

Remarks on the *Echiniscus viridis* group, with the description of a new species (Tardigrada, Echiniscidae)

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ABSTRACT

A new species, *Echiniscus viridianus* sp. n., is described in the *Echiniscus viridis* group from North America and the Azores Islands. It clearly differs from *E. viridis* in some details of the cuticular ornamentation (it has dark tubercles quite close to each other and larger light spots). A comparison of the new species with the others in the group indicates that this group is less homogeneous than traditionally believed.

Key words: *Tardigrada*, *Echiniscus viridis* group, *E. viridianus* sp. n.

1. INTRODUCTION

Very few species of *Echiniscus* are green, but those that share the presence of cirrus A and lack other lateral and dorsal appendages (*Echiniscus viridis* Murray, 1910, *Echiniscus rufoviridis* du Bois-Reymond Marcus, 1944, *Echiniscus viridissimus* Péterfi, 1956, and *Echiniscus perviridis* Ramazzotti, 1959) are traditionally considered members of the so-called *viridis* group. But the colour green is not restricted to species of the *viridis* group and, conversely, not all species in this group are completely green. In addition, *Echiniscus pooensis* Rodriguez Roda, 1948, is green but it has lateral and dorsal appendages, and it is not considered a member of the *viridis* group. Fontoura (1985) attributed to *E. viridis* some specimens from Ilha do Pico (Azores Islands) having a dark grey colour when mounted in polyvinyl-lactophenol.

Kaczmarek & Michalczyk (personal communication) recently found specimens that were almost black and, in their opinion, attributable to this group. Although Kristensen (1987) referred to an undescribed black species of the *viridis* group only found in the Arctic, the colour black, or almost black, is not restricted to species of the *viridis* group. In fact, *E. ehrenbergi* Dastych & Kristensen (1995) is blackish-brown but it does not belong to the *viridis* group as it has long lateral appendages and dorsal spines. *Echiniscus perviridis* appears green when examined by transmitted light but greenish-brown, or almost black, under reflected light; therefore, colour alone does not appear to be a definitive indicator of phylogenetic affinity.

According to the literature (Ramazzotti & Maucci 1983; McInnes 1994; Peluffo *et al.* 2002) only one species in the *viridis* group has a limited geographic distri-

bution; *E. rufoviridis* is recorded from Brazil and Argentina. The other three species are more widespread (Ramazzotti 1959; Grigarick *et al.* 1983; Ramazzotti & Maucci 1983; Kim & Moon 1988; McInnes 1994; Séméria 1994; Utsugi 1996; Abe & Takeda 2000, 2005). *Echiniscus perviridis* is recorded from Europe, North America and probably from Asia – Japan, South Korea and Taiwan; *E. viridissimus* from Europe, North America, South America, and probably Japan; and *E. viridis* from the Hawaiian Islands (*locus typicus*), Europe, North America and South America.

We examined specimens collected by Christenberry in Alabama, by Beasley in New Mexico and by Fontoura in Azores Islands and attributed by these authors to *E. viridis*. We did not examine specimens of *E. rufoviridis*, or the type material of *E. viridis*, because no specimen of this species is present in the collection of Murray deposited at the National Museum of Edinburgh or at the British Museum of London (Morgan 1977; and personal communication of Nigel Marley). As a result of our comparisons, we identified a new species in the *viridis* group and noted some problems with the identifying characters that should be discussed.

2. METHODS

We examined some specimens from North America collected by Christenberry (Auburn: Alabama) in 1978 and by Beasley (Dona Ana: New Mexico) (1988), and from the Azores, collected in Ribeira Fria, Lages do Pico by Fontoura (1985), which we have attributed to the new species *E. viridianus*. The specimen from New Mexico was mounted in liquid of Faure after the treatment indicated by Beasley (1978). All other examined specimens were mounted in polyvinyl lactophenol. The specimens from the Azores were treated with lignin

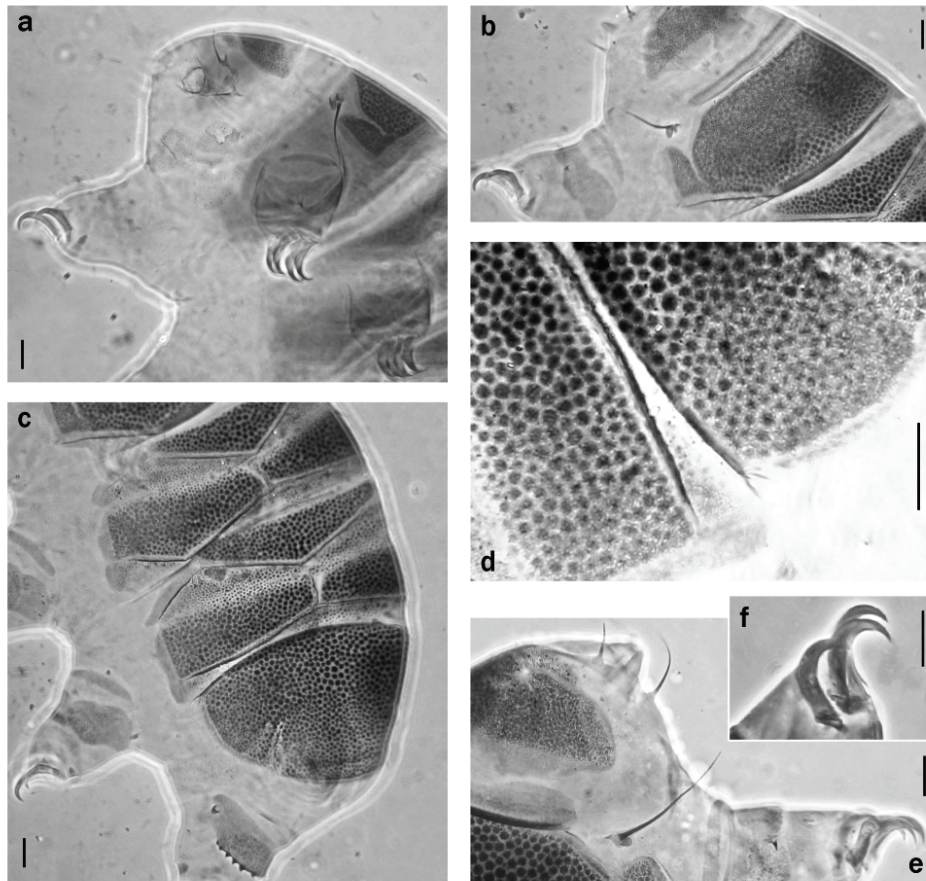


Fig. 1. *Echiniscus viridianus* sp. n. **a:** Anterior portion of the body. **b:** Detail of the anterior portion of the body. **c:** Central and posterior portions of the body; the marginal cuticular ornamentation is clearly visible. **d:** Detail of the cuticular ornamentation of paired plate III and terminal plate: the dark tubercles and, in some portions, small dots and small light spots are visible. **e:** Buccal cirri, cirrus A, cuticular ornamentation of the cephalic plate and small spine on the first pair of legs are visible. **f:** Claws of the third pair of legs; a small spur on internal claws is visible.

a-c: holotype; d-f: a specimen from the Azores. Scale bar: a-f = 10 μ m.

pink. One paratype of *E. perviridis* from Pallanza (Italy) was kindly loaned by the "Museo Civico di Storia Naturale di Verona" from the Ramazzotti collection. One specimen of *E. viridissimus* from Alabama was kindly sent to us by D. Christenberry. Measurements and comparisons of various characters were made under oil immersion with phase contrast and DIC with a Leica compound microscope.

3. DESCRIPTION

Echiniscus viridianus sp. n. (Fig. 1)

Locus typicus: North America: Auburn, Alabama.

Material examined: Auburn, Alabama: holotype (slide N. 2679) and 19 paratypes in a moss sample (all females); New Mexico (1 specimen); Azores Islands: 9 specimens collected in Ribeira Fria, Lages do Pico, in a moss sample, by Fontoura (1985).

Type repository: Holotype, paratypes and one specimen from the Azores Islands are deposited in the collection

of Binda & Pilato (Museo del Dipartimento di Biologia Animale "Marcello La Greca", Università di Catania, Italy); 8 specimens from the Azores Islands in the collection of Fontoura (Department of Zoology and Anthropology, Faculty of Sciences, University of Porto, Portugal).

Species diagnosis: Colour green (U.S.A.) or dark grey (Azores); eye spots present; plate margins well marked, median plate 1 triangular and distant from scapular plate; median plate 3 absent but the area between paired plates III and terminal plate is sculptured. On some plates, or portion of plates, slightly raised dark tubercles and fine dots are present. In a particular focus position, small light spots appear; distance between the dark tubercles significantly shorter than the diameter of the tubercles. Some portion of paired plates II and III, the anterior portion of median plate 2, and the area between paired plates III and the terminal plate have only small dark tubercles. Cirrus A short; no other lateral or dorsal appendages present. Claws well-developed; internal claws with a small spur, difficult to see.

Tab. 1. Lengths of some structures of the smallest and the largest measured specimens (paratypes) of *Echiniscus viridianus* sp. n. %bo = % of body length; %sc = % of scapular length.

	Smallest specimen			Largest specimen		
	µm	%bo	%sc	µm	%bo	%sc
Body length	175.0			310.0		
Internal buccal cirrus	13.0			17.5		
External buccal cirrus	?			22.0		
Cephalic papilla	5.0			8.0		
Clava	4.0			6.0		
Cirrus A	23.0			39.0		
Scapular plate length	35.0			61.0		
Spine on leg I	2.3			3.0		
Internal claw leg I	11.0	6.3	31.4	21.0	6.8	34.4
External claw leg I	10.3	5.9	29.4	18.0	5.8	29.5
Internal claw leg IV	12.0	6.9	34.3	21.0	6.8	34.4
External claw leg IV	10.8	6.2	30.9	20.0	6.5	32.8
Papilla leg IV	4.0			4.8		

Description of the holotype: female; body length 231 µm, plate colour green; cephalic plate with an anterior notch (Fig. 1e); a true neck plate is absent, but a thickened transverse area is present between the cephalic plate and the scapular plate (Fig. 1b); the scapular plate is subdivided into a wide central portion and two small lateral ones (Fig. 1b); in the median line it is 43.1 µm long; median plate 1 is triangular and distant from the scapular plate (Fig. 1b, c); median plate 3 is absent but the corresponding area is sculptured (Fig. 1c); terminal plate unafaceted with two incisions (Fig. 1c). Cephalic plate (Fig. 1e) with faint dark tubercles only slightly raised, very close to each other and with many fine dots; scapular plate, median plate 1, caudal portion of paired plates II and III, caudal portion of median plate 2, and terminal plate with a regular ornamentation with larger, dark, polygonal or almost circular, slightly prominent tubercles (Fig. 1b, c, d), and many very fine dots; at a different level of focus, many small light spots become visible also where the tubercles are present (Fig. 1d). The largest tubercles are present in the central portion of the plates (diameter up to 2.4 µm); the distance between the dark tubercles is much shorter than the diameter of the tubercles (about 0.8 µm).

Crowe *et al.* (1970) studied the fine structure of the cuticle of North-American specimens from North Carolina attributed to *E. viridis*. We noted that their transmission electron micrograph of the cuticle (Crowe *et al.* 1970, page 319, Fig. 4) perfectly explains the appearance of the cuticle of *E. viridianus* sp. n. when examined with the light microscope under phase contrast; the dark polygons coincide with slightly raised tubercles, the light spots with lacunae, and the small dots with trabeculae. The ventral body cuticle has very fine, dense dots, smaller than the dorsal ones, that coincide with small dark dots described by Crowe *et al.* (1970, page 323, Fig. 9).

Paired plates II and III (Fig. 1c, d) with a posterior portion with the typical ornamentation described above

and an anterior portion divided into a small anterior most part with only small dark tubercles, a central portion with the typical ornamentation, and a posterior part with only small dark tubercles. Anterior portion of median plate 2 (Fig. 1c) and area between paired plates III and the terminal plate (Fig. 1c) with only dark tubercles. Trunk plates bordered by a narrow area with the same colour of the plates and a fine ornamentation (Fig. 1c). As in other species of the genus, the legs have three sculptured areas, two of which are dorsal to the claws and one near the base of the claws (Fig. 1b, c). Only fine dots, or also very faint tubercles (slightly more evident, when present, on the fourth pair of legs) are present in these areas.

Internal buccal cirrus is 13.9 µm long; external buccal cirrus is 14.7 µm; cirrus A is a short filament, 29.0 µm long (Fig. 1a, e); cephalic papilla is 5.8 µm long; clava 5.5 µm long. No other lateral or dorsal appendages present. A small spine present on the first pair of legs (Fig. 1e); a papilla 4.8 µm long and a dentate fringe (with about 12 teeth) on the fourth pair of legs (Fig. 1c).

Claws well-developed; internal and external claws 15.1 µm and 14.5 µm long, respectively, on the first pair of legs; 16.2 µm and 14.5 µm, respectively, on the fourth pair of legs. The length of the longest claws is 6.3-7.0 % of the body length and 33.6-37.6% of the scapular plate length (Tabs 1 and 2). All internal claws (Fig. 1f) with a thin, straight spur, directed downwards and difficult to see.

The paratypes are similar to the holotype in both qualitative and metric characters (Tabs 1 and 2), but the specimens from the Azores Islands are dark grey, instead of green.

Etymology: The name *viridianus* refers to the colour of the holotype; *viridianus* = greenish.

Remarks: *Echiniscus viridianus* sp. n. differs from *E. viridis* in details of the cuticular ornamentation. Murray (1910) wrote that in *E. viridis* the dots do not appear as either pits or papillae, but simply as darker patches, and he did not mention small dots and light points. Hawaiian

Tab. 2. Lengths of some structures of single specimens of *Echiniscus viridianus* sp. n., *Echiniscus viridis*, *Echiniscus rufoviridis*, *Echiniscus viridissimus* and *Echiniscus perviridis*.

%bo = % of body length; %sc = % of scapular length. ¹Measurements from Murray, 1910. ²This length, indicated by Ramazzotti (1959), refers to Brazilian specimens. ³Measurements from Peluffo *et al.* 2002.

	<i>E. viridianus</i> sp. n.			<i>E. viridis</i> ¹			<i>E. rufoviridis</i> ³			<i>E. viridissimus</i>			<i>E. perviridis</i>		
	µm	%bo	%sc	µm	%bo	%sc	µm	%bo	%sc	µm	%bo	%sc	µm	%bo	%sc
Body length	231.0			250.0			298.0			234.0			290.0		
Internal buccal cirrus	13.9			?			?			19.0			?		
External buccal cirrus	14.7			?			?			22.0			?		
Cephalic papilla	5.8			?			?			7.3			6.0		
Clava	5.5			?			?			8.2			?		
Cirrus A	29.0			40.0 ²			63.0			85.0			114.0		
Spine on leg I	2.6			?			?			5.5			?		
Scapular plate	43.1			?			?			53.5			56.5		
Internal claw leg I	15.1	6.6	31.4	?	?	?	?	?	?	?	?	?	?	?	?
External claw leg I	14.5	6.3	29.4	?	?	?	?	?	?	?	?	?	21.4	7.4	37.9
Internal claw leg IV	16.9	7.3	34.3	25.0	10.0	?	26.0	8.7	?	20.5	8.8	38.3	30.0	10.3	53.1
External claw leg IV	15.2	6.6	30.9	?			?			20.0	8.6	37.4	28.5	9.8	50.4
Papilla leg IV	4.8			?			?			5.1			?	?	?

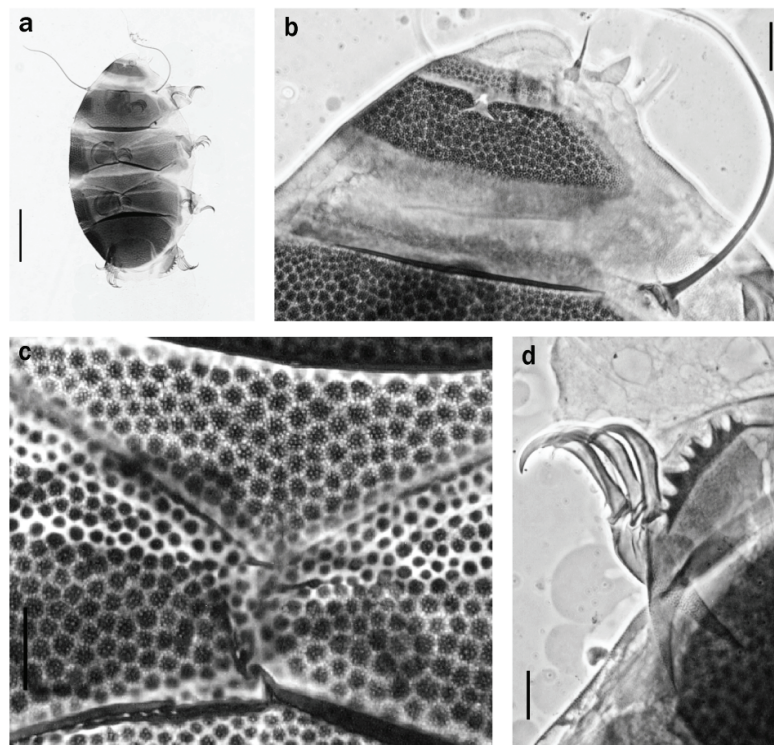


Fig. 2. *Echiniscus perviridis*. **a:** Habitus. **b:** Detail of the anterior portion of the body; dark tubercles and small dots are visible on the cephalic plate. **c:** Cuticular ornamentation of the median plate 1 and paired plates II; dark tubercles, small dots and small light spots are visible. **d:** Claws of the fourth pair of legs; the dentate fringe and claws (the internal with a small spur) are visible. Scale bar: a = 70 µm; b-d = 10 µm.

specimens of *E. viridis* in the Schuster collection from the Bohart Museum, University of California-Davis, have no light spots (Nelson, personal communication). In addition, *E. viridianus* sp. n. has dark tubercles quite close to each other; the distance between the tubercles is clearly shorter than the diameter of these structures.

The new species differs from *E. perviridis* by having cuticular ornamentation with less evident light points

(Figs 1d and 2c), a much shorter cirrus A and shorter claws (Tab. 2).

The new species differs from *E. viridissimus* in some characters of the cuticular ornamentation. In *E. viridissimus* the fine dots are clearly smaller and denser. On the scapular plate, on the posterior portions of paired plates II and III, on the median plate 1, on the posterior portion of median plate 2, and on the terminal plate

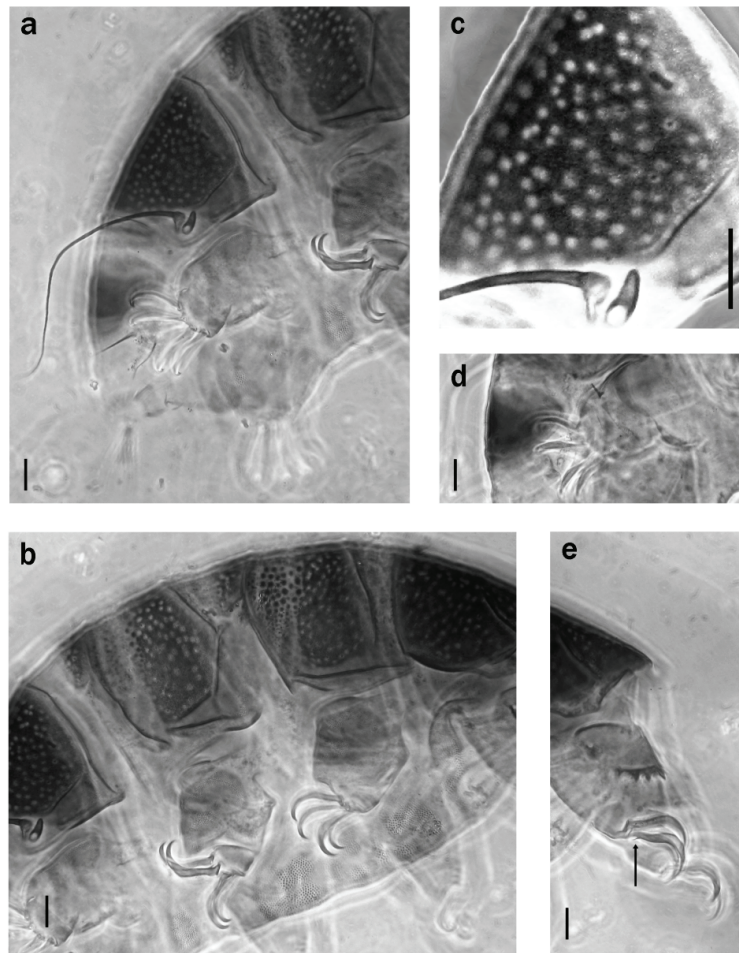


Fig. 3. *Echiniscus viridissimus*. **a:** Anterior portion of the body. **b:** Central portion of the body; the cuticular ornamentation of paired plates II and III is visible with large dark tubercles in the anterior portion, and large, rounded light patches in the posterior portion. The smaller dots are almost not visible. **c:** Detail of the cuticular ornamentation of the scapular plate; large rounded light patches and very small dots are visible. **d:** First pair of legs with a very long thin spine. **e:** Fourth pair of legs; the dentate fringe, claws and a small spur (arrow) on internal claws are visible. Scale bar: a-e = 10 μ m.

small light spots are absent, and large, rounded light patches instead of dark tubercles are present (Figs 1 and 3). In addition, *E. viridianus* sp. n. has a shorter cirrus A, shorter claws, shorter clavae, and a shorter spine on the first pair of legs (Tab. 2).

Echiniscus viridianus sp. n. differs from *E. rufoviridis* by having uniform colour in both the anterior and posterior parts of the body, whereas *E. rufoviridis* is colourless in small specimens but green on the posterior part of the body, extending towards the anterior region, even reaching the scapular plate in larger individuals (Peluffo *et al.* 2002). In addition, *E. viridianus* has an unafaceted terminal plate with two incisions, and *E. rufoviridis* has a faceted terminal plate with a pair of lateral-caudal cuticular folds (Peluffo *et al.* 2002). The plate ornamentation also has some differences. In *E. rufoviridis*, according to du Bois-Reymond Marcus (1944) and Peluffo *et al.* (2002), besides fine dots, depressions are present instead of tubercles. *E. virid-*

ianus sp. n. also has internal claws with a spur; however, the absence of these structures in *E. rufoviridis* needs to be confirmed.

4. DISCUSSION

Some of the characters previously used in descriptions of species in the *viridis* group are problematic, while others are reliable specific characters.

- A) As previously mentioned, colour alone does not appear to reflect phylogenetic affinity in all cases, but may be used to group species in some instances.
- B) The length of the cirrus A is generally a good specific character due to its limited individual variability (see Tab. 1). In some species of the *viridis* group this cirrus is short. It is reported to be 30-40 μ m in *E. viridis* by Ramazzotti (1959), but he did not examine type material, instead referring to Brazilian specimens; it ranges 18-63 μ m (positively correlated with body size) in *E. rufoviridis* according to Peluffo

et al. (2002). In *E. viridissimus*, cirrus A is of intermediate length (80 μm); it is longer in *E. perviridis* [according to Ramazzotti (1959) it is 150-170 μm long in specimens about 260 μm long, but it is 114 μm long in a paratype 290 μm long we measured].

- C) The terminal plate, according to the literature, is faceted in *E. rufoviridis*, slightly faceted or unfaceted in *E. perviridis*, and unfaceted in *E. viridis*, *E. viridissimus* and *E. viridianus* sp. n. However, all of the species have two incisions in the terminal plate that may lead to different individual interpretations of whether the plate is faceted.
- D) Median plate 3 is "present" in *E. rufoviridis* according to du Bois-Reymond Marcus (1944), but Peluffo *et al.* (2002) showed it is not a real plate but an interplate with sculpture. Murray (1910), when describing *E. viridis*, wrote: "...the third median is somewhat obscure, being little more than a dotted area with obscure margins, close to the second pair...". This is the case in the other species of the group.
- E) A small spur is present on the internal claws of *E. viridis*, *E. perviridis* and *E. viridianus* sp. n.; in *E. viridissimus*, and *E. rufoviridis*, according to the literature, the spur is absent, but in *E. viridissimus* we and Nelson (personal communication) noted a very small spur on the internal claws; Peluffo *et al.* (2002) did not report whether the spur was present or absent in *E. rufoviridis*, so this needs to be confirmed.
- F) Plate ornamentation led to some confusion, including the terminology. Murray (1910), in the description of *E. viridis*, wrote: "...colour of plates olive-green, dots darker green, regularly spaced... The dots do not appear as either pits or papillae, but simply as darker patches. They are very regularly spaced and are separated by spaces of about the same diameter as themselves...". Ramazzotti (1959), however, attributed to *E. viridis* a "fine sculpture". Later Ramazzotti & Maucci (1983), on the basis of examination of Brazilian specimens that were considered *E. viridis* by Ramazzotti, changed the description of the cuticular ornamentation of this species, and wrote that in *E. viridis* the plates are "uniformly granulated with dark patches present or absent". Other authors have reported *E. viridis* (see Marcus 1939; du Bois-Reymond Marcus 1944; Schuster & Grigarick 1966; Crowe *et al.* 1970; Morgan & King 1976; Beasley 1978, 1988; Fontoura 1985), but none of them described the fine details of the cuticular ornamentation.
- In specimens of *E. viridis* from the Hawaiian Islands, in *E. perviridis* and in the specimens from North America and the Azores Islands that we describe as the new species *E. viridianus*, the scapular plate, the posterior portions of the paired plates II and III, the median plate 1, the posterior portion of the median plate 2 and the terminal plate have a cuticular

ornamentation consisting, with minor specific differences, of very fine dark dots, larger dark tubercles and very small light spots (Figs 1d and 2c). In these plates of *E. viridissimus* (Fig. 3b, c), the fine dots are clearly smaller and denser, small light spots are absent, and large, rounded light patches instead of dark tubercles are present.

In *E. rufoviridis* the plate ornamentation is also double with very fine dots and light depressions according to du Bois-Reymond Marcus (1944) and Peluffo *et al.* (2002).

- G) All the species of the *viridis* group have claws well developed. In *E. viridianus* sp. n. they are slightly shorter than in the other species of the group (Tab. 2).

In conclusion we maintain that the *viridis* group is well characterised by its particular double cuticular ornamentation (with some differences between the members of the group), by the absence of lateral and dorsal appendages except cirrus A, by well-developed claws, and by a green or grey colour over all the body or in a portion of it. In addition, in our opinion, it is evident that the specimens from North America and from the Azores we examined do not belong to *E. viridis* but to a different new species we have described here and named *E. viridianus* sp. n. Therefore the presence of *E. viridis* in these geographical areas needs to be confirmed.

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