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Authors: Sublett, Clayton A., and Cook, Jerry L.

Source: Florida Entomologist, 98(2) : 704-713

Published By: Florida Entomological Society

URL: <https://doi.org/10.1653/024.098.0246>

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# Morphology of the 1st gonapophysis in the genus *Neoplea* (Hemiptera: Heteroptera: Pleidae), including an evaluation of its taxonomic importance

Clayton A. Sublett<sup>1</sup> and Jerry L. Cook<sup>1,2\*</sup>

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## Abstract

The 1st gonapophysis of species in the genus *Neoplea* Esaki and China, 1928, includes a pattern of spurs that aids in depositing eggs into plant tissue. Within each species the pattern of spurs is relatively consistent, especially toward the apical end. Thus, there is taxonomic value in the morphology of this structure. Many of the currently known species of *Neoplea* can be identified using only the 1st gonapophysis, although intraspecific variation exists and characteristics may overlap in closely related species. All *Neoplea* species whose 1st gonapophyses are known are described and illustrated.

Key Words: external genitalia; classification; taxonomic character; pygmy backswimmer

## Resumen

El ovipositor de las especies en el género *Neoplea* incluye un patrón de espinas que son utilizadas presumiblemente para ayudar en la deposición de huevos en el tejido vegetal. Dentro de cada especie, el patrón de estas espinas es relativamente consistente, especialmente hacia el extremo apical. Por lo tanto, hay valor taxonómico en la morfología de esta estructura. Muchas de las especies conocidas actualmente de *Neoplea* pueden identificarse utilizando únicamente el ovipositor, aunque existe variación en la especie y en las especies estrechamente relacionadas presenta cierta superposición en caracteres. Se describen e ilustran todas las especies de *Neoplea* cuyos ovipositores son conocidos.

Palabras Clave: genitales externos; clasificación; carácter taxonómico; notonectido pigmeo

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External genitalia of insects are morphologically diverse and have considerable taxonomic value. Gullan & Cranston (2005) summarized that the male external genitalia often have characteristics that are widely used in distinguishing species, whereas the female external genitalia are often simpler and less varied. In the order Hemiptera, the female reproductive system often has substantial taxonomic value at the levels of superfamily, family, genus, and species (Pendergrast 1957; Scudder 1959; Papáček 2002, 2008; Cook 2011). At the levels of superfamily and family, the ovipositor has valuable taxonomic characters (Scudder 1959), and at the genus level, the spermatheca is taxonomically informative (Pendergrast 1957). In the family Helotrephidae, the sister family to Pleidae, Papáček (2002, 2008) showed that the 1st gonapophysis is taxonomically informative at the genus level. Cook (2011) showed that aspects of the 1st gonapophysis may be informative at both the species and genus level in pleids.

The morphology of the external genitalia of pleids has been treated in a general sense by several authors. Wefelscheid (1912) gave a general description of the ovipositor of *Plea minutissima* Leach, 1817. Scudder (1957) refined the terminology and Scudder (1959) illustrated the ovipositor of *Plea atomaria* (Pallas, 1771) (= *P. minutissima*). Of the female pleid external genitalic components, the 1st gonapophysis has the most modifications among species and is relatively large and dis-

tinct. This portion of the female external genitalia has been historically referred to as the ovipositor by pleid researchers. However, we will use the term 1st gonapophysis, because we are referencing a specific part of the ovipositor (see Snodgrass 1935).

Drake & Chapman (1953) noted that there was a large amount of overlap in the morphological characters being used to identify species in the family Pleidae. The first basis of species designation relied entirely on color and facial pattern (Fieber 1844), but these characters were later shown to be unreliable (Lundblad 1933). Drake & Chapman (1953) expanded the characters used to describe pleids, including comparing widths of the pronotum and scutellum, the state of body sculpturing, and the form of the clavus. In a subsequent paper, which was never published, they planned to illustrate pleid antennae, opercula (sternite VIII) of the male and female, sternal carinae, male parameres, and female 1st gonapophyses, all of which they thought had taxonomic significance. Several authors began incorporating some of these characters in descriptions of *Neoplea* (Bachmann 1968; Roback & Nieser 1974; Nieser 1975) but Benzie (1989) still found taxonomic character use to be inconsistent and confusing.

The 1st gonapophysis of species of *Neoplea* has been illustrated by several authors (Bachmann 1968; Roback & Nieser 1974; Nieser 1975) but none have discussed the taxonomic usefulness of the character. All

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simply stated that their new species had 1st gonapophyses as illustrated in the figures they provided. However, it is clear from these figures that 1st gonapophysis morphology differs between the species they described and that their intent was to illustrate this structure for its taxonomic usefulness. In this study, we compare the 1st gonapophysis of 12 of the 15 species of *Neoplea* as well as the morphological variation of this structure within 2 species, *Neoplea harnedi* (Drake 1922) and *N. striola* (Fieber 1844). Herein, we also expand on the description of the 1st gonapophysis of Pleidae given by Scudder (1959), with a concentration on the species of the genus *Neoplea*.

## Materials and Methods

Specimens were identified by JLC, and CAS performed dissections. Multiple specimens of *N. striola* and *N. harnedi* and 1 specimen each of the remaining available species were dissected. Genital dissections were based on the methods of Flowers (1999). Specimens were relaxed in warm water for approximately 10 min before dissecting the genitalia from under the overlying sclerites. Some specimens had the 8th abdominal sternite lifted and were soaked for an additional 5 min before they were sufficiently relaxed for dissection. Abdomens of some of the specimens were removed before dissecting the genitalia. To isolate the 1st gonapophysis, genitalia were further dissected in 70% ethanol. All dissections were performed using a Motic SMZ-168 stereomicroscope.

Genitalia were temporarily stored in 99.5% anhydrous glycerin for initial observations and photographed before being permanently mounted on slides. Slide mounts were based on the methods of Smith-

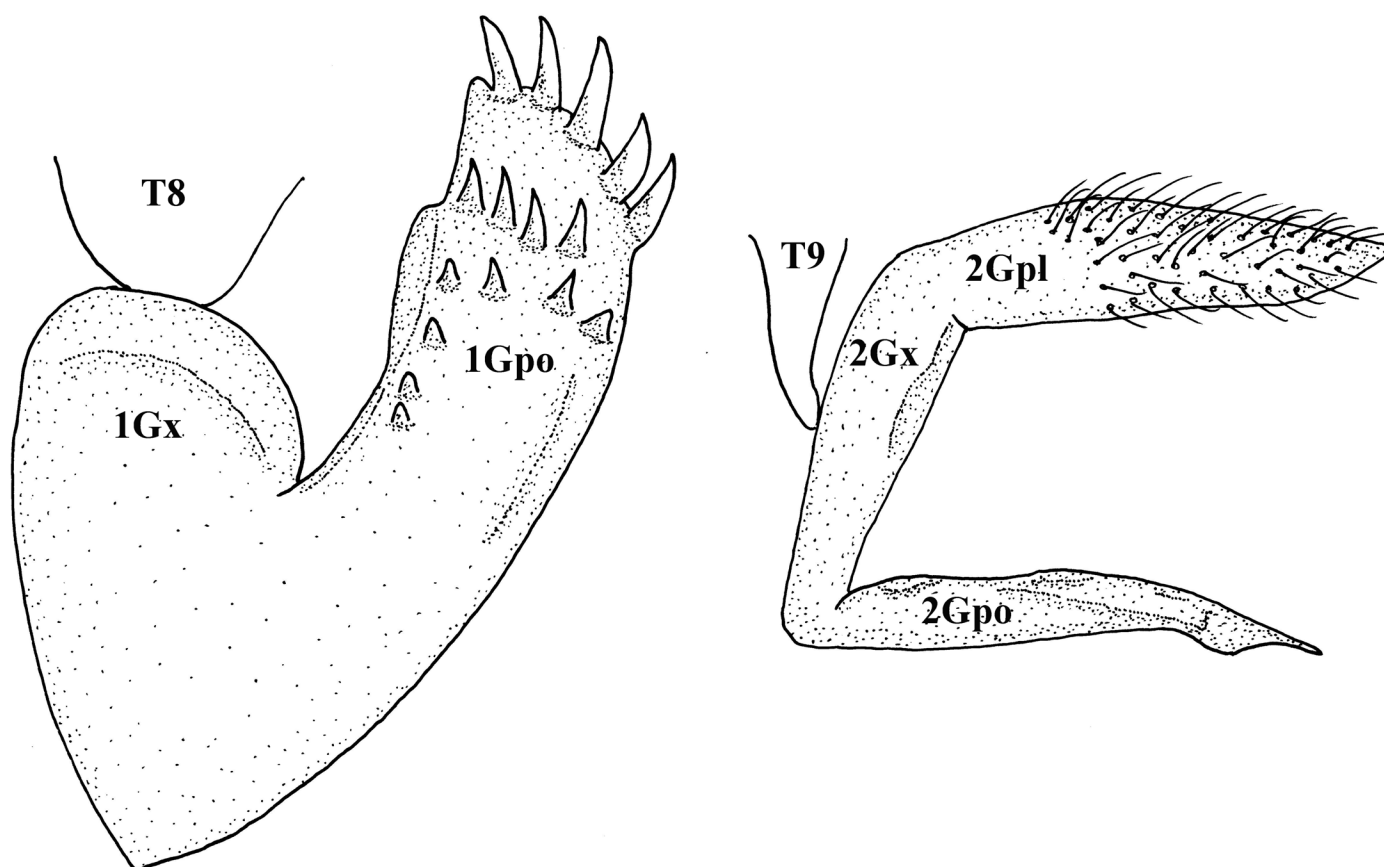
Herron & Cook (2014). First gonapophyses were dehydrated in an ethanol series, cleared in xylene, and mounted in Damar balsam.

Observations were made using an Olympus B-Max 52 compound microscope with 10X and 20X universal objectives with differential interference contrast prisms, and 1st gonapophyses were photographed as temporary mounts with an Olympus DP-72 camera on the aforementioned microscope using cellSens Standard (Olympus Corporation 2010) and the stacking program Combine ZP (<http://www.hadleyweb.pwp.blueyonder.co.uk/>). Drawings were made directly from photographs or redrawn from published figures as noted.

## Results and Discussion

### GENERAL PLEID FEMALE GENITALIC MORPHOLOGY

The sclerotized external genitalia of Pleidae are all part of abdominal segments VIII and IX (Fig. 1). At rest, the abdominal sterna conceal the external genitalia, although part of the 1st gonapophysis is sometimes visible. The 1st gonocoxa is subtriangular and fused through most of 1 side to the 1st gonapophysis. It is broadly attached, but not fused, to the 8th tergite. The 1st gonapophysis is rectangular, longer and narrower than 1st gonocoxa, and sclerotized. The apical half of the 1st gonapophysis has rows of spurs that are generally larger toward the apex. The 2nd gonocoxa is smaller and narrower than the 1st, ventrally connected to the 2nd gonapophysis and dorsally connected to the gonoplares. The right and left 2nd gonapophyses are fused in the apical half. In lateral profile the fused 2nd gonapophyses are narrow and arched toward



**Fig. 1.** General external female genital morphology in *Neoplea*, showing abdominal segments VIII and IX; T8 and T9 are tergal sclerites of abdominal segments VIII and IX, respectively; 1Gx and 2Gx are the 1st and 2nd left gonocoxae; 1Gpo and 2Gpo are the 1st and 2nd left gonapophyses; 2Gpl is the gonoplares, which is located on segment IX. Orientation of these structures is skewed to allow for viewing of all structures, but they overlap and tilt when attached to the abdomen.

the gonoplace. The apex is acuminate and in ventral profile the apical end appears bulbous. The gonoplace is an elongated lobe with the apical half to two-thirds densely covered in long setae.

#### FEMALE 1ST GONAPOPHYSIS MORPHOLOGY OF NEOPLEA

The 1st gonapophysis in species of *Neoplea* is a rectangular structure with a generally species-specific pattern of rows of spurs that are directed posteriorly and slightly dorsally. On the dorsal apical edge, nearly all species of *Neoplea* have a lobe-like projection, here designated the dorsal lobe of the 1st gonapophysis (Fig. 2, dl), which is intraspecifically consistent in size. Only 1 described species, *Neoplea notana* (Drake & Chapman 1953), does not have a defined dorsal lobe, but instead has a crenate dorsoapical surface. Most species of *Neoplea* have a well-defined dorsal depression (Fig. 2, dd), which is provided with a small spine on the apical margin in some species. These small spines differ from the spurs in that the spurs emerge from sockets and are moveable. It is unknown if this movement is associated with independent muscles or if the socket simply allows them to be moved relative to the 1st gonapophysis and other spurs. Along the ventral edge there is a cuticular ridge (Fig. 2, vr) present in some species. At the ventroapical corner some species have a small tooth (Fig. 2, vt). Setae are often associated with the 1st gonapophysis, and although they do not form species-specific patterns, the abundance of setae is consistently densely setose, sparsely setose, or glabrous.

Along the apical edge there is a vertical row of 5 to 6 spurs, usually relatively large, that are hereby designated as the apical spurs (Fig. 2, A<sub>1</sub>). Anterior to the apical spurs in all species of *Neoplea* is a 2nd vertical row of 4 to 6 spurs, designated as the primary spurs (Fig. 2, P<sub>1</sub>). In some species, such as *N. striola*, there is some variation in the number of primary spurs; however, in other species, such as *N. harnedi*, the number appears to be fixed. Anterior to the primary spurs is a 3rd vertical row of spurs, and in some cases this is followed by a partial 4th row of spurs, designated as the secondary and tertiary spurs (Fig. 2, S<sub>1</sub>; T<sub>1</sub>), respectively. The primary, secondary, and tertiary rows of spurs

are usually relatively straight, but may be slightly arched. Just ventral to the dorsal edge of the 1st gonapophysis is a horizontal line of spurs that extends toward the base of the 1st gonapophysis, designated as the lateral spurs (Fig. 2, L<sub>1</sub>). Often 1 each of the primary, secondary, and tertiary spurs are in line with the lateral spurs, but only those not designated as primary through tertiary are designated as lateral. Occasionally spurs do not fall into any of these categories and are designated as accessory spurs (Fig. 2, U).

Although many of the structures and patterns are relatively consistent for each species, there is some variability. The relative size and number of spurs tends to be most stable in the apical and primary rows and most variable in the lateral and tertiary rows. Therefore, it is not possible to use exact counts and sizes of spurs to identify species, but the general characteristics of the 1st gonapophysis, especially if more than 1 specimen of a species is available, can usually be used as a sound taxonomic character. Below are the general characteristics of the 1st gonapophysis of each species of *Neoplea*, except where the 1st gonapophysis is unknown. Intraspecific variation is documented for *N. striola* and *N. harnedi*.

#### *Neoplea absona* (Drake & Chapman, 1953) (Fig. 3)

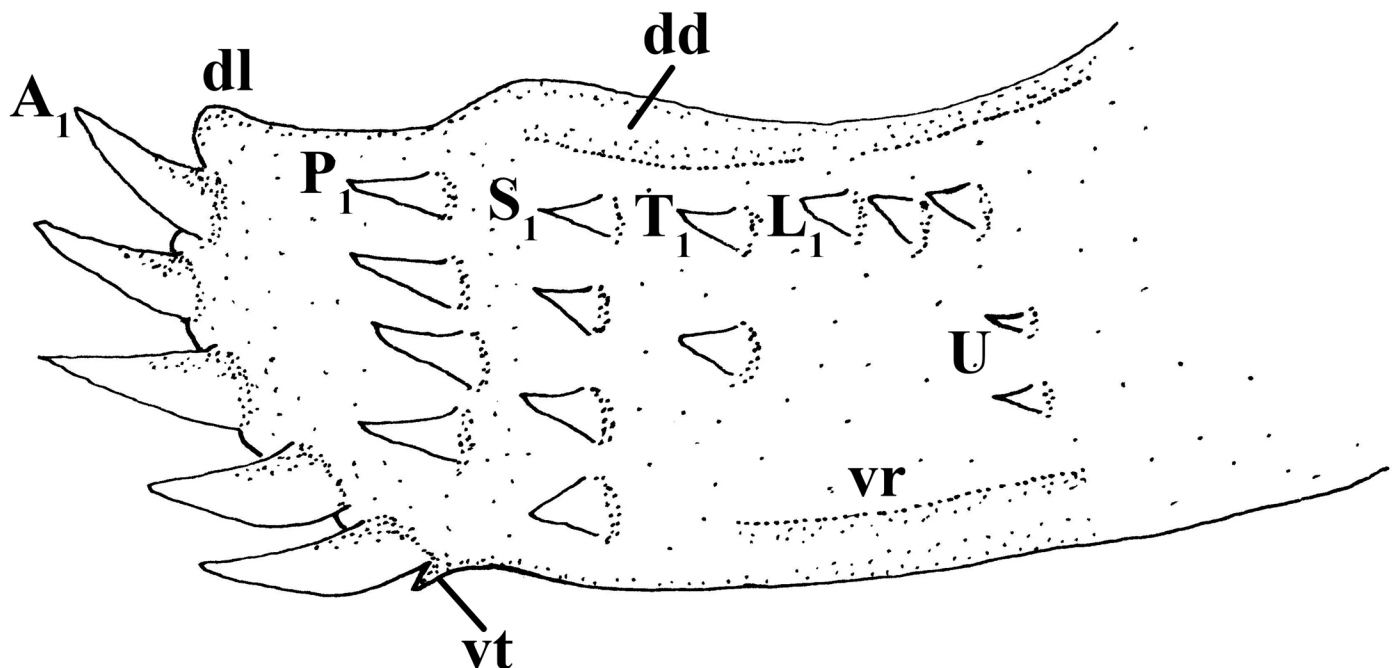
Apical row: 5 spurs; A<sub>3</sub> and A<sub>5</sub> subequal, largest apical spurs; A<sub>1</sub> and A<sub>4</sub> subequal; series of A<sub>1</sub> to A<sub>5</sub> increase incrementally in size.

Primary row: 5 spurs; P<sub>5</sub> longer and thinner than other primary spurs, located near apex and may be mistaken for an apical spur; series of P<sub>1</sub> to P<sub>5</sub> increases in length, P<sub>1</sub> and P<sub>2</sub> subequal; primary row weakly arched towards apex.

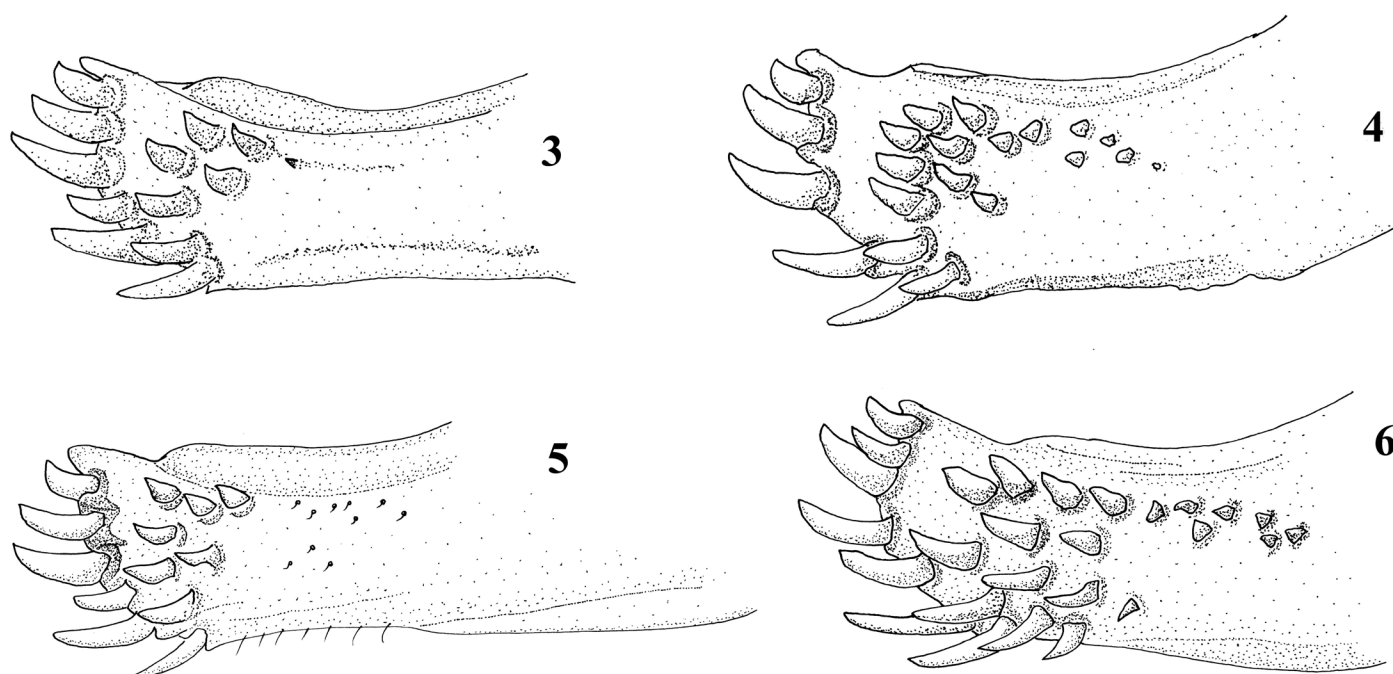
Secondary row: 2 spurs; S<sub>1</sub> and S<sub>2</sub> subequal; both near dorsal edge; S<sub>1</sub> more posterior than S<sub>2</sub>.

Tertiary row: 1 spur; T<sub>1</sub> very small, almost missing, just anterior to S<sub>1</sub>.

Additional features: small tooth-like projection of 1st gonapophysis ventral to P<sub>5</sub>; dorsal lobe thin, thinner than apical spurs; thin spur



**Fig. 2.** General 1st gonapophysis morphology in *Neoplea*. Outer lateral surface of the right 1st gonapophysis with apex to the left and dorsal edge at the top of the figure. All following figures are oriented to match Fig. 2. A<sub>1</sub>: 1st spur of apical row; P<sub>1</sub>: 1st spur of primary row; S<sub>1</sub>: 1st spur of secondary row; T<sub>1</sub>: 1st spur of tertiary row; L<sub>1</sub>: 1st spur of lateral row; U: accessory spurs; dd: dorsal depression; dl: dorsal lobe; vr: ventral ridge; vt: ventral tooth.



Figs. 3–6. Outer lateral surface of the right 1st gonapophysis of species of *Neoplea*. *Neoplea absona* (3); *Neoplea apokkana* (4); *Neoplea argentina* (5); *Neoplea borellii* (6).

on opposing side of 1st gonapophysis can sometimes be seen projecting above dorsal surface of 1st gonapophysis (not shown in Fig. 3); dorsal depression prominent and complete; ventral depression observable on about 80% of 1st gonapophysis.

Nieser (1975) included a figure of the 1st gonapophysis but made no comment on its structure. From his figure, the general 1st gonapophysis structure and size of spurs are consistent with the above description except for 2 minor differences. He figured 2 additional secondary spurs ventral to those in Fig. 3. One of these is likely the projection of the spur we noted on the opposing side of the 1st gonapophysis, thus leaving his specimen with 1 extra secondary spur. Nieser (1975) also showed 3 small lateral spurs. Because we did not examine his specimens, the accuracy of the drawings is unknown. The distribution of *N. absona* is unclear. It has been collected from Suriname and Argentina and could be a widespread species or possibly a species complex.

#### *Neoplea apokkana* (Drake & Chapman, 1953) (Fig. 4)

Apical row: 5 spurs;  $A_3$  longest apical spur;  $A_4$  and  $A_5$  subequal, slightly shorter and thinner than  $A_3$ ; distinct gap between  $A_3$  and  $A_4$ ; spurs progressively longer from  $A_1$  to  $A_3$ ;  $A_1$  robust, subtriangular, shortest apical spur.

Primary row: 6 spurs;  $P_4$ ,  $P_5$  and  $P_6$  subequal, longest primary spurs;  $P_1$  and  $P_2$  slightly shorter than  $P_3$ ; primary row weakly arched apically.  $P_6$  is almost on the apex and could be confused for an apical spur.

Secondary row: 4 spurs;  $S_1$ ,  $S_2$ , and  $S_3$  subequal in length, similar in size to  $P_1$  and  $P_2$ ;  $S_1$ ,  $S_2$ , and  $S_3$  in line with  $P_1$ ,  $P_2$ , and  $P_3$ , respectively, form a straight line;  $S_4$  in line with  $P_4$  but offset from  $S_3$ , could be confused for a tertiary spur.

Tertiary row: 1 spur; slightly smaller than secondary spurs.

Lateral row and accessory spurs: 3 well-developed, short spurs; well-developed spurs followed by 3 short nub-like spurs; all spurs de-

crease in size from posterior to anterior end; spurs not in regular rows making it difficult to designate spurs as lateral or accessory.

Additional features: 1 thin spur on opposing side of 1st gonapophysis (not shown in Fig. 4); ventral tooth-like projection absent; dorsal lobe small, about as wide but less than half the length of  $A_1$ ; dorsal depression complete but not prominent; broad, arched emargination between dorsal lobe and depression; ventral ridge present along most of ventral edge; distinct separation between the apical row and primary row, except near ventral edge.

A distinctive character of *N. apokkana* is the broad gap between the apical and primary spur rows. A gap is found between these rows in other species of *Neoplea*, but it is most pronounced in *N. apokkana*. This species inhabits the eastern Gulf Coast region of the United States and has been recorded from Florida and Mississippi; it has also been found in Hawaii, possibly as an introduced species (Polhemus, 1996).

#### *Neoplea argentina* (Drake & Chapman, 1953) (Fig. 5)

Apical row: 5 spurs;  $A_3$  and  $A_5$  subequal in length, longest apical spurs;  $A_1$  and  $A_4$  subequal in length, shortest apical spurs,  $A_1$  more robust.

Primary row: 5 spurs;  $P_5$  long, slender;  $P_3$  and  $P_4$  about 0.75 $\times$  length of  $P_5$ ;  $P_1$  and  $P_2$  subequal in length, shorter than  $P_3$ ,  $P_1$  conical.

Secondary row: 2 spurs;  $S_1$  shorter, more robust than  $S_2$ , conical.

Tertiary row: 1 spur;  $T_1$  subequal to  $S_1$ .

Additional features: dorsal lobe as broad but slightly shorter than  $A_1$ ; ventral tooth short, between  $A_5$  and  $P_5$ , apex rounded. Patch of setae near midline. Dorsal depression complete, beginning apically near  $P_1$ . Ventral ridge apparent.

*Neoplea argentina* has a unique combination of characters in having several small hairs along the midline and no lateral spurs. The dorsal lobe is relatively large, being almost as long as  $A_1$ . This species is known only from Argentina.



*Neoplea borellii* (Kirkaldy, 1899) (Fig. 6)

Apical row: 6 spurs;  $A_6$  long, narrow, nearly straight;  $A_4$ ,  $A_3$  and  $A_5$  subequal in length and shape;  $A_5$  slightly more robust;  $A_1$  and  $A_2$  subequal in length;  $A_2$  and  $A_3$  contiguous.

Primary row: 4 spurs; spurs increase in size from  $P_1$  to  $P_4$ ;  $P_3$  and  $P_4$  about equally robust, contiguous; distinct gap between  $P_1$  and apical row.

Secondary row: 4 spurs; spurs increase in size from  $S_1$  to  $S_4$ ;  $S_3$  and  $S_4$  about equally robust;  $S_1$  and  $S_2$  about equally robust, more so than  $S_3$  and  $S_4$ .

Tertiary row: 4 spurs;  $T_3$  longer, less robust than  $T_4$ ;  $T_2$  smaller than  $T_3$ , as robust as  $T_1$ ;  $T_1$  subequal to  $T_4$ .

Lateral row: 8 spurs;  $L_1$  subequal to  $T_1$ , largest lateral spur;  $L_2$  to  $L_5$  subequal in size;  $L_6$  to  $L_8$  subequal in size, smaller than  $L_2$  to  $L_5$ ;  $L_4$  and  $L_7$  ventrally offset from lateral row.

Accessory spurs: 1 spur;  $U_1$  anterior to  $T_3$ , triangular, apex pointed.

Additional features: dorsal lobe short, less than 0.5' length of  $A_1$ , apex rounded; ventral tooth absent; primary, secondary, tertiary rows closely spaced; dorsal depression and ventral ridge observable but not prominent.

Rows of spurs of *N. borellii* are easily confused as they are closely packed and include full rows that go from the dorsal to ventral edge. These rows are relatively equally spaced except for a couple of pairs of contiguous or subcontiguous spurs. The dorsal lobe is small relative to those of most species of *Neoplea*. Although not many samples have been examined, it is likely that there is substantial variation in the lateral spurs. The 1st gonapophysis of *N. borellii* is characterized as being generally covered with stout spurs. This species is currently known only from

Argentina, but there are many other specimens that suggest it is either more widespread or part of a species complex. That determination is outside the scope of this study.

*Neoplea gauchita* Bachmann, 1968 (Fig. 7)

Apical row: 5 spurs;  $A_5$  large, at least 2' size of  $A_4$ , curved dorsally;  $A_4$  shorter, narrower than other apical spurs;  $A_2$  and  $A_3$  subequal in length, slightly shorter than  $A_5$ ;  $A_2$  more arched, broader laterally than  $A_3$ ;  $A_1$  slightly shorter than  $A_2$ , as broad laterally as  $A_3$ .

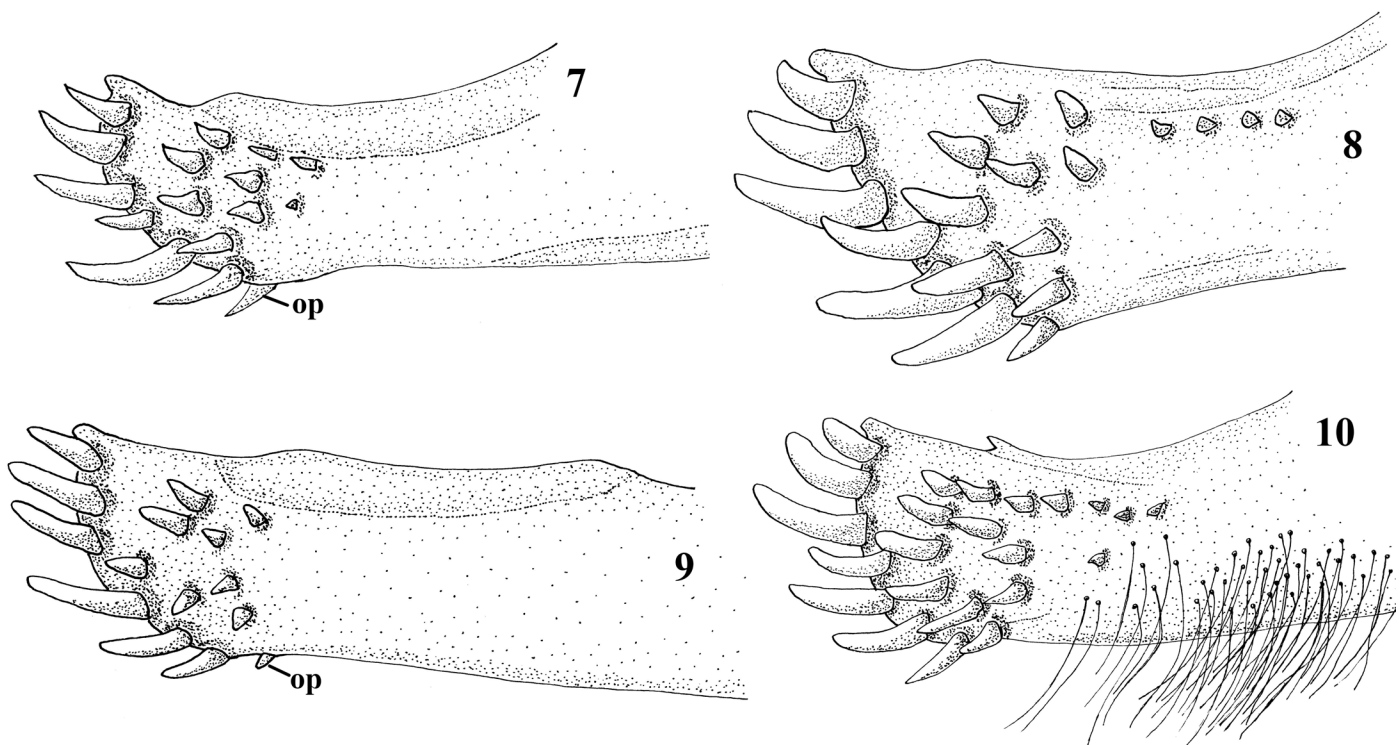
Primary row: 5 spurs;  $P_5$  about 2' length of  $P_4$ , nearly straight;  $P_2$ ,  $P_3$ , and  $P_4$  subequal in length;  $P_2$  and  $P_3$  similar shape;  $P_1$  shorter, as robust as  $P_2$ ; primary row weakly arched towards apex.

Secondary row: 3 spurs;  $S_2$  and  $S_3$  subequal in size, triangular;  $S_1$  slightly shorter, much narrower than  $S_2$  or  $S_3$ .

Tertiary row: 2 spurs;  $T_2$  small, triangular;  $T_1$  more than 2' length of  $T_2$ ;  $T_1$  and  $T_2$  widely spaced.

Additional features: dorsal lobe short, about 0.25' length of  $A_1$ , prominently observable, apex rounded; ventral tooth absent; spur on opposing face visible, pointed ventroapically (Fig. 7, op); dorsal depression large, somewhat obliterated towards apical end; ventral ridge small, only seen posteriorly.

The figure of the 1st gonapophysis of *N. gauchita* is taken from the figure provided by Bachman (1968), who commented only that the structure was armed with robust spurs. Thus, it is unclear as to the degree of accuracy of this drawing and description. In the apical and primary rows, the most ventral spur of *N. gauchita* appears to be much larger than other spurs, and these are found on a ventral edge that curves dramatically toward the base. This 1st gonapophysis has relatively large apical spurs but



**Figs. 7–10.** Outer lateral surface of the right 1st gonapophysis of species of *Neoplea*. *Neoplea gauchita* (7), re-drawn from Bachmann (1968); *Neoplea harnedi* (8); *Neoplea lingula* (9), re-drawn from Roback & Nieser (1974); *Neoplea maculosa* (10); op: spur on opposing face of 1st gonapophysis.

much smaller spurs in the remaining rows. *Neoplea gauchita* is known only from the type locality in Argentina and the original description.

*Neoplea globoidea* Nieser, 1975

*Neoplea globoidea* was described from a single male, and therefore there is no knowledge of the 1st gonapophysis. Nieser (1975) reported that the holotype would be deposited in the Zoological Museum at Utrecht, but this had not happened by 2013 (Yvonne van Nierop, personal communication). The species is known only from Suriname.

*Neoplea harnedi* (Drake, 1922) (Fig. 8)

Apical row: 5 spurs;  $A_3$  and  $A_5$  subequal in length,  $A_5$  more robust;  $A_2$  and  $A_4$  subequal in length,  $A_2$  more robust;  $A_1$  shorter, more robust than  $A_2$ .

Primary row: 5 spurs;  $P_5$  longer, most robust primary spur;  $P_3$  and  $P_4$  subequal in length;  $P_2$  about 0.75' length  $P_3$ ;  $P_1$  slightly shorter than  $P_2$ , triangular; primary row weakly arched towards apex.

Secondary row: 4 spurs;  $S_3$  and  $S_4$  nearly straight, triangular;  $S_1$  and  $S_2$  subequal in length; distinct gap between  $S_1$  and  $S_2$ ; secondary row starts slightly below  $P_2$ .

Tertiary row: 2 spurs;  $T_1$  and  $T_2$  subequal in size, in line with  $P_1$  and  $P_2$ , respectively.

Lateral row: 4 spurs;  $L_1$  through  $L_4$  subequal, row nearly parallel to dorsal edge.

Additional features: dorsal lobe less than 0.5' length  $A_1$ , apex bluntly rounded; ventral tooth absent; dorsal depression present, prominent, incomplete, clearly observable anterior to tertiary row of spurs; dorsal edge broadly, shallowly emarginate between apical and primary rows; ventral ridge small, parallel to dorsal depression.

The apical spurs of *N. harnedi* are all relatively large and there is a distinct gap between the dorsal apical spurs and dorsal primary spurs. There is intraspecific variation in the vestiture and number of lateral spurs. Many specimens have a few long hairs on the 1st gonapophysis, especially along the ventral edge. The number of lateral spurs varies from 2 to 5. All other characters are stable for the species.

There has been discussion in the literature as to whether *N. harnedi* should be synonymized with *N. striola* (Ellis 1950, 1965; Drake & Chapman 1953). These arguments were based on characters that are mostly highly variable, and the conclusion of Drake & Chapman (1953) was that Ellis (1950) based his argument on observations of only 1 species instead of a comparison using both species. The 1st gonapophyses of *N. harnedi* and *N. striola* are very similar, although careful observation suggests that there are distinct and consistent differences between the species. Based on all current evidence, including the 1st gonapophyses, both species should be considered valid until a more thorough study that includes molecular data can be undertaken.

Because of the uncertainty of the status of *N. harnedi* and *N. striola*, the distribution is also unclear. *Neoplea harnedi* was reported from the United States (Florida, Louisiana, Mississippi, Oklahoma, and Texas [specimens for the present study were mostly from Texas]), Mexico, and Panama (Drake 1922; Blatchley 1926; Hungerford 1936; Ellis 1950, 1965; Drake & Chapman 1953; Wilson 1958; Schaefer & Drew 1964). It is most likely that the distribution of *N. harnedi* is restricted to the Gulf Coast region of the United States.

*Neoplea lingula* Roback & Nieser, 1974 (Fig. 9)

Apical row: 5 spurs;  $A_1$ ,  $A_3$ , and  $A_5$  subequal in length;  $A_2$  and  $A_4$  subequal in length;  $A_3$  and  $A_4$  more widely spaced than other spurs.

Primary row: 4 spurs;  $P_4$  about 2' length of  $P_3$ ;  $P_3$  short, robust;  $P_1$  and  $P_2$  subequal in length;  $P_2$  offset from primary row (Fig. 9,  $P_2$ ); primary spurs widely spaced. This row is irregularly spaced and only defined by the well-organized apical and secondary rows.

Secondary row: 4 spurs;  $S_1$  longest secondary spur, nearly contiguous with  $P_1$ , could be confused for a primary spur;  $S_2$ ,  $S_3$ , and  $S_4$  subequal in length, about 0.5' length  $S_2$ ,  $S_4$  broadest laterally; secondary spurs in a nearly straight line angled slightly anteroventrally.

Tertiary row: 1 spur;  $T_1$  subequal to  $S_2$ .

Additional features: 1 spur from the opposing side can be seen at times (Fig. 9, op); dorsal lobe small, about 0.25'  $A_1$ , apex broadly rounded; ventral tooth absent; apex of dorsal half truncate, ventral half of apex evenly rounded; dorsal depression complete; ventral ridge lacking.

The 1st gonapophysis of *N. lingula* was re-drawn after Roback & Nieser (1974), and the accuracy of the drawing cannot be confirmed. With the assumption that the original drawing was correct, the 1st gonapophysis of *N. lingula* is relatively simple. The spurs of the apical row are large and relatively equal in size. The remaining spurs are small in both number and size. *Neoplea lingula* is known only from Colombia and has not been reported since the original description.

*Neoplea maculosa* (Berg, 1879) (Fig. 10)

Apical row: 6 spurs;  $A_2$  and  $A_6$  subequal in length,  $A_2$  more robust;  $A_3$  and  $A_4$  slightly shorter than  $A_6$ ;  $A_4$  slightly offset from apex;  $A_3$  longest apical spur;  $A_1$  shortest apical spur.

Primary row: 5 spurs;  $P_4$  and  $P_3$  subequal to  $P_5$ , distinct gap between  $P_4$  and  $P_5$ ;  $P_1$  slightly shorter than  $P_2$ ; primary row weakly arched apically.

Secondary row: 4 spurs;  $S_1$ ,  $S_2$ , and  $S_4$  subequal in length;  $S_3$  longest secondary spur, slender; distinct gap between  $S_2$  and  $S_3$ .

Tertiary row: 3 spurs;  $T_2$  and  $T_3$  subequal in length;  $T_1$  about 0.75' length  $T_2$ ; tertiary row nearly vertical.

Lateral row: 4 spurs;  $L_1$  subequal to  $T_1$ ;  $L_2$ ,  $L_3$ , and  $L_4$  about 0.5' length  $L_1$ .

Accessory spurs: 1 spur;  $U_1$  subequal to  $L_2$ , broader laterally; located ventral to  $L_2$ .

Additional features: dorsal lobe short, apex truncate; dorsal edge with tooth, located dorsal to  $S_1$ ; ventral tooth absent; basoventral half setose, setae long; 1st gonapophysis apex nearly truncate; dorsal depression relatively small, inconspicuous; ventral ridge absent.

The 1st gonapophysis of *N. maculosa* is the most robust of the species examined. It can readily be identified by the large number of generally robust spurs, truncate dorsal lobe, prominent tooth on the dorsal surface, and the extensive basoventral tuft of setae. The specimens we examined match the original species description; however, because of its large distribution, it is likely that what we now call *N. maculosa* is actually multiple species. Because we were not able to examine specimens from the type locality and the current location of the type specimen is unknown, the specimen described here could be a different species within a species complex. The specimens for this study were from Brazil, but specimens from Argentina, Paraguay, Suriname, Bolivia, and Peru have also been identified as *N. maculosa* (Berg

1879; Horváth 1918; Drake & Chapman 1953; Bachman 1960, 1968; Nieser 1975; Lopez Ruf & Bachmann 1994).

*Neoplea mexicana* (Drake & Chapman, 1953)

*Neoplea mexicana* was described from a type specimen whose sex was undetermined because the operculum was not clearly visible and the genitalia were not exposed. We examined the holotype and concluded it is not possible to observe the genitalia except by dissection. Because the species is known only from the holotype, we refrained from dissecting it. The species was described from Veracruz, Mexico.

*Neoplea notana* (Drake & Chapman, 1953) (Fig. 11)

Apical row: 6 spurs;  $A_6$  and  $A_4$  subequal, longest apical spurs;  $A_5$  and  $A_3$  subequal;  $A_5$  slightly shorter than  $A_3$ ;  $A_1$  shortest apical spur.

Primary row: 4 spurs;  $P_4$  longest primary spur;  $P_2$  and  $P_3$  subequal in length;  $P_1$  triangular, shortest primary spur;  $P_1$ ,  $P_2$ , and  $P_3$  widely spaced, oriented dorsoapically.

Secondary row: 2 spurs;  $S_1$  about 2' size  $S_2$ ; row begins in ventral half of 1st gonapophysis

Additional features: dorsal lobe absent, dorsoapical edge crenate; single specimen available for this study appears to have a ventral tooth anterior to  $S_2$  with apex broadly rounded but this could be an empty spur socket, which would constitute  $S_3$ ; 1st gonapophysis apex truncate; dorsal depression easily observed and large but only extending forward to about the level of the secondary spurs; ventral depression present.

The 1st gonapophysis of *N. notana* is simple, with relatively fewer and smaller spurs than those of other species of *Neoplea*. The crenu-

late dorsoapical edge distinguishes *N. notana* from other species of *Neoplea*. This species is known from the United States (Florida and Mississippi).

*Neoplea punctifer* (Barber, 1923) (Fig. 12)

Apical row: 6 spurs;  $A_3$  and  $A_5$  subequal;  $A_2$  and  $A_6$  subequal, shorter than  $A_3$ ;  $A_4$  slightly shorter than  $A_2$ ;  $A_1$  shortest apical spur.

Primary row: 5 spurs; spurs increase in size from  $P_1$  to  $P_4$ ;  $P_5$  subequal to  $P_3$ , most slender primary spur.

Secondary row: 3 spurs;  $S_1$ ,  $S_2$ , and  $S_3$  subequal; distinct gap between  $S_2$  and  $S_3$ ; secondary row in a vertical line that is nearly dorsal to  $P_5$ .

Tertiary row: 4 spurs;  $T_1$ ,  $T_2$ , and  $T_3$  subequal;  $T_4$  about 0.5' size of  $T_1$ ; tertiary spurs in a nearly straight line except  $T_4$  is slightly closer to the apex.

Lateral row: 2 spurs;  $L_1$  and  $L_2$  subequal; almost in line horizontally with  $T_2$ .

Additional features: dorsal lobe more than 0.5' length of  $A_1$ , apex rounded; ventral tooth absent; setae moderately long, 2 patches along ventral edge; patch 1 small, in line with  $L_1$ ; patch 2 larger, more dense, ending at base of ventral ridge; 2 weak ridges flanking  $T_4$ , nearly parallel to midline; dorsal depression present but not well defined; ventral ridge present.

The 1st gonapophysis of *N. punctifer* is heavily spurred, somewhat like that of *N. maculosa*. The dorsal lobe is distinctive for its relatively large size and shape, similar to, but more exaggerated than, the state found in *N. striola*. It has several stout setae like *N. maculosa*, but the setae are less dense in *N. punctifer*. The species is known only from Puerto Rico.

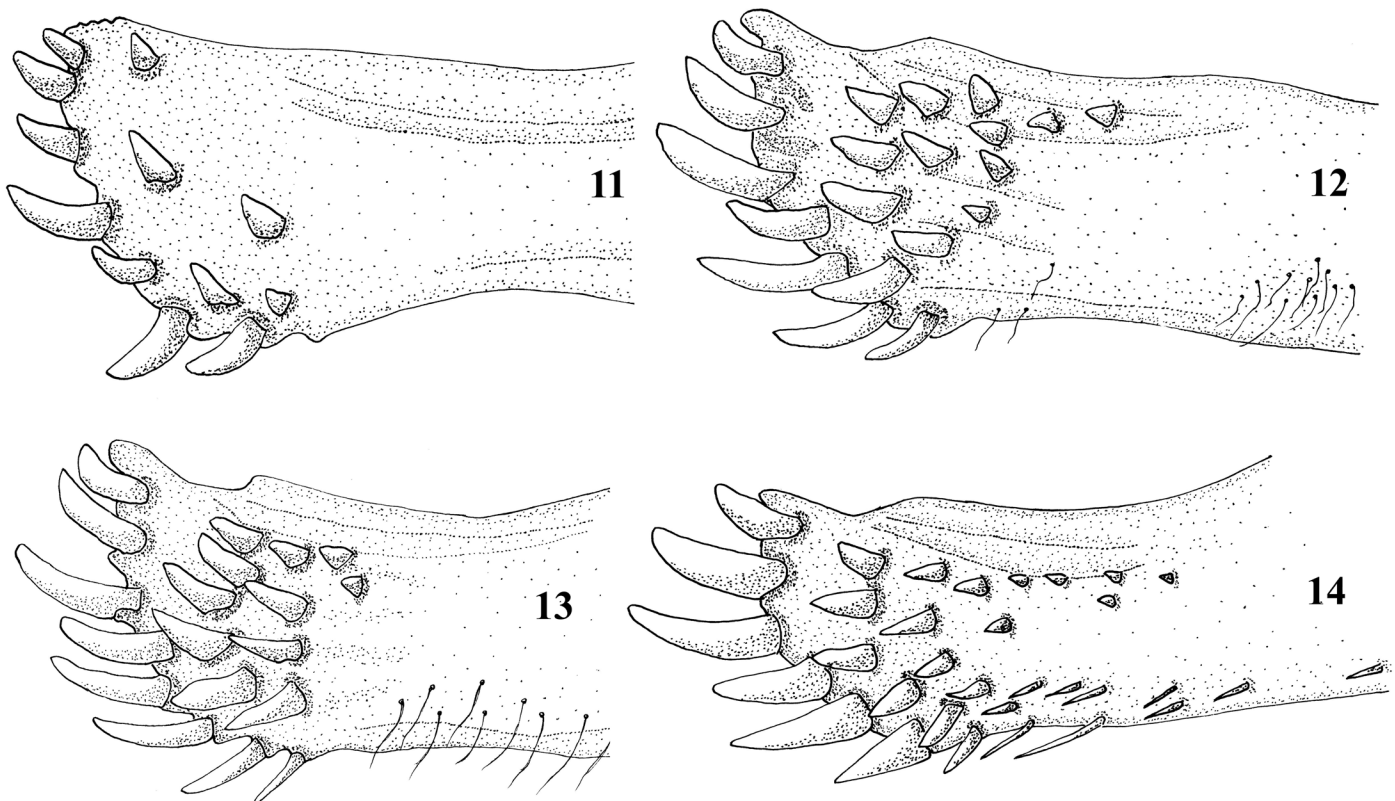


Fig. 11–14. Outer lateral surface of the right 1st gonapophysis of species of *Neoplea*. *Neoplea notana* (11); *Neoplea punctifer* (12); *Neoplea striola* (13); *Neoplea tenuistyla* (14), re-drawn from Roback & Nieser (1974).



*Neoplea semipicta* (Horváth, 1918)

*Neoplea semipicta* is described from a type specimen whose sex was undetermined. Syntypes of *N. semipicta* are now deposited in the US National Museum, as part of the J. T. Polhemus collection, and will soon be available for study. The species is known from Columbia and Paraguay.

*Neoplea striola* (Fieber, 1844) (Fig. 13)

Apical row: 6 spurs;  $A_1$  shortest apical spur;  $A_2$  and  $A_4$  subequal;  $A_3$  longest apical spur;  $A_5$  and  $A_6$  subequal.

Primary row: 6 spurs; spurs increase in length from  $P_1$  to  $P_6$ ;  $P_4$  and  $P_5$  almost equal in length,  $P_5$  robust;  $P_6$  slender, straight; distinct gap between bases of  $P_5$  and  $P_6$ .

Secondary row: 5 spurs;  $S_1$  about 0.5' length  $S_2$ ;  $S_2$ ,  $S_3$ , and  $S_4$  subequal, all slightly longer than  $S_5$ ;  $S_5$  slender; distinct gap between  $S_4$  and  $S_5$ ; secondary row nearly straight vertically.

Tertiary row: 2 spurs; short, robust, triangular;  $T_2$  shorter than  $T_1$ .

Additional features: dorsal lobe over 0.5' length  $A_1$ , apex broadly rounded; dorsal tooth short, blunt, aligned vertically with  $P_1$ ; dorsal depression broad; ventral ridge present but weak; patch of setae along ventral margin, setae moderately long.

*Neoplea striola* has a 1st gonapophysis similar to that of *N. harnedi* (see discussion of *N. harnedi*). The dorsal lobe is consistently larger in *N. striola*, but this is only discernible if a series of each species is observed together, and it is not easily quantified. A distinct dorsal tooth above the primary row was present in all specimens of *N. striola*, but we only saw 1 specimen of *N. harnedi* that had a weakly developed dorsal tooth. Spurs are generally more robust, especially in the primary and secondary rows, in *N. striola*, but there is some overlap in this characteristic. These 2 species are probably sister species, and there are only minor differences in the 1st gonapophysis that suggest they are distinct.

Variation is found in several 1st gonapophysis characters of *N. striola*. Some specimens have 1 fewer primary spur and/or 1 fewer secondary spur. One tertiary spur is missing in some specimens. Lateral spurs are found in some specimens, and the number is almost always either 0 or 4. Some spurs appear blunt; environmental factors may blunt spurs, so sharpness of spurs may not be a good taxonomic character.

The reported distribution of *N. striola* is almost certainly incorrect and confused with that of *N. harnedi*, because authors have sometimes viewed them as the same species and left no vouchers. Additionally,

since the 1950s when *N. harnedi* was synonymized with *N. striola* (Ellis, 1950) and when it was suggested they remain synonymized (Wilson 1958; Ellis 1965), most New World pleids were all reported as *N. striola*, again with no vouchers to sort out correct identifications. The reported distribution from the literature includes the United States (California, Colorado, Florida, Illinois, Indiana, Iowa, Kansas, Maryland, Michigan, Mississippi, Nebraska, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, Texas, Utah, Virginia, and West Virginia), Canada, Mexico, Guatemala, the Antilles, Cuba, St. Vincent, and Granada (Fieber 1844; Champion 1901; Torre-Bueno 1912, 1924; Drake 1922; Clark 1925; Bare 1926; Blatchley 1926; Rice 1942; Wilson 1958; Schaefer & Drew 1964; Gittleman 1974, 1975, 1977, 1978; Takahashi et al. 1979; McPherson 1986; Dufree et al. 1999).

*Neoplea tenuistyla* Roback & Nieser, 1974 (Fig. 14)

Apical row: 6 spurs;  $A_1$  and  $A_6$  subequal, slightly shorter than  $A_4$ ;  $A_2$  and  $A_5$  subequal;  $A_3$  longest apical spur;  $A_4$ ,  $A_5$ , and  $A_6$  nearly straight, triangular.

Primary row: 6 spurs;  $P_1$  and  $P_4$  subequal;  $P_2$  and  $P_3$  subequal;  $P_5$  and  $P_6$  subequal, similar in shape, less robust than  $P_4$ , slightly shorter than  $P_2$ ; row curves basally toward ventral edge starting at  $P_4$ .

Secondary row: 6 spurs;  $S_1$ ,  $S_3$ , and  $S_4$  subequal;  $S_2$  and  $S_6$  subequal;  $S_1$ ,  $S_2$ , and  $S_3$  triangular;  $S_5$  slightly shorter than  $S_2$ , less robust;  $S_6$  longest secondary spur, very slender; row curves basally toward ventral edge  $S_2$  to  $S_6$ .

Tertiary row: 2 spurs;  $T_1$  and  $T_2$  subequal, triangular.

Lateral row: 5 spurs;  $L_1$ ,  $L_2$ ,  $L_3$ ,  $L_4$ , and  $L_5$  subequal; distinct gap between  $L_2$  and  $L_3$ ; lateral spurs in nearly straight line except  $L_3$  ventral to  $L_4$ .

Accessory spurs: 8 spurs; 3 distinct groups separated by gaps:  $U_1$ – $U_4$ ,  $U_5$ – $U_7$ , and  $U_8$ ;  $U_1$ ,  $U_2$ , and  $U_3$  subequal;  $U_4$  about 2.5' length  $U_1$ , directly below  $U_3$ ;  $U_5$ ,  $U_6$ , and  $U_7$  subequal;  $U_7$  directly below  $U_5$ ;  $U_8$  subequal to  $U_6$ ; all accessory spurs very slender.

Additional features: dorsal lobe about 0.5' length of  $A_1$ , apex rounded; dorsal depression broad, extending from  $L_3$  to  $P_1$ , with weak medial ridge.

A distinguishing characteristic of the 1st gonapophysis of *N. tenuistyla* is the presence of several narrow spurs along the ventral edge, which is not seen in other species. The apical spurs are much larger than all other spurs, which also occurs in *N. gauchita* and *N. lingual*; however, *N. tenuistyla* has substantially more spurs than these other species. *Neoplea tenuistyla* is known only from Colombia.

KEY TO SPECIES OF *NEOPLEA* BASED ON 1ST GONAPOPHYSIS MORPHOLOGY

Many species of *Neoplea* can be identified reliably using characters of the 1st gonapophysis. Although there is some intraspecific variability in these structures, 1st gonapophysis morphology is still a valuable taxonomic character and is adequate by itself for distinguishing most species. Given here is a key to the species of *Neoplea* based on 1st gonapophysis morphology. Note that *N. globioidea*, *N. mexicana*, and *N. semipicta* are not included, because the morphology of their 1st gonapophyses is not known.

Provisional Key to Species of *Neoplea*

- 1.— Apical lobe present and apical dorsal edge smooth (Fig. 8); dorsal depression limited to complete; ventral tooth present or absent,  $P_1$ ,  $P_2$ , and  $P_3$  not all widely spaced ..... 2
- 1'.— Apical lobe absent and apical dorsal edge crenate (Fig. 11); dorsal depression limited, terminating at level of secondary row; ventral tooth present between  $A_6$  and  $P_4$ , short, broadly rounded;  $P_1$ ,  $P_2$  and  $P_3$  widely spaced ..... *N. notana*
- 2.— Lateral row of spurs absent (Fig. 3) ..... 3
- 2'.— Lateral row of spurs present (Fig. 8) ..... 7

- 3.— Tertiary row with 2 spurs (Fig. 13) ..... 4
- 3'.— Tertiary row with 1 spur (Fig. 5) ..... 5
- 4.— Apical and primary rows with 5 spurs; dorsal lobe about 0.25' length of  $A_1$  (Fig. 7); dorsal depression broad, without medial ridge and without marginal tooth; emargination between dorsal depression and dorsal lobe moderately deep, arcuate ..... *N. guachita*
- 4'.— Apical and primary rows with 6 spurs; dorsal lobe about 0.5' length of  $A_1$  (Fig. 13); dorsal depression with medial ridge, margined apically with short, rounded tooth; ventral ridge ending in apical half, margined with setae subequal to  $A_3$  in length; emargination between dorsal depression and dorsal lobe broad, truncate ..... *N. striola*
- 5.— Primary row well defined and linear, no spurs offset from row (Fig. 3); dorsal lobe more than 0.25' length of  $A_1$  ..... 6
- 5'.— Primary row not well defined as linear, at least 1 spur offset from row (Fig. 9); dorsal lobe less than 0.25' length of  $A_1$ ; apical spurs about 1.5' length of non-apical spurs ..... *N. lingula*
- 6.— Tertiary spur much smaller than secondary spurs; dorsal lobe narrow, about half the width of  $A_1$  (Fig. 3); ventral tooth below  $P_5$ ; glabrous ..... *N. absona*
- 6'.— Tertiary spur the same size as secondary spurs; dorsal lobe about as wide as  $A_1$  (Fig. 5); ventral tooth between  $A_5$  and  $P_5$ ; with several short hairs medially and a series of longer hairs along the ventral edge ..... *N. argentina*
- 7.— With several relatively long slender accessory spurs along ventral edge (Fig. 14); all apical spurs longer than any other spurs ..... *N. tenuistyla*
- 7'.— Without several relatively long slender accessory spurs along ventral edge (Fig. 8); length of apical spurs variable with respect to other spurs ..... 8
- 8.— Dorsal lobe rounded at apex (Fig. 4); no tooth on dorsal edge; hairs on 1st gonapophysis variable but not consisting of a large number on the basal and ventral half ..... 9
- 8'.— Dorsal lobe truncate at apex (Fig. 10); tooth on dorsal edge, above secondary row of spurs; dense patch of long hairs in basal and ventral half of 1st gonapophysis ..... *N. maculosa*
- 9.— With 6 apical spurs (Fig. 6) ..... 10
- 9'.— With 5 apical spurs (Fig. 4) ..... 11
- 10.— Dorsal lobe at least 0.66' length of  $A_1$  (Fig. 12);  $A_2$  clearly longer than  $A_1$  ..... *N. punctifer*
- 10'.— Dorsal lobe less than 0.5' length of  $A_1$  (Fig. 6);  $A_1$  and  $A_2$  about equal in size ..... *N. borellii*
- 11.— Distinct gap between  $P_1$ – $P_2$  and apical spurs (Fig. 8);  $A_4$  offset behind apex ..... *N. harnedi*
- 11'.— Distinct gap between  $P_1$ – $P_4$  and apical spurs (Fig. 4);  $A_4$  on apex ..... *N. apopkana*

## Acknowledgments

We thank Thomas Henry at the Smithsonian and Zachary Falin for access to *Neoplea* specimens.

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