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Description of the larvae of *Sphaenognathus* (*Chiasognathinus*) *gaujoni* (Oberthür, 1885) and *S.* (*C.*) *xerophilus* Bartolozzi & Onore, 2006 (Coleoptera: Lucanidae), with observations about their altitudinal range extension

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Abstract

The third instar larvae of *Sphaenognathus* (*Chiasognathinus*) *gaujoni* and *S.* (*C.*) *xerophilus* (Coleoptera: Scarabaeoidea: Lucanidae) are described. They have the following characters: no basal tooth in the scissorial area of both mandibles; presence of a sclerotised furrow, clearly divided in two parts, on each side of the prothorax; raster thickly covered by setae. Furthermore, keys for the identification of the larvae of the species belonging to the subgenus *Chiasognathinus* are proposed. The monophyletic origin of the subgenus is confirmed.

Ecological remarks on the altitudinal range of *S.* (*C.*) *gaujoni* are also given. Old larval faecal pellets have been found in the soil from 2862 m of altitude, but larvae are now only present from 3100 to 3438 m. The shifting of the populations of these Lucanidae to higher altitude is probably related to temperature changes in the Ecuadorian Andes due to the global warming.

Key words: Ecuador, altitudinal range, larval faeces, Peru, white grubs.

Resumen

Se describen las larvas de tercera edad de *Sphaenognathus* (*Chiasognathinus*) *gaujoni* y de *S.* (*C.*) *xerophilus* (Coleoptera: Scarabaeoidea: Lucanidae). Se caracterizan por la siguiente combinación de caracteres: ausencia del diente basal en el área scissorial de ambas mandíbulas; presencia, en cada lado del protórax, de un surco esclerotizado y claramente dividido en dos partes; raster densamente cubierto con setae. Se dan a conocer las claves dicotómicas para las larvas del subgénero *Chiasognathinus* y de las especies dentro del subgénero. Se confirma el origen monofiletico del subgénero.

En un transecto altitudinal en el biotopo de *S.* (*C.*) *gaujoni*, en los Andes del sur del Ecuador, se encontraron excrementos larvales "antiguos" a partir de 2862 m, pero las larvas solamente estuvieron presentes desde los 3100 m hasta los 3438 m. El fenómeno sigue el mismo patrón de desplazamiento ascensional de los animales y vegetales observados por otros investigadores en los Andes, y constituye una prueba más del calentamiento global.

Palabras claves: Ecuador, transecto alitudinal, excrementos larvales, Perú, gusanos blancos.

Introduction

The South American Lucanidae are quite well known and during the last 25 years many authors have published papers on their taxonomy and biology (Bartolozzi et al., 1991; Boucher, 1993; Bartolozzi & Onore, 1993; Onore, 1994; Chalumeau & Brochier, 1995; Grossi et al., 2003; Molino-Olmedo, 2003; Paulsen & Mondaca, 2006; Arnaud & Bomans, 2004; Grossi & Racca-Filho, 2004; Bartolozzi & Onore, 2006; Arnaud & Bomans, 2006a, 2006b, 2006c, 2007; Chalumeau & Brochier, 2007; Grossi & Vaz-de-Mello, 2007).

The genus *Sphaenognathus* Buquet, 1838 occurs in the Andes throughout Bolivia, Peru, Ecuador, Colombia and Venezuela with about 30 species. Molino-Olmedo (2003) studied the four subgenera of *Sphaenognathus: Sphaenognathus* s. s., *Chiasornithodus* Chalumeau & Brochier, 1995, *Chiasognathinus* Didier & Séguy, 1953, and *Sphaenognathinus* Chalumeau & Brochier, 1995, on the basis of the phylogenetical analysis of 15 species.

According to Molino-Olmedo (2003), the subgenus *Chiasognathinus* includes two species: *S. gaujoni* (Oberthür, 1885) and *S. peruvianus* (Waterhouse, 1869). The recently described *S. xerophilus* Bartolozzi & Onore, 2006 belongs to the same subgenus. Chalumeau & Brochier (2007) strongly criticize Molino-Olmedo's analysis, and consider *Chiasognathinus* as a separate genus. In this paper we still consider it as a subgenus, awaiting further studies better clarifying the taxonomical situation.

The larvae of *Sphaenognathus* are poorly known. Since the work of Onore (1994), with the description of the larvae of *S. lindenii* Murray, 1857, *S. metallifer* Bomans & Lacroix, 1972, *S. nobilis* Parry, 1874, *S. oberon* Kriesche, 1922, *S. peruvianus* (Waterhouse, 1869), and *S. subtilis* Lacroix, 1987, no more species were treated.

In this paper the larvae of *S.* (*C.*) *gaujoni* and *S.* (*C.*) *xerophilus* are described and compared with *S.* (*C.*) *peruvianus;* all these species inhabit high altitudes in the Huancabamba depression, along the Ecuadorian and Peruvian Andes (fig. 1).

Materials and Methods

Larvae associated with adults were collected, fixed in

boiling water for five minutes and preserved in 80% ethanol. Observations about the faeces were done.
The dissection of the specimens and the terminology used in this paper follow Böving (1936), Ritcher (1966), and Onore (1994).
Local people and farmers, interviewed by one of us (G. O.), gave useful information about the former presence of adults and larvae in parts of the studied area.
The altitude was measured with GPS 12CX, Garmin, Olathe, along an altitudinal transect.

Results

One of us (G. O.) conducted researches in the Huancabamba depression, along the Ecuadorian and Peruvian Andes, and observed that in the soil, at the lowest altitudinal range of the species distribution, no *Sphaenognathus* larvae were present, but there was abundance of the remaining of their faeces, easy to recognise for their peculiar shape (figs. 3, 4). Only at the upper altitudinal range larvae were present.

The larvae of *S.* (*C.*) *gaujoni* and *S.* (*C.*) *xerophilus* live in very dry soil where the only moisture is provided by the water of the short rainy season between February and April, and by the dew that accumulates during the night in the "paramo". To lay eggs the female digs galleries in the ground using its strong fore tibiae, following remains of vegetation such as roots, or stones and existing cavities.

White grubs of *S.* (*C.*) *gaujoni* and *S.* (*C.*) *xerophilus* live at altitudes above 2600 m, in very dry habitats. Vegetation varies from grass, shrubs or simply rocky soil covered with moss and lichens or, in some cases, bare ground. The soil may be clayey, sand-clay mixtures or lateritic. Larvae were never found in flooded substrates, or in saturated soil, nor in small cavities that are periodically inundated; they apparently prefer hilly stream banks or areas where water drains rapidly. The larvae of *Sphaenognathus* do not live in rotten wood, as many other stag beetle larvae.

The larvae were found in groups (one or two groups every square meter), about 5-15 cm underground, in numbers that can reach as many as 38 individuals, apparently all of similar age, but exceptions can occur when adjacent colonies overlap. Similarly, when pupae were found, they apparently belonged to the same clutch and in this case they were found only with other pupae, or with larvae in the process of pupating.

During the research of *S.* (*C.*) *xerophilus* some old brownish larvae were found, possibly infected by a virus or a fungus, and dead, hollow pupae were found with fly puparia within (Tachinidae?).

Within the studied area in the southern Andes of Ecuador at Loja Province (fig. 1), the larval faecal pellets of *S.* (*C.*) *gaujoni* were abundant

Key for the known *Sphaenognathus* larvae to subgenera

1. Prothorax with lateral sclerotized furrow clearly interrupted by unsclerotized area (fig. 14). Raster with more than 900 short to long setae (fig. 23) .... subgen. *Chiasognathinus*

1´. Prothorax with lateral sclerotized furrow continuous. Raster with less than 900 short to long setae .... subgen. *Sphaenognathus*

Key for *Chiasognathinus* larvae to species

1. Thoracic spiracle kidney-shaped (fig. 15). Pars stridens of mesocoxa with more than 200 teeth (fig. 17) .... *gaujoni*

1´. Thoracic spiracle C-shaped (fig. 16). Pars stridens of mesocoxa with less than 200 teeth (fig. 18) 2

2. Anal lobes densely tomentose (fig. 24). Plectrum of metatrochanter with more than 100 teeth (fig. 20) .... *xerophilus*

2´. Anal lobes glabrous or with scattered setae. Plectrum of metatrochanter with less than 100 teeth .... *peruvianus* upon the substrate. Due to the dry conditions and the efficient drainage of the soil surface, the pellets can remain intact for a long period: up to 15 years (G. O., personal observations) or even 25 years (native people information).

Larvae were collected for the first time the 20 February 1992 at 2740 m. Later, in March 2007, one of us (G. O.), during an altitudinal transect at the biotope, found old larval dry faeces from 2862 up to 3100 m, but no larvae were present. Only from the latter elevation and up to the top of the mountain, at 3438 m, larvae and fresh larval faeces were present (fig. 2). Similar observations were done, but with no measurements, for *S.* (*C.*) *peruvianus* from Loja Province, in 2007, and *S.* (*C.*) *xerophilus* from Huancabamba in the northern Peruvian Andes, in 2005.

Description of the faeces of the third instar larvae: roughly corn seed - like, hard, brown when moist and grey when dry. In the dry soil these are immediately distinguishable as pellets and do not decompose for several years. The size average of the faeces (n = 100) for *S.* (*C.*) *gaujoni* is 6.0–6.2 x 4.8–5.7 x 2.1–3.0 mm and 115 mg each (figs. 3, 4); 6.8–8.0 x 5.8–6.4 x 2.1–3.0 mm and 152 mg each for *S.* (C.) *xerophilus.*

Sphaenognathus (Chiasognatinus) gaujoni
(Oberthür, 1885)

Larva - Mediolateral length - 49-62 mm.

Head - Width of cranium 7.0-7.8 mm; cranium surface reddish brown, yellowish spotted. Stemma circular to ovate, not pigmented, without definite margin, not raised above head surface. Dorsoepicranial setae on each side. Frons on each side with 1-2 setae at anterior frontal angle, 1-3 external frontal setae, and 0-1 anterior frontal seta. Clypeus trapezoidal with length/width ratio 2.23-3.00/1, with one anterior clypeal seta and one external clypeal seta on each side. Labrum with 18-29 posterior labral setae and two anterior labral setae. Antennae with three antennomeres. Epipharynx (fig. 7): haptomerum with two heli; pedium with 24-27 sensilla; right chaetoparia with 29-33 long and some smaller setae; left chaetoparia with 30-36 long and some smaller setae; tormae triangular, asymmetrical, caudally directed, dexiotorma usually truncate at the basis and shorter then laeotorma.

Left mandible with four blade-like scissorial teeth, lacking basal tooth (fig. 9). Right mandible, in dorsal and ventral view, with not well-defined teeth. Each maxilla with 5-6 large setae lateral to uncus of galea and 13-16 large setae behind uncus of lacinia (fig. 12).

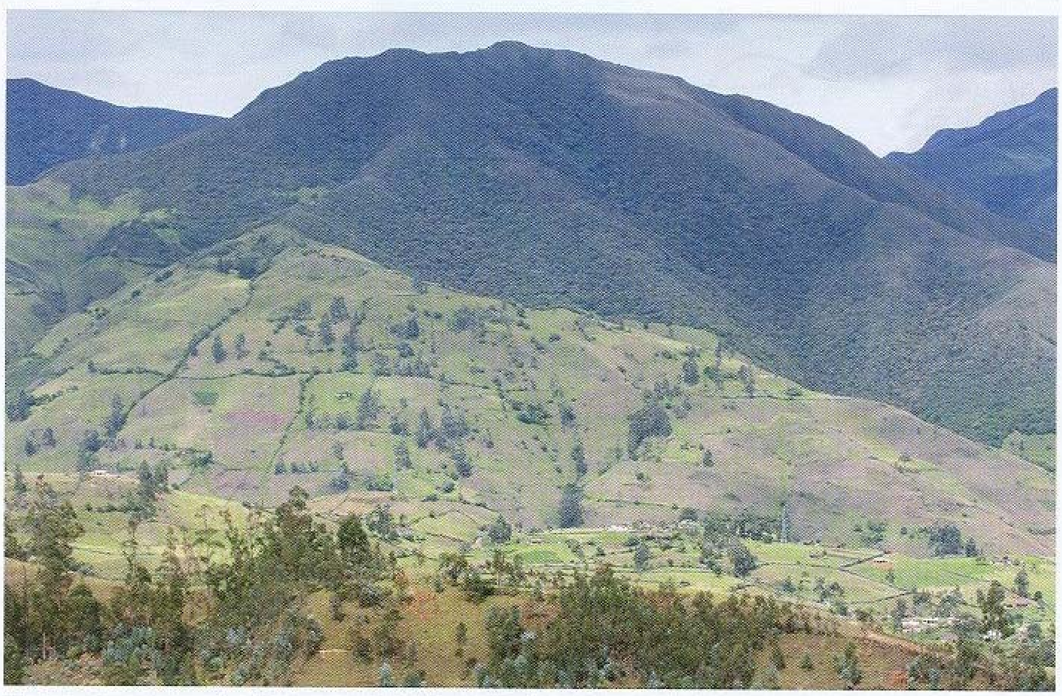


Fig. 1. Ecuador, Loja. Locality of *Sphaenognathus (Chiasognathinus) gaujoni.*

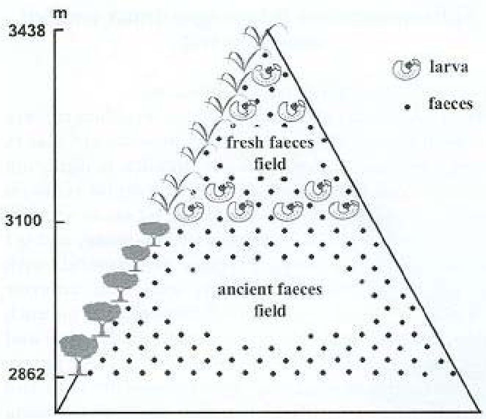


Fig. 2. *Sphaenognathus (Chiasognathinus) gaujoni*. Altitudinal range of larvae and faeces.

Thorax - Respiratory plate of thoracic spiracle semicircular or kidney shaped with concavity cephally directed (fig. 15).

Prothorax with lateral furrow clearly divided in two parts, dorsal/ventral part ratio 2.0-2.5/1. Mesothoracic leg with pars stridens of 207-231 teeth; at the proximal end of the row of teeth, one or two granulate areas are present (fig. 17). Metathoracic leg with plectrum consisting of 92-107 oval teeth, decreasing in size distally (fig. 19).

Abdomen - Upper and lateral anal lobes densely tomentose, anal pad bare (fig. 21). Raster with 1896-2013 short to long reddish setae (fig. 23).

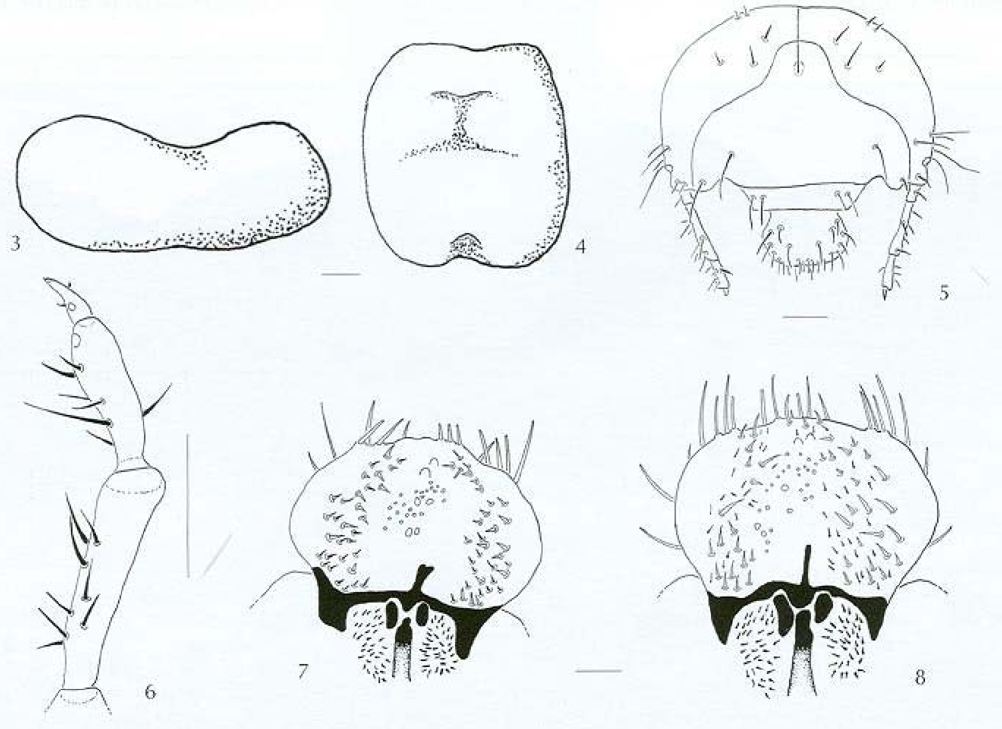
Material - Third instar larvae: 18 males and 14 females with associated adults, deposited in the (QCAZ) Museum of Pontificia Universidad Católica, Quito, Ecuador.

Locality - Ecuador: Loja, 2780 m, 20 February 1992, legit G. Onore, in topsoil 5-15 cm deep.

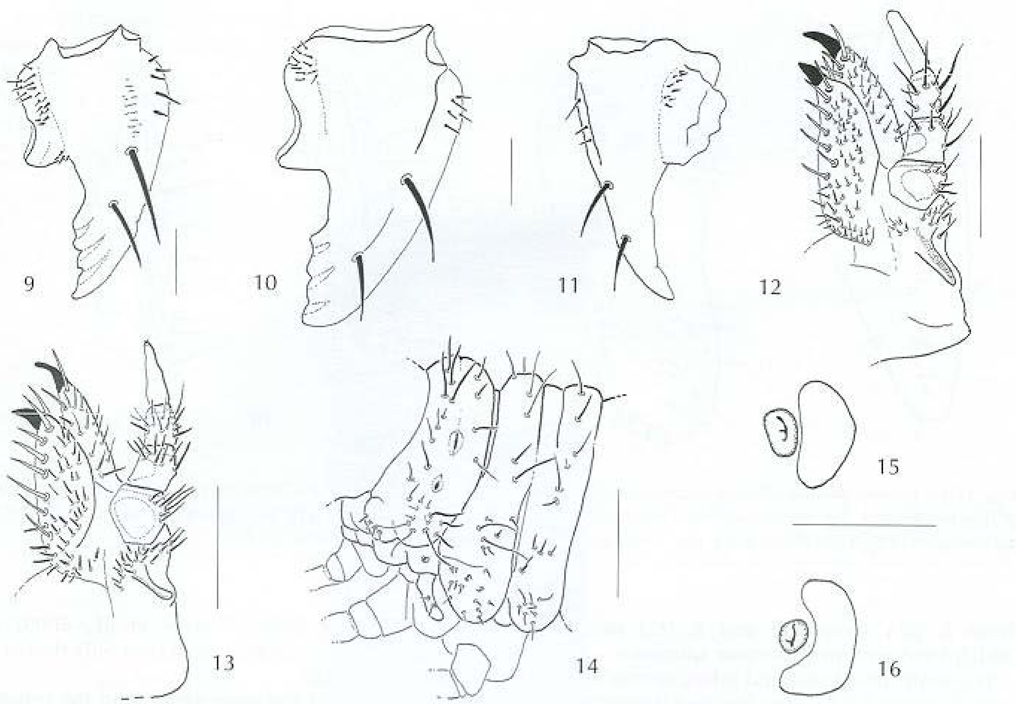
Sphaenognathus (Chiasognathinus) xerophilus Bartolozzi & Onore 2006

Larva - Mediolateral length - 45-56 mm.

Head - Width of cranium 7.1-8.5 mm; cranium surface



Figs. 3-8. *Sphaenognathus (Chiasognathinus) gaujoni;* 3: faeces of the third instance larva, frontal view; 4: dorsal view; 7: epipharynx. *Sphaenognathus (Chiasognathinus) xerophilus;* 5: head; 6: right antenna, dorsal view; 8: epipharynx. Scale bars 1mm.



Figs 9-16. *Sphaenognathus (Chiasognathinus) gaujoni;* 9: left mandible, dorsal view; 12: right maxilla, dorsal view; 14: thorax, left lateral view; 15: left thoracic spiracle. *Sphaenognathus (Chiasognathinus) xerophilus;* 10: left mandible, dorsal view; 11: right mandible, dorsal view; 13: right maxilla, dorsal view; 16: left thoracic spiracle. Figs 9-13 and 15-16: scale bars 1 mm; fig. 14: scale bar 5 mm.

reddish brown, yellowish spotted (fig. 5). Stemma not pigmented, hardly distinguishable and reduced to and oval spot. Dorsoepicranial setae 5-6 on each side. Frons on each side with 1-2 setae at anterior frontal angle, one exterior frontal seta and 0-1 anterior frontal seta. Clypeus trapezoidal with length/width ratio 3.08-4.3/1, with one anterior clypeal seta and one exterior clypeal seta on each side. Labrum with 13-15 posterior labral setae and two anterior labral setae. Epipharynx (fig. 8): haptomerum with two heli; pedium with 24-30 sensilla; right chaetoparia with 16-25 long and some smaller setae, left chaetoparia with 23-26 long and some smaller setae; tormae triangular, symmetrical and caudally directed. Antennae with thee antennomeres (fig. 6). Left mandible with four blade-like scissorial teeth, lacking basal tooth (fig. 10). Right mandible in dorsal and ventral view with not well-defined teeth (fig. 11). Each maxilla with 2-4 large setae lateral to uncus of galea and 11-14 large setae behind uncus of lacinia (fig. 13).

Thorax - Respiratory plate of thoracic spiracle c-shaped, with concavity cephally directed (fig. 16).

Prothorax - with lateral furrow clearly divided in two parts, the dorsal one 2-3 times longer than ventral one. Mesothoracic leg with pars stridens of 161-188 teeth; at the proximal end of the row of teeth, a granulate area is present (fig. 18). Metathoracic leg with plectrum consisting of 103-142 oval teeth, decreasing in size distally (fig. 20).

Abdomen - Upper and lateral anal lobes densely tomentose, anal pad bare (fig. 22). Raster with 2208-2531 short to long reddish setae (fig. 24).

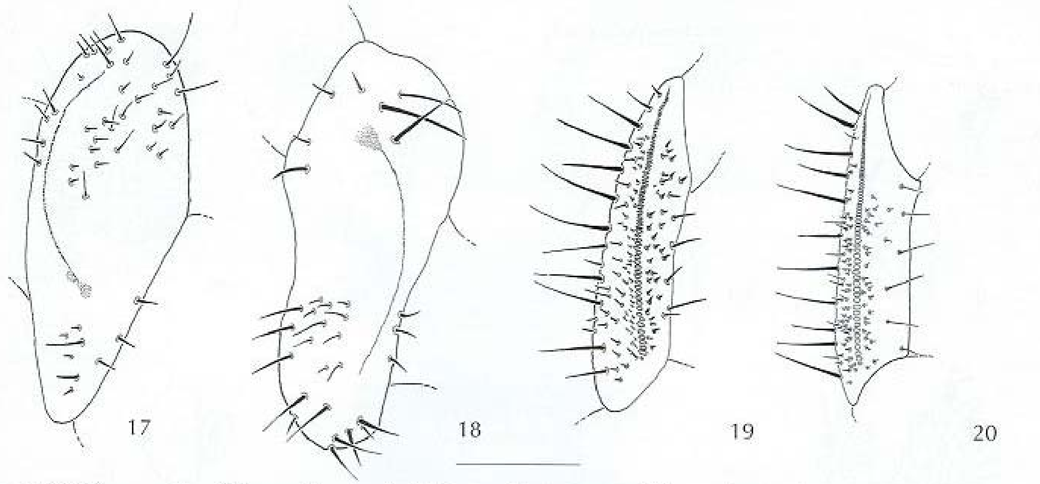
Material - Third instar larvae: 26 males and 38 females with associated adults, deposited in the (QCAZ) Museum of Pontificia Universidad Católica, Quito, Ecuador.

Locality - Peru: Huancabamba District, Huancabamba, 2860 m, December 2005, legit G. Onore, in topsoil 4-19 cm deep.

Discussion

The larvae of *S. (C.) gaujoni*, *S. (C.) xerophilus* and *S. (C.) peruvianus* belong to a monophyletic group defined by the following synapomorphies: absence of the basal tooth on the scissorial margin of the mandibles; two lateral furrows present on each side of the prothorax; presence of very dense reddish setae on the raster.

The larvae of *S. (C.) gaujoni* have a thoracic kidney-shaped spiracle and can be easily separated



Figs. 17-20. *Sphaenognathus* (*Chiasognathinus*) *gaujoni*; 17: pars stridens on coxa of left mesothoracic leg; 19: plectrum on trochanter of right metathoracic leg. *Sphaenognathus* (*Chiasognathinus*) *xerophilus*; 18: pars stridens on coxa of left mesothoracic leg; 20: plectrum on trochanter of right metathoracic leg. Figs 17-18: scale bar = 0.5 mm; figs 19-20: scale bar = 1 mm.

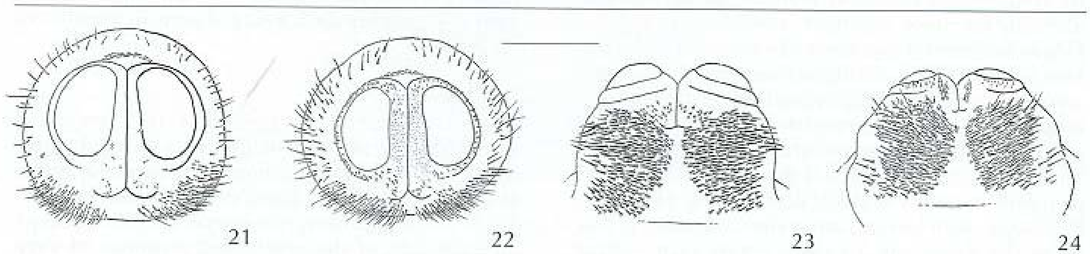
from *S.* (*C.*) *xerophilus* and *S.* (*C.*) *peruvianus* which have c-shaped thoracic spiracles.

The vestiture of the anal lobes, sparse in *S.* (*C.*) *peruvianus* and *S.* (*C.*) *gaujoni* and dense in *S.* (*C.*) *xerophilus*, may be seen as a synapomorphic character of the first two species.

The finding of old faeces in the soil without any larva in the lower altitudinal range of the *S.* (*C.*) *gaujoni* area (figs. 1, 2) may suggest a relationship between the upwards shifting of the altitudinal range extension and the global warming. The data gathered in the altitudinal transect, based on larval faeces evidence, shows an upwards drift of about 238 meters and may have occurred, according to personal observations and information from native people, in the last 15-25 years. It seems that these stag beetles are having an upward altitudinal range shift like other Andean animals (Francou et al., 2003; Vuille et al., 2003; Bustamante et al., 2005; La Marca et al., 2005; Pounds et al., 2006) and plants (de Vries, 2006), most probably due to the global warming.

The larvae of *Sphaenognathus* and the presence of their old faeces in the soil can probably be used as bio-indicators of the global climate change. The shift to lower temperature at higher elevations seems to be related to temperature changes in the Ecuadorian Andes due to the global warming, which has caused glacier retreats (Francou et al., 2003; Vuille et al., 2003; Seimon et al., 2006), as well as catastrophic amphibian extinctions (Ron et al., 2003; La Marca et al., 2005; Merino-Viteri et al., 2005).

It seems possible that, if the trend of the upward shift of the altitudinal range extension of *Sphaenognathus* will continue, these stag beetle species could finally overlap with the range of other vicariant taxa living in the opposite mountain slope.



Figs. 21-24. *Sphaenognathus* (*Chiasognathinus*) *gaujoni*; 21: caudal view of the last abdominal segment; 23: raster. *Sphaenognathus* (*Chiasognathinus*) *xerophilus*; 22: caudal view of the last abdominal segment; 24: raster. Scale bar 3 mm.

The consequences of the global warming are not easily predictable, but they may cause biodiversity loss with extinction of many taxa.

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