cadena-Castañeda et al. 2019, fig. 14))	Colombia; Ecuador; Panama; Nicaragua
<i>S. ferruginea</i> Hancock, 1909	(1) 1♀ Brasil: Rondônia: Candeias do Jamari, Usina Hidrelétrica de Samuel (S8.95, W63.18) 17.VIII.2016. leg. D.M.M. Mendes, F.F. Xavier F°, A.A. Agudelo, & J.A. Rafael (INPA); (2) 1♀ Bolivia: La Paz: Parque Nacional Madidi, (photographic record (Cadena-Castañeda et al. 2019)); (3) 1♀ Colombia: Vaupés: Mitu (N1.27, W70.22) (photographic record (Cadena-Castañeda et al. 2019))	Brazil (Rondônia state); Colombia
<i>S. lineata</i> Bolívar, 1887	(1) LT: 1♂ Peru: Alto Amazonas (S5.56, W76.00) (MNCN); (2) PLT: 1♀ Peru: Alto Amazonas (S5.56, W76.00) (MNCN) (photographic record (Cadena-Castañeda et al. 2019, figs 15, 16))	Ecuador (Pastaza Province); Peru (Department of Loreto)
<i>S. veruta</i> (Grant, 1956)	(1) HT: 1♀ Peru: Junín, Puerto Bermudez, Río Pichis, 12–19.VII.1920 (ANSP) (photographic record: Cadena-Castañeda et al. 2019, fig. 17) (wrongly cited 'male' in OSF); (2) 1♀ Bolivia: PN Madidi (photographic record (Cadena-Castañeda et al. 2019, fig. 34)); (3) 1♀ Peru, P.N. Manu, Pantiacolla rainforest (photographic record: <a href="http://orthoptera.speciesfile.org/Common/basic/ShowImage.aspx?TaxonNameID=1100469&amp;ImageID=203222">http://orthoptera.speciesfile.org/Common/basic/ShowImage.aspx?TaxonNameID=1100469&amp;ImageID=203222</a> )	Peru (Río Pichis, Puerto Bermúdez)
<b><i>Scaria (producta)</i> group</b>		
<i>S. maculata</i> Giglio-Tos, 1898	LT: 1♂ Ecuador: Valle de Santiago (S3.53, W78.46) (MRSNT)	Ecuador (Valle de Santiago)
<i>S. producta</i> Hancock, 1907	(1) 1♂: Peru: Loreto, Picuroyacu, 2013, (photographic record (Cadena-Castañeda et al. 2019, fig. 32)); (2) 1♀: Colombia: Putumayo: Mocoa (N1.15, W76.64) 500 m a.s.l. 2017. (Photographic record (Cadena-Castañeda et al. 2019, fig. 32))	Colombia; Ecuador; Peru
<b><i>Scaria (laeta)</i> group</b>		
<i>S. laeta</i> Günther, 1940	(1) LT: 1♂ Brasil: Amazonas: São Paulo de Olivença, southern banks of upper Amazonas, leg. S. & I. Waehner (SMTD); (2) PLT: 1♀ Brazil, Amazonas: São Paulo de Olivença, mouth of Rio Javary (S3.76, W69.09) leg. S. & I. Waehner (SMTD); (3) PLT: 1♂ Brasil: Amazonas: São Paulo de Olivença, southern banks of upper Amazonas, leg. S. & I. Waehner (SMTD); (4) PLT: 1♀ Brasil: Amazonas: São Paulo de Olivença (S3.38, W69.07) 65 m a.s.l., leg. S. Waehner (NMW); (5) 1♀ Brasil: Amazonas: Tefé (photographic record (Cadena-Castañeda et al. 2019, fig. 31)); (6) 1♂ (photographic record (Cadena-Castañeda et al. 2019, fig. 8)); (7) 1♀ (photographic record (Cadena-Castañeda et al. 2019, fig. 9))	Colombia; Ecuador; Peru

genera of Batrachideinae; and 6) hind femora sulcated in *Scaria*, unlike carinated in *Rehndium*. We identify this species as *Scaria* Bolívar, 1887 because it shows the following characters typical of the genus: 1) median carina of the pronotum projected above the head anteriorly in the form of a well-developed spine (similar to *Rehndium* Grant, 1956 in which the spine is less pronounced); 2) slender (slim) and elongated body (differing it from robust members of the genus *Rehndium* Grant, 1956); 3) black basal color of

tegmina (not brown as in *Rehndium*); and 4) flat pronotum (not roof-like as in *Rehndium*).

The two individuals of the newly reported species are macrop-terous and macropnotal, pronotum being longer than hind femora. Characters that are present in all *Scaria* species known so far, but at first seem to be absent in the unnamed one, are 1) absence of clearly visible pale colored spot at posterior part of tegmen and 2) a lack of dark lateral stripe on the pronotum. The

tegmenal spot might be present in the reported specimens, but it is simply covered by a wide yellow-colored stripe that lies in the middle part of tegmen. This is the first *Scaria* species with medial stripe on tegmina (for comparison, *S. laeta* Günther, 1940 has the yellow stripe in the ventral portion of the tegmen, while *S. jonasi* Cadena-Castañeda et al. 2019 has it on the dorsal portion of tegmina). Arguments for not identifying the species as *Rehmidium* are 1) members of *Rehmidium* always have a brown base color of tegmina and 2) members of the genus *Rehmidium* have short and wide ovipositor valves (Cadena-Castañeda and Cardona 2015, Cadena-Castañeda et al. 2019).

### *Scaria* sp.

**Material examined.**—PERU • 1 M, 1 F; Department of Amazonas: Bongará Province: Peroles near Yambrasbamba, mountain rainforest belonging to the Peruvian Yungas biogeographic ecoregion; 5.67°S, 77.92°W; 1905 m a.s.l.; 19 August 2008; R. Sindaco leg.; photographs only, available on iNaturalist (<https://www.inaturalist.org/observations/9968031>), supplemented by Figures in this publication.

**Habitat.**—The specimens were observed and photographed on the ground inside a well-preserved patch of forest with muddy base covered by abundant leaf litter; tree trunks were covered by mosses, rich epiphytic vegetation (many Bromeliaceae), and arboreal ferns.

**Specific traits.**—The main differences between *Scaria* sp. and the five other morphologically similar species that occur in the region are listed in Table 2. The unnamed species is easily distinguished from other *Scaria* species by the following set of characters: 1) vertex wider than in any other known *Scaria* species, 2) small apical teeth on mid femora (in almost all the other species, teeth are larger), 3) longer fore and mid femora (length/width ratio of 6 or more) than in any other species, 4) generally stouter appearance than any other *Scaria* species, 5) yellow stripe placed medially on tegmina, and 6) distinctive coloration pattern of pronotum. Concerning the key to *Scaria* species by Cadena-Castañeda et al. (2019), our unnamed species shows a unique combination of characters not present in any other known species, namely yellowish face, eyes

projected above the dorsalmost level of tegmina, absence of dorsal midline (coloration), lightly colored stripe covering the median part of tegmina, and absence of stripe on the upper half of the lateral margin of pronotum. The only *Scaria* species similar to this unnamed one is *Scaria veruta* (Grant, 1956), which also has longer fore and mid femora.

**Morphological description.**—**General characters and coloration:** Relatively slender body, slightly stouter than other *Scaria* species described so far. Body smooth, without warts or dorsal projections. Coloration pattern of the entire body homogeneous, with interchanging black and yellow coloration. Yellow coloration varying from dark to paler yellow (close to white coloration) in some parts of the body. Antennae black, sometimes with a paler tip. Head exhibiting similar coloration and texture to that of the rest of the body, with black stripe behind the eyes. Compound eyes pale at the top, otherwise black. Carinae of pronotum (interhumeral carinae, external lateral carinae, internal lateral carinae, prozonal carinae, and median carina) mostly yellow to light yellow. Fore and mid femora black with all carinae yellow; fore and mid tibiae following the same pattern. Hind femora bearing a yellow to light yellowish stripe in the mid part. Front and mid tarsi dark; hind tarsi lighter but with dark coloration on the first segment ventrally. Tegmen black with a yellow longitudinal stripe in the middle covering more than three quarters of the area of the tegmen.

**Head:** (Fig. 2A, E) Antennae with 20 antennomeres. Scapus oval in cross-section. Short axis of the scapus 1.5 times wider than second antennomere (pedicel); long axis 2 times wider than second antennomere. Second antennomere 1.5 times wider than the third and all other antennomeres. Basal antennomeres from 3<sup>rd</sup> to 7<sup>th</sup>, central antennomeres from 8<sup>th</sup> to 14<sup>th</sup>, preapical antennomeres from 15<sup>th</sup> to 17<sup>th</sup>, and apical antennomeres final three segments (18<sup>th</sup> to 20<sup>th</sup>) reduced. Pale rings in joints visible in central segments. In fronto-lateral view: Frontal costa bifurcates above the middle of the compound eyes (Fig. 5). Head below level of pronotum (head in contact with the underside of the anterior side of pronotum). Lateral ocelli barely above mid-level of a compound eye. Fastigium verticis barely below level of dorsal margin of a compound eye. Frontal costa bulging for half the length of

**Table 2.** Tabular comparison of *Scaria* sp. to five other species that are morphologically similar or found in the same area.

	<i>Scaria</i> sp.	<i>S. hamata</i>	<i>S. lineata</i>	<i>S. maculata</i>	<i>S. ferruginea</i>	<i>S. veruta</i>
fore femur length/width (height) ratio	6	3.9–4.5	4.7–5.1	5.1	4.65–4.85	6.25
relation between lateral and humero-apical carinae	parallel	almost touch	almost touch	parallel	almost touch	almost touch
convexity in fronto-lateral area of pronotum	noticeable	slight	absent	absent	absent or very weak	absent
tarsal pulvilli	rounded, bulbous	pointed, triangular	rounded, bulbous	pointed, triangular	rounded, triangular	bulbous, rounded
apical teeth of mid femora	small	large	medium-large	small-medium	medium-large	medium
width of vertex to compound eye length (dorsal view)	1 (male), 1.7 (female)	1.3	1.3	1 (male)	1.4	1.2 (female)
PM elevation	present	present	absent	present	sometimes present	slight
humeral angles	rounded	rounded	rounded	slightly angled	slightly angled	rounded
rising of pronotum after PM towards anterior spine	very slight	slight	pronounced	pronounced	pronounced	pronounced
ovipositor valve length	long	medium	medium-long	N/A	short	medium-long
pronotum length in comparison with hind knee	surpassing	surpassing	surpassing	surpassing	surpassing	barely surpassing
post ocular stripe	present	present	present	absent	absent or very weak	present
tegmenal coloration	wide band	spot	no coloration	no coloration	spot	spot





Fig. 2. Example of AI enhancement of *Scaria* sp. body details compared to original photography in the background. A. Upper part of the head, showing an eye, a scapus, and a pedicel; B. Ovipositor; C. Hind tarsus; D. Ventral and tegminal sinuses; E. Bottom part of the head, showing the mouthparts. Photo credit: Roberto Sindaco.

scapus. Pedipalps white. Transverse carinae concave. Fossulae deep and pronounced. Median carina absent. In dorsal view: Vertex the same width as compound eye (male) or 1.7 times as wide as compound eye (female). Eyes of a bulbous kidney shape. Frontal costa not straight after bifurcation (see Fig. 4A).

**Pronotum:** Frontal view is not seen in the photographs. In lateral view: Pointy short frontomedial (anterior spine) present in the anterior margin. Prozonal carina visible, yellow in coloration. Sulci visible, dark in coloration. Humeroapical carina connected with external lateral carina, both yellow in coloration. Posterior margin of the lateral lobe yellow/pale with ventral sinus more obtuse than tegminal sinus. Pronotal disc flat; median carina flat except on the places of promedial and first metamedial projections. Pronotum reaching far beyond hind knees. Extralateral carina not visible, but a yellow spot in its place. Infrascapular area virtually non-existent. In dorsal view: Pronotum covering the whole abdomen. Pronotal apex surpassing hind femora. Coloration of pronotum similar to rest of body. promedial projection with characteristic yellow coloration. Prozonal carinae parallel. Humeral angles slender, oblique. Pronotal process bearing yellow to pale yellowish x-shaped mark. Median carina present, clearly visible thanks to the contrast in coloration, but rather flat. Internal lateral carina yellow to pale yellow and clearly visible. Posterior margin of pronotum truncated. Interhumeral carina absent. Characteris-

tic yellow line visible in the area where an interhumeral carina is usually present.

**Wings:** Macropterous specimen. Wings (alae) well developed, visibly longer than pronotum, black with white anterior edge. Tegmina present; reaching coxa of hind legs; black with thick yellow medial stripe from anterior to posterior part of tegmen.

**Legs:** Fore legs: Femora and tibiae smooth, without teeth. Yellow and black stripes following visually unperceivable carinae on femora. Fore femora 6 times longer than wide. Yellow and black stripes present on tibiae as well. Tarsi two segmented. Proximal segment much shorter than distal. Mid legs: Femora and tibiae smooth except for the apical (genicular) teeth present and clearly visible in distal part of femora. Yellow and black stripes, which are 6 times longer than wide, following virtually non-existent carinae on femora. Yellow and black stripes present on tibiae. Tarsi two segmented, proximal segment much shorter than distal. Hind legs: Femora 3.6 times longer than wide. Dorsal margin with minuscule teeth along dorsal margin. Genicular and antigenicular teeth clearly visible, but small. Ventral margin smooth. Inner external area of hind femora with a few transverse ridges of yellow color. In the mid length of femur, a transverse yellow to pale yellow band is present. Tibiae yellow in dorsal, black in ventral part, with recognizable minuscule teeth on dorsal margins with few larger, but still tiny, teeth. Third segment of





Fig. 3. The picture of the habitat taken by R. Sindaco during the trip to Peru during which the pictures of *Scaria* sp. were taken (*Homo sapiens* (Alberto Venchi) for scale).

arsus (Fig. 2C) 1.4 times longer than proximal segment. Tarsal pulvilli orbicular, first and second of same length, third (= distal) 1.4 times longer than first two. Proximal segment of tarsus in dorsal part yellow to light yellowish; in ventral part black, but tarsal pulvillus pale.

**Sexual dimorphism.**—This unnamed species exhibits marked sexual dimorphism in general appearance of sexes, vertex width, pronotum stature, and coloration. Some of the observed differences could be due to the limited sample, i.e., we have examined photographs of only one male and one female, but we nonetheless decide to discuss them as they could prove to be useful in the future. Vertex: Ratio of vertex width and width of compound eye in dorsal view much higher in female (1.7) than in male (1). Pronotum: Ratio of width between prozonal carinas and the width between humeral angles are equal in both sexes. However, the ratio of the length of the pronotum and the widest width between the humeral angles is much less in the female (5.15) than in the male (5.7). Coloration: Observed pattern of coloration is almost identical in both sexes, with varying degrees of color saturation in certain areas. Legs in male appear more saturated than in female. Pronotum of female appears more saturated than that of male.



Fig. 4. Living female of *Scaria* sp. in A. Dorsal view; B. Lateral view. Photo credit: Roberto Sindaco.

**Limits of the description from photographs.**—Since some angles are missing from the pictures, certain characters were described incompletely or were not described at all. We must stress, once again, that those characters do not limit us in concluding that this is a new species, but could limit the comparison with future specimens or photographs. The following is a list of characters seen only in frontal and ventral views, which should, for detailed description, be examined in a laboratory environment when a physical specimen is collected. Frontal view: level of bifurcation of the frontal costa; scutellum width; position of the antennal grooves; distance between the antennal grooves; position of lateral ocellus; shape of the vertex. Ventral view: shape of thoracic and abdominal sternites (incl. sternomentum and subgenital plate).

**Measurements.**—No specific measurements can be given due to lack of physical specimens, but some specific proportions can be calculated from photographs (see Table 2).

## Discussion

### On the taxonomy of *Scaria*

Specimens of *Scaria* sp. that we report here are somewhat similar to the holotype of *Scaria veruta* (originally placed in *Rehndium*





Fig. 5. Living female of *Scaria* sp. in frontolateral view. Photo credit: Roberto Sindaco.

Grant, 1956) (Grant 1956, Cadena-Castañeda et al. 2019, Silva et al. 2021). The lack of a lateral stripe on the pronotum of *Scaria* sp. might be caused by the fact that our species has a multicolored pronotum on which the stripe might simply be difficult to notice and distinguish. A similar case has been observed in a living specimen of *S. hamata* (De Geer, 1773) reported by Cadena-Castañeda et al. (2019: fig. 36). In the key given by Cadena-Castañeda et al. (2019), *Scaria veruta* can be distinguished from other species by tegmen with an ovoid subapical spot. However, the key then forwards a reader to the previously mentioned figure 17, a specimen of *S. veruta* with yellowish ventral line on the tegmina. Also, figure 34 shows a living specimen of *S. veruta* with tegminal sinus and tarsal pulvilli different from the ones on specimen from figure 17. This brings us to question whether all these specimens belong to the same species.

### Describing species from photographs

#### On the nature of the name

The nature of the name is an important point deserving to be separately discussed. Despite the existing rules of nomenclature provided by the ICZN, we did not manage to “legally” name this new species. The name is one of the first steps in investigating any species, learning about its behavior, habitat, and distribution. Article 72.5.6. of the ICZN states, “In the case of a nominal species-group taxon based on an illustration or description, or on a bibliographic reference to an illustration or description, the name-bearing type is the specimen or specimens illustrated or described (and not the



Fig. 6. Living male of *Scaria* sp. in dorsal view. Photo credit: Roberto Sindaco.

illustration or description itself).” Article 73.1.4. states, “Designation of an illustration of a single specimen as a holotype is to be treated as designation of the specimen illustrated; the fact that the specimen no longer exists or cannot be traced does not of itself invalidate the designation.” Recommendation 73B of the ICZN states, “An author should designate as holotype a specimen actually studied by him or her, not a specimen known to the author only from descriptions or illustrations in the literature” (ICZN 1999). It is clear that, despite the recommendation that new species should be based on physical specimens, it is not forbidden to describe a species from a photograph, i.e., from the specimen a photograph represents, if there is reason to do so. As 73B is ‘only’ a recommendation, it has provided room for well-documented exceptions from physically collected species (Marshall and Evenhuis 2015, Ingrisch et al. 2016). If the goal of the taxonomic community was to disallow photo-based descriptions entirely, Recommendation 73B should have been made into an Article. Since it is not an Article, there obviously are exceptions where photography-based description should be permitted. Thus, according to the ICZN (1999), it is not legal to reject a photography-based new species description unless the provided data does not support a new species alongside being useful for its identification in the future.

The ICZN anticipated descriptions of typeless species. Recommendation 73G asks the authors to provide an explanation for why they lack physical types, and this is asked in order to avoid



"immediate science," i.e., fast typeless descriptions of taxa found in online photographs but for which physical types could easily be provided. The ICZN asks as follows: "An author should provide detailed reasoning why at least one preserved specimen, whether a complete individual organism or a part of such an individual, was not used as the name-bearing type for the new taxon and why the formal naming of the taxon is needed at a point in time when no preserved name-bearing type will be available" (ICZN 1999). Marshall and Evenhuis (2015) raise a good point to complement the above-mentioned technical aspects of publishing photo-based descriptions. It is not practical or realistic to speak about a distinct new species with a code, such as "*undescribed species #nnn*," only because the physical holotype was not collected, when there are perfectly valid rules to provide it with a name.

A name of any kind would make referring to this species easier in subsequent publications. A proper binomial name would carry taxonomic information. A nomenclatural valid name would allow species systematization in databases of all kinds.

### On the nature of the holotype

The ICZN states that "*a holotype is the single specimen upon which a new nominal species-group taxon is based in the original publication*" (ICZN 1999). The holotype is only one because numerous problems existed with the syntypes, such as more than one species being contained within a single type series (Baur and Coray 2004). Hence, there is only one holotype, only one lectotype, and only one neotype. The exact nature of the holotype has been sporadically discussed, but the intuitiveness of the practice of depositing and studying holotypes makes this discussion unimportant in the general case. Schopf (1960) pointed out that the word itself is partly misleading, as the holotype is not and cannot possibly be "typical" of any taxon, as one specimen cannot include all the characteristics present in the population. The holotype is the name-bearer, a voucher upon which a taxon's name rests. If a holotype is atypical, it does not invalidate it at its function as a name-bearer. Although the primary role of the holotype is to bear the name, it is immensely valuable as a reference for any possible future research concerning the species in question and has the quality of retaining information that the original author might have missed or deemed unimportant. The value of the holotype has already been pointed out (Amorim et al. 2016) and can be further solidified by the example of a 145-year-old holotype from which DNA was successfully extracted and which helped resolve a cryptic species problem (McGuire et al. 2018). If this were not possible, the status of the original specimen in relation to the closely related species would be unsolvable, but differentiation of the species would still be quite possible, as only the status of the holotype as the name-bearer would be called into question. McGuire et al. (2018) also provide commentary on fixation methods that damage the specimen. Alongside improper conservation, improper curation can lead to damaging of the stored types and loss of information (Borczyk 2013). While an obvious effort to preserve the types as much as possible is apparent, there are no explicit standards for fixation and curation. Curation is especially problematic as it is dependent on the individuals who curate the collections and on the institutions that oversee their efforts; both can show blatant disregard for their inventory, which can also be damaged by unpredictable circumstances such as fires or earthquakes.

Another problem is the inaccessibility of certain holotypes, either in museums (Tang et al. 2020) or in private collections (Korb 2011, Pacheco 2017, Kral et al. 2021). Recommendation 16C of

the ICZN states: "*Recognizing that name-bearing types are international standards of reference (see Article 72.10) authors should deposit type specimens in an institution that maintains a research collection, with proper facilities for preserving them and making them accessible for study (i.e. one which meets the criteria in Recommendation 72F)*" (ICZN 1999), which further illustrates the double standards in interpreting recommendations. As can be seen in the cited papers, new species are published with holotypes that are not deposited according to the ICZN's recommendations, which is allowable if the rules are consistently interpreted. However, a holotype that is buried in an inaccessible private collection or in an uncared basement of a museum is of equal value as an undeposited holotype, the difference being that one is allowed without explanation and the other according to the personal preferences of journals' editors. It is not unheard of for holotypes to disappear. In some cases, the only remaining records of the name-bearing type are illustrations that depict taxonomically important characteristics (Woodman 2009). Even in the absence of illustrations, the taxon is valid, and a neotype can be designated only if there is some doubt about the definition of the taxon (ICZN 1999).

The taxonomic community seems content with the idea that the holotype merely exists somewhere but does not clearly mandate the ways of their preservation, accessibility, or eventual replacement due to inevitable degradation. This is excusable if the function of the holotype is to provide the basis for a name (which it is) but is equivalent to institutionalized malpractice if the holotype is supposed to be accessible at any moment (which it is not). If the designated holotype or the depiction of it represents sufficient evidence to differentiate the named taxon from the others, its function is fulfilled. The missing data can be acquired in subsequent research and published separately. Publishing a species name does not entail providing complete and non-editable information about the species.

### On the nature of fruitless research

The decision to try to describe a new species from photographs (iNaturalist) was made after we found no similar pygmy grasshopper in the literature. This nameless *Scaria* was recorded only once in 2008 in a severely deforested area. The fact that we made no attempt to physically find it, either by ourselves or with help from potential colleagues in Peru, is one of the criticisms we received, and it certainly warrants an explanation. After examining the photographs of the specimens and concluding that they represent a currently unknown species, we felt obliged to add this species to the globally accessible fund of knowledge, which entails naming it according to the accepted rules. As this was all we set out to do and the data available to us allowed for delimiting the new species from its congeners, there is no need for additional research at this stage.

Plenty of papers that present only basic information, i.e., without DNA sequences (Hemp 2017, Zha et al. 2020, Zhu et al. 2020) or with DNA sequences only (Sharkey et al. 2021), are being published regularly, the only difference being that they had access to physical specimens. This demonstrates that it is not the lack of information that is problematic, but the fact that no physical holotype exists even though the results of those publications and our own point to the same thing: a scientific name with accompanying characteristics by which the animal bearing the name can be recognized. All the photographs are publicly available and can be independently checked by other researchers to reaffirm or deny our hypothesis.

Field work is a necessary part of research, and we will, in time, take steps to either visit the locality or have it visited by somebody else. Considering the cost of this endeavor, the time it takes to forge a robust relationship with local researchers, and the restrictions imposed by the pandemic, this will happen later rather than sooner.

Incidentally, research concerning the genus *Scaria* in an area that encompasses the area in which the nameless *Scaria* lives was recently conducted by Cadena-Castañeda et al. (2019). They found three new species, none of which is the herein identified one. The absence of the nameless *Scaria* in this research shows that the species cannot be easily found and the efforts to do so would prove to be inexcusably great considering the scope of this paper.

The existence of protected areas where collecting specimens is prohibited and even touristic visits are heavily regulated is very positive, and governments around the world should be urged to designate more such areas for obvious reasons. However, those strict limitations can impede research to the point that many expeditions of a smaller scope will simply not be undertaken. It is impossible to acquire permits for those areas, as the process is arduous and (understandably) discouraging (SEARRP 2021). Ingrisch et al. (2016) faced this exact problem. They decided to describe a new katydid species based on photographs taken in a protected area. They correctly concluded the following: "*Therefore, we opted for a timely description of both species, hoping that our publication will lead to further photographic and/or acoustic detections, that it will convince authorities to grant permits for collection of type material, and that it may stimulate habitat protection measures for these enigmatic species.*" By describing a new species, Ingrisch et al. (2016) illustrated the problem and made steps not only to inspire further research but also to grasp the elusive limits of modern species research. The paper was published in this very journal, proving that exceptions do exist. The photographed katydid could, compared to the nameless *Scaria*, be collected with relative ease, requiring just a few months of effort (SEARRP 2021). This was not asked of the authors while we are being urged to undertake unjustifiable collection.

## On conservation

Even though the name carries a certain significance by itself, it also has one strictly practical value. Laws are written in such a way as to direct conservation efforts towards entities bearing a certain name, and not towards the species itself. Changing the name can impact the conservation status of a species regardless of its actual status (IUCN SSC 2012, ICZN 2021).

From the available data, it is impossible to make less than speculative statements about the status of the nameless *Scaria*, and we will refrain from doing so. It does not have to be extinct or even endangered for these arguments to have weight. Every species should be named if the naming can be done legitimately. This allows the law to recognize it and take appropriate action. The name can be changed in cases of fresh discoveries, so there is no apparent reason to circumvent rules in order to *disallow* a name and, in doing so, make further research on the species more difficult while robbing the area's checklist of a new species. What is discussed here is principle, not the significance of a single species.

## Concluding thoughts

There is a nameless new *Scaria* species from Peru, clearly distinguishable from other species of the genus. All of the species of that genus are clearly differentiable by their morphology and col-

oration, which are visible in photographs. The ICZN allows naming species from photographs if there is reason to do so; however, we did not manage to name this nameless species. We do not propose that photograph-based descriptions become the norm, only that in certain cases and for certain taxa this can be beneficial. We understand how important the physical holotype is, but because of numerous issues, we did not manage to collect one.

By the time a scientist collects, examines, and describes one new species, several more have gone extinct (Stork 2009). Every new species' description serves as a reminder of those that could not be studied in time and are now irretrievably lost. We have thus decided to describe this nameless species, celebrating the role that taxonomy has on species preservation (O'Brien and Mayr 1991, Johnson et al. 2018). A charismatic name would have allowed it to reach a wider audience, but the nameless *Scaria* will nonetheless serve as a symbol of the species we wait for, hoping that it will not be only Godot.

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