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ECOSYSTEMS

Sudden and simultaneous population outbreak of *Neoaulacoryssus speciosus* in an urban area of 12 municipalities in the Caatinga biome

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Abstract: The ground beetle, *Neoaulacoryssus speciosus* (Coleoptera: Carabidae) is of high relevance to field because it has been recorded as a pest of seeds and young plants of vegetables and other crops and a predator in agricultural crops, forest and weeds in Brazil. However, natural habitat changes are increasing agriculture and forest insect outbreaks in urban areas. A *N. speciosus* population outbreak occurred in October and November 2018 simultaneously in 12 neighboring municipalities at the beginning of the rainy season in the northern region of Minas Gerais State, Brazil. The objectives of this study were to report a sudden and simultaneous population outbreak of *N. speciosus* and to describe the factors of habitat change that could have contributed to this invasion in 12 municipalities in the northern region of Minas Gerais State in the Caatinga biome of Brazil. In addition, female and male genitals were described and illustrated, the scientific classification revised and common names of *N. speciosus* listed. Thousands of males and females of *N. speciosus* agglomerated in shady, humid places during the day and night for about 15 days. *Neoaulacoryssus speciosus* has been identified and illustrated, its scientific classification revised and four common names listed for this species.

Key words: Carabidae, Genitalia, Ground beetle, Infestation, Insect pest, Invasion.

INTRODUCTION

Population outbreaks of carabids (Coleoptera) occur in agricultural, forest and urban areas, with high density of individuals in a short period of time, usually after emergence of their last larval instars or adults from the soil (Eo et al. 2016, Hammond et al. 2018). Carabids, with different feeding habits and producing toxic substances, can be predators in agriculture and forests and negatively affect urban areas and health in humans and animals (Raupp et al. 2010, Tavares et al. 2014). Population outbreaks of carabids in urban areas may be related to regional environmental imbalance influenced by factors such as deforestation, reduction in the number of biocontrol agents, agricultural and/or forest crops in monocultures (Queiroz & Garcia 2007, Albuquerque et al. 2008), and climatic phenomena (Alva-Dávalos et al. 2002).

Neoaulacoryssus speciosus (Dejean) (Coleoptera: Carabidae: Harpalinae) larvae, reported as its synonym *Arthrostictus speciosus* (Dejean), develop in the soil and their adults live in forest fragments and can move to nearby agricultural and/or urban areas in population outbreaks (Cividanes et al. 2003, 2010). This insect, reported as *A. speciosus* (Drury), prefers dark environments with high air and soil moisture

(da Costa Lima 1952). Adults and larvae of *N. speciosus*, reported as *A. speciosus* (Drury), feed on post-sown seeds of pearl millet, *Pennisetum glaucum* (L.) R. Br. (Poales: Poaceae) and young plants of vegetables and other crops (da Costa Lima 1952). However, necrophagy on carcasses of pigs, *Sus* L. (Artiodactyla: Suidae) has been reported for this species, reported as *A. speciosus* (Drury), in Serra Talhada, Pernambuco State, Brazil (Mayer & Vasconcelos 2013, de Almeida et al. 2015) and a predatory habit on caterpillars of the velvetbean caterpillar, *Anticarsia gemmatalis* Hübner (Lepidoptera: Noctuidae) by *Athrostictus* sp. 1 and *Athrostictus sulcatulus* (Dejean) in Jaboticabal, São Paulo State, Brazil (Cividanes et al. 2014). In addition, *N. speciosus* reported as *A. speciosus* (Dejean) is recorded as a predator in agricultural crops of corn *Zea mays* L., lettuce *Lactuca sativa* L. (Poales: Poaceae), eggplant *Solanum melongena* L., gilo *Solanum aethiopicum* L., tomato *Solanum lycopersicum* L. (Solanales: Solanaceae), soybean *Glycine max* (L.) Merr. (Fabales: Fabaceae), etc. and forest of pine *Pinus* sp. (Pinales: Pinaceae) besides a range of weed species in Guaíra and Jaboticabal, São Paulo State (Cividanes & Cividanes 2008, Cividanes et al. 2003, 2017, 2018a) and forest fragments and orange orchards, *Citrus × sinensis* (L.) Osbeck (Rutales: Rutaceae) in Gavião Peixoto, São Paulo State (Cividanes et al. 2010).

The objectives of this study were to report a sudden and simultaneous population outbreak of *N. speciosus* and to describe the factors that could have contributed to this invasion in an urban area of 12 neighboring municipalities in the northern region of Minas Gerais State, Brazil in the Caatinga biome. In addition, female and male genitals were described and illustrated, its scientific classification revised and common names of *N. speciosus* presented.

MATERIALS AND METHODS

A population outbreak of *N. speciosus* suddenly began on 30 October 2018 with thousands of adults of this insect in the urban area of Januária municipality (Figure 1 and Table I). This outbreak lasted about 15 days and the number of beetles gradually decreased after the first week. Rainfall and average air temperature in Januária in October and November 2018 during the occurrence of *N. speciosus* were 32.0 and 136.1 mm and 28.3 and 25.3 °C, respectively (INMET 2018).

In addition to Januária, the population outbreak of *N. speciosus* extended to the urban area of 11 neighboring municipalities in the northern region of Minas Gerais State, Brazil (Figure 1 and Table I). The occurrence of *N. speciosus* in these municipalities was confirmed by telephone calls, reading reports on internet blogs and direct observation in visits to some of them by the authors and partners of this work.

The locations of *N. speciosus* population outbreaks in the 12 listed municipalities were georeferenced and their coordinates used to prepare an occurrence map (Figure 1) for this insect in a laboratory of the *Departamento de Ciências do Meio Ambiente* at the *Universidade Federal Rural do Rio de Janeiro* in Três Rios, Rio de Janeiro State, Brazil using the ArcGIS Geographic Information System program, version 10.2.1 (Environmental Systems Research Institute®; Redlands, California, United States of America), with use licensed by SJM da C de M.

Photographs of *N. speciosus* in an urban area of the municipality of Januária were obtained (Figures 2a-2d) with a digital camera having a 35 mm lens, ISO-40, attached to a Smartphone (Samsung Electronics Co., Ltd.®; Seoul, South Korea).

About 40 *N. speciosus* adults, without sex identification, were collected per municipality

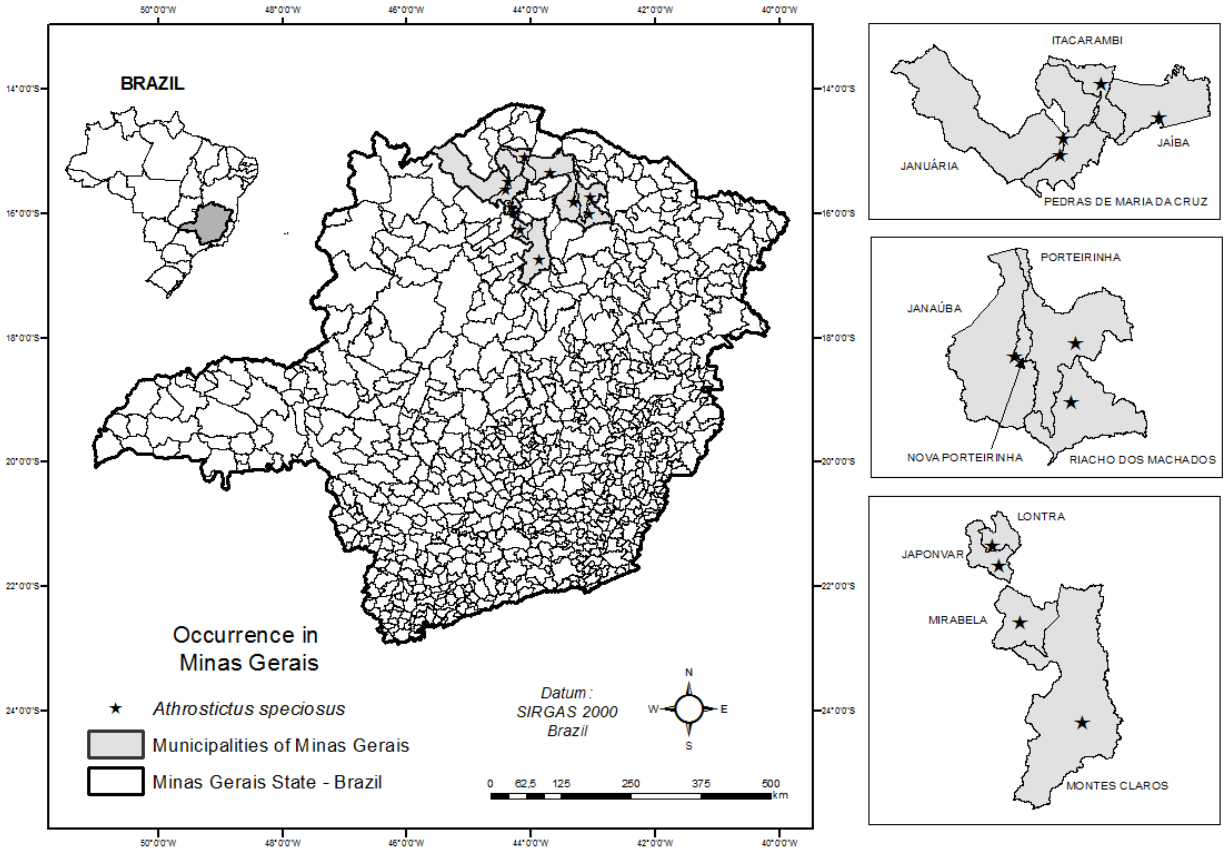

Figure 1. Municipalities of the northern region of Minas Gerais State, Brazil with recorded occurrence of *Neoaulacoryssus speciosus* (Coleoptera: Carabidae).

and placed in 250 mL plastic pots with the perforated lid. These insects were brought to the *Laboratório de Entomologia* of the *Instituto Federal do Norte de Minas Gerais* in Januária, sexed and mounted using an entomological pin. A part of the beetles was sent to Dr. Germano Henrique Rosado Neto, from the *Departamento de Zoologia* of the *Universidade Federal do Paraná* (UFPR) in Curitiba, Paraná State, Brazil, to identify the species by its external and internal morphological characteristics with dichotomous key of the genus *Neoaulacoryssus* provided by Noonan (1985) and Shpeley et al. (2017). The specimens sent to the UFPR were deposited at the *Museu de Entomologia* of this institution under registration number 0152B/2018-RN. Another part of the beetles was preserved in 70% ethanol and sent to the *Laboratório de Biologia Celular* of the *Universidade Federal dos Vales do Jequitinhonha e Mucuri* in Diamantina, Minas Gerais State, Brazil where the female and male genitals were extracted, photographed and described.

Neoaulacoryssus speciosus females and males were sexed by extraction of the female ovipositor and male aedeagus with surgical forceps (Figures 3a-3d). Genitals were described after analysed, based on those of the internal morphology of insects of the Carabidae family provided by Noonan (1985) and Shpeley et al. (2017).

The scientific classification of *N. speciosus* has been updated (Table II) and scientific papers with the name "*Neoaulacoryssus speciosus*" and its synonyms "*Athrostictus speciosus*" and "*Selenophorus speciosus*", published until the

Table I. South latitude, West longitude, altitude, and area (Km2)* of 12 municipalities of the northern region of Minas Gerais State, Brazil with recorded occurrence of *Neoaulacoryssus speciosus* (Coleoptera: Carabidae).

Municipality	South latitude	West longitude	Altitude	Area (Km^2)
Itacarambi	15° 06'	44° 05'	445 m	1,252,074
Jaíba	15° 20'	43° 40'	470 m	2,740,276
Janaúba	15° 48'	43° 18'	516 m	2,181,319
Januária	15° 29'	44° 21'	434 m	6,691,174
Japonvar	15° 59'	44° 16'	847 m	376,371
Lontra	15° 54'	44° 18'	602 m	257,220
Mirabela	16° 15'	44° 09'	600 m	720,828
Montes Claros	16° 44'	43° 51'	678 m	3,568,941
Nova Porteirinha	15° 48'	43° 18'	500 m	121,017
Pedras de Maria da Cruz	15° 36'	44° 23'	464 m	1,520,086
Porteirinha	15° 44'	43° 01'	556 m	1,749,683
Riacho dos Machados	16° 00'	43° 02'	1130 m	1,308,545
Total	-	-	-	22,487,534
Average	-	-	603	-

***Total area of the municipality.**

date of submission of this manuscript, read to listing of names of this species.

Neoaulacoryssus speciosus (Dejean 1829)

Description. Diagnosis. Elytral macrosculpture is composed of elongate punctures in merging and chain-like places, with very short pubescence, with its length almost half or less the width of the elongated punctures. Elytra are reddish, pronotum is greenish and head is greenish-bluish-violaceous. **Female reproductive tract and genitalia.** Gonocoxite 2 is moderately thick, nearly straight. Bursa copulatrix is moderately large; spermatheca is long curved inflated initiating near base of common oviduct; spermatheca is terminated with two sausage-like extensions; spermatecal gland duct initiates near base of spermateca. Spermatecal gland duct is moderately long, gland triramous, with bulb-like swelling of duct basad gland. Setae in the female genitalia probably have sensory function. **Male aedeagus.** Top portion of phallic median lobe is long, narrowly tapered, symmetrically rounded in dorsal/ventral feature, with two small ventral hooks; endophalus with three fields of short fine spines, a longer and wider field in dorsal feature, a shorter and narrow field in left lateral feature, and a small field near the ostium; without lamina. Ventral surface of shaft with two rows of basad directed sharp saw-toothed ridges.

Outbreak. The insect causing the outbreak was identified as *N. speciosus* and the description and illustration of the female and male genitals are important for the identification of this species. *Selenophorus* (p. 80) and *speciosus* (p. 117) were described by Dejean in 1829 as the original binomen *Selenophorus speciosus* Dejean. In 1932, Csiki listed *speciosus* as a species in the genus *Athrostictus* (p. 1195). In 1985, Noonan described a new genus *Neoaulacoryssus*, and designated *Selenophorus speciosus* as the type species (Table II). Four common names were found for *N. speciosus*. They are carabid, carabe, ground beetle (Bousquet 2012), and vegetable beetle.

The sudden and simultaneous population outbreak of *N. speciosus* was recorded in 12 neighboring municipalities, with altitude between 434 and 1,130 m, at the beginning of

Figure 2. ***Neoaulacoryssus speciosus*** **(Coleoptera: Carabidae) in an urban area of the municipality of Januária, northern region of Minas Gerais State, Brazil (a and b); an adult of** ***N. speciosus*** **(c);** ***N. speciosus*** **at the base of a streetlight pole located in an urban garden (arrow) (d).**

the rainy season in the northern region of Minas Gerais State in the Caatinga biome of Brazil. Thousands of adults of both sexes of *N. speciosus* were observed in the analyzed municipalities, but the presence of this insect may also have occurred in other municipalities. Insects in the daytime were observed agglomerated in shady and moist places on the ground, including the base of streetlight poles, manhole and sidewalk edges, gardens, and rooftop gutters (Figures 2a-2d). At night, the beetles were observed in any artificially lit places including trade store lamps, streetlights, houses, and streets.

During the daytime, thousands of *N. speciosus* individuals were observed on myrtle trees, *Myrtus* sp. (Myrtales: Myrtaceae), a common plant in the urban gardens in Januária, but without damaging them (Figures 2a-2b). *Neoaulacoryssus speciosus* mating was observed during the night, but no egg was found at the sites of this insect occurrence in Januária.

Some people reported minor accidents from direct contact with *N. speciosus* adults during the outbreak of this insect, such as skin irritation. However, no official record of an accident with this insect was obtained from health facilities in the municipalities listed.

The genus *Neoaulacoryssus* Noonan includes only the species *Neoaulacoryssus cupripennis* (Gory) and *N. speciosus* (Noonan 1985). *Neoaulacoryssus cupripennis* has been reported to the West Indies, specifically in the eastern South America region known from Cayenne on the mainland, the islands of the Dutch Antilles and the islands of Saint Lucia, Mustique and Grenada in the Lesser Antilles (Shpeley et al. 2017). *Neoaulacoryssus speciosus* has been reported for South America (Shpeley et al. 2017).

Neoaulacoryssus cupripennis differs from *N. speciosus* by having the entire dorsum metallic cuprous (Shpeley et al. 2017). *Neoaulacoryssus cupripennis* and *N. speciosus* may be conspecific, due to the nearly identical form of the phallic medial lobe of the endophallus of these species (Noonan 1985). The three spine fields of these insects are similar in placement on the surface of the everted endophallus and length of spines, but differed in size and shape of the field (Shpeley et al. 2017).

The lack of information on *N. speciosus* morphology increases the importance of characterizing the female and especially the male genitalia of this insect for taxonomic

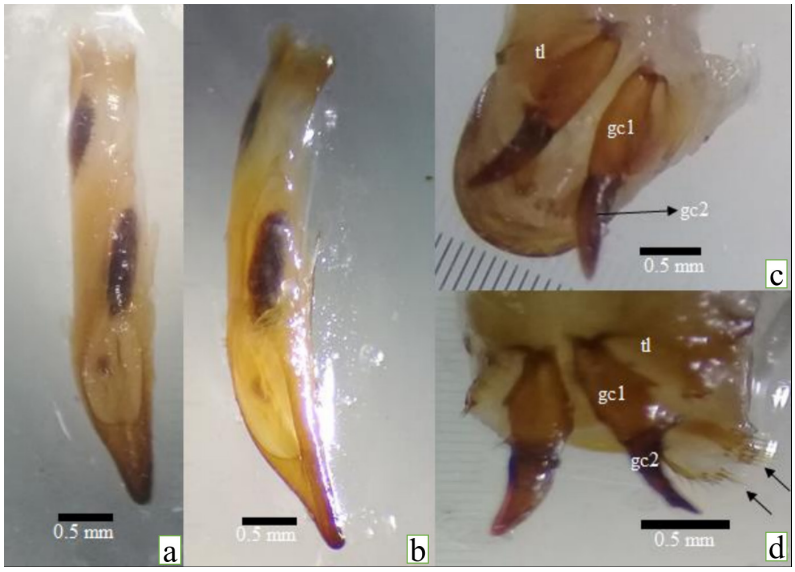

Figure 3. Female ovipositor and male aedeagus of *Neoaulacoryssus speciosus* (Coleoptera: Carabidae): dorsal (a) and lateral (b) aspects of male aedeagus; female ovipositor sclerite (c and d), gc 1= gonocoxite 1, gc 2= gonocoxite 2 and tl= lateral tergite. Arrows show the seta. Bar= 0.5 mm.

and evolutionary studies (Shpeley et al. 2017). Photographs of *N. speciosus* can be used in medical situations to identify the species during diagnosis of allergies or irritations caused by insect contact. The valid name for the species studied is *Neoaulacoryssus speciosus* (Dejean), as confirmed by Shpeley et al. (2017). The common names of *N. speciosus* are also used for other species in this group and no common name is specific for *N. speciosus*.

Potential associating factors to invasion

Neoaulacoryssus speciosus outbreaks have been reported at least since 1996 in Januária, with a significant beetle population, mainly in 1996 and 2009 as reported by local people. The outbreaks described occurred from October to February, months of the rainy season, and with increasing numbers of individuals since at least 2014. The outbreak reported in this work was the most significant (personal information, CWG de M). Outbreaks of a field cricket species, near *Gryllus* L., 1758 (Orthoptera: Gryllidae) were reported from early March to late April 2018 and 2019 after *N. speciosus*, with the largest population of this field cricket in 2018 in Januária (personal information, CWG de M). The begining of the rainy season in the northern region of Minas Gerais State coincided with the *N. speciosus* population outbreak, characterized by high air temperatures and air relative humidities (Silva et al. 2017). Deforestation and expansion of monoculture crops (de Araújo et al. 2019) may have contributed to the population outbreaks of *N. speciosus* in the northern region of Minas Gerais State. On the other hand, weed emergence at the beginning of the rainy season attracted carabids as shelter and food in Wageningen, Netherlands (Saska et al. 2007).

Myrtus L. trees, used as shelter by *N. speciosus* in Januária, are of a botanical genus native to southwestern Europe and northern Africa (Siracusa et al. 2019), but any plant species in the urban area of Januária could have been used as a shelter by this insect. *Neoaulacoryssus speciosus*, reported as *A. speciosus* (Drury), damages post-sown seeds of *P. glaucum* and young plants of vegetables and other crops (da Costa Lima 1952). However, predatory behavior by *N. speciosus* reported as *A. speciosus* (Dejean) has been recorded on orchards of *C.* × *sinensis* and forest fragments (Cividanes et al. 2010) and agricultural crops of *G. max*, *L. sativa*, *S. aethiopicum*, *S. lycopersicum*, *S. melongena*, *Z. mays*, etc. and

Table II. Scientific classification of *Neoaulacoryssus speciosus.*

Scientific classification	
Order	Coleoptera L., 1758
Suborder	Adephaga Schellenberg, 1806
Family	Carabidae Latreille, 1802
Subfamily	Harpalinae Bonelli, 1810
Supertribe	Harpalitae Bonelli, 1810
Tribe	Harpalini Bonelli, 1810
Subtribe	Harpalina Bonelli, 1810
Genus	*Selenophorus* Dejean, 1829
	Athrostictus (Csiki, 1932)
	Neoaulacoryssus (Noonan, 1985)
Binomial name	
Species	*Selenophorus speciosus* Dejean, 1829 (original binomial)
	Athrostictus speciosus (Csiki, 1932)
	Neoaulacoryssus speciosus Dejean, 1829 (current valid name)

forest of *Pinus* sp. besides a range of weeds in Gavião Peixoto, Guaíra and Jaboticabal, São Paulo State, Brazil (Cividanes & Cividanes 2008, Cividanes et al. 2016, 2018a, 2018b). The predation of *A. gemmatalis* caterpillars by *Athrostictus* sp. 1 and *A. sulcatulus* adults was studied for the biological control of this pest, with percentage of adult carabids that caused prey mortality and dry mass consumed of the prey (mean ± SE) of 50.0 (N= 20) and 8.0% (N= 12) and 0.0048 ± 0.0003 and 0.0027 ± 0.0001 mg, respectively (Cividanes et al. 2014). *Neoaulacoryssus speciosus*, reported as *A. speciosus* (Dejean), prefers to forage in dark places and with moist soil during the daytime like those with litter accumulation (Cividanes et al. 2003, 2010).

Other ecological importance

Neoaulacoryssus speciosus direct contact with the human skin can cause dermatitis due to the repellency defense mechanism of this insect, but they are rare because the insect has reduced flight capacity. The secretion of chemicals, such as formic acid with irritating effect on invertebrates and vertebrates, by carabid adults is common as a defense against predators (Bonacci 2013). This compound has also been reported for ants of the subfamily Formicinae (Hymenoptera: Formicidae) (Rossini et al. 1997). However, studies of the defense mechanism and repellency of *N. speciosus* are scarce.

CONCLUSIONS

Neoaulacoryssus speciosus has been identified as the insect causing sudden and simultaneous outbreaks in an urban area of 12 municipalities in the northern region of Minas Gerais State in the Caatinga biome of Brazil, its female and male genitals illustrated, its scientific classification revised and four common names listed for this species. Deforestation and expansion of monoculture crops may have contributed to the population outbreaks of *N. speciosus* in the northern region of Minas Gerais State. The begining of the rainy season in the northern region of Minas Gerais State coincided with the *N. speciosus* population outbreak, characterized by high air temperatures and air relative humidities.

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geographical distribution, and morphological description of *Neoaulacoryssus speciosus*. To Prof. Ana Paula Araújo Silva for the information on *N. speciosus* infestation in the municipalities of Janaúba, Nova Porteirinha, Porteirinha, and Riacho dos Machados. To the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) - Finance Code 001, Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG), and Programa Cooperativo sobre Proteção Florestal (PROTEF) of the Instituto de Pesquisas e Estudos Florestais (IPEF) for their financial support.

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