

Recognition of Imported Lady Beetles in the Tribe Scymnini Released in Eastern North America

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Abstract

Adults of lady beetles in the tribe Scymnini imported for biological control of hemlock woolly adelgid, *Adelges tsugae* Annand, in eastern North America can be readily distinguished from native lady beetles (Coccinellidae). The imported lady beetles are in the genera *Pseudoscymnus* and *Scymnus* (*Neopullus*), both of which are Palearctic. These taxons have characteristics that can be used to separate them from Nearctic lady beetles. The most useful morphological feature is that the number of antennal segments is less than 11; ten-segmented in *Scymnus* (*Neopullus*) and nine-segmented in *Pseudoscymnus*. Elytral patterns and coloration also can be useful in field recognition. Larvae of the imported lady beetles are all in the tribe Scymnini, which can be distinguished from lady beetles in other tribes. A characteristic of the Scymnini is the wax covering of the last two larval instars and, for most species, the body lacks pronounced spines and is neither black or heavily sclerotized. Identification of a *Scymnini* larva to the genus level requires careful microscopic examination. *Pseudoscymnus tsugae* larval antennae have been described as one-segmented, but our examination indicates that they are two-segmented. *Scymnus* (*Neopullus*) larvae have three-segmented antennae.

Keywords:

Scymnini, native lady beetles, *Scymnus*, *Pseudoscymnus*, adult identification.

Introduction

Several members of the tribe Scymnini have been introduced into North America for use as biological control agents (Gordon 1985, Hagen et al. 1999). The tribe Scymnini is composed primarily of species that feed on mealybugs, scales, mites, and adelgids (White 1983), which are all considered to be pests. Members of the genera *Scymnus* and *Pseudoscymnus* are currently being

used in the biological control of *Adelges tsugae*, the hemlock woolly adelgid (HWA), an insect native to Asia that is a pest of hemlock (McClure et al. 2001). Chemical and cultural control methods for HWA are unfeasible in a forest situation necessitating research into biological control options (McClure 1987).

Evaluation of the performance of a species as a biological control includes field monitoring of establishment and correct identification of collected specimens. Here we examine practical methods for identification of both adults and larvae of several Scymnini beetles currently established or soon to be released for control of HWA. Characteristics of *Pseudoscymnus tsugae*, *Scymnus suturalis*, *S. sinuanodulus*, and *S. ningshanensis* are compared along with higher-level taxonomy and clarification of the subgenera of *Scymnus*. For practical purposes of field identification, our discussion is restricted to external characteristics.

Adult Identification

The family Coccinellidae is characterized by a 3-3-3 tarsal formula (some are actually 4-4-4 but the third tarsus is hidden), an expanded pronotum concealing the head dorsally, a body that is convex dorsally and flat ventrally, and a first abdominal sterna that is entire (Majerus 1994). The tarsal formula often is an important characteristic in identification at the genus level. Three types of tarsal formulae exist within the coccinellids: trimerous (three-segmented), tetramerous (four-segment), and cryptotetramerous (four segment but appearing three) (Sasaji 1971).

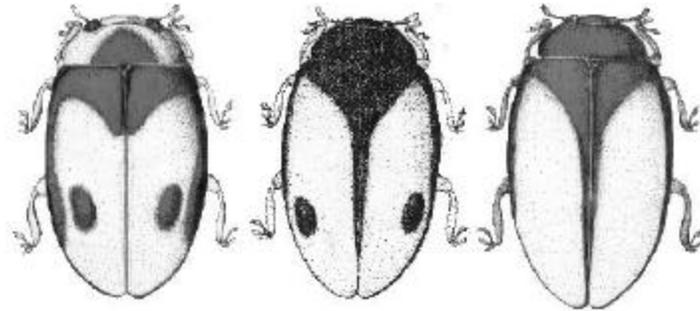
The tribe Scymnini contains 22 genera, some of which are found in abundance in eastern North America. The genus *Scymnus*, with more than 600 described species, is the largest genus in the region (Gordon 1976). The genus *Scymnus* has six subgenera, of which *S. (Scymnus)*, *S. (Didion)*, and *S. (Pullus)* are Holarctic and *S. (Neopullus)*, *S. (Miniopullus)*, and *S. (Parapullus)* are Palearctic. *Scymnus suturalis* belongs to the subgenus *Pullus*, while *S. ningshanensis* and *S. sinuanodulus* are in the subgenus *Neopullus*. The genus *Pseudoscymnus* is restricted to Asia, Oceania, and Africa.

A combination of characters is used to separate the adult Scymnini from other tribes. A good practical characteristic is their small size, less than 3 mm, and pubescence on the dorsal surface and eye. Characters used in keys include the apical segment of the maxillary palpus that diverges apically and is more parallel-sided than securiform; the antennae are two-thirds or less the width of the head, six visible abdominal sterna that are not fused, and the prosternum that is unlobed (Gordon 1985).

Pseudoscymnus was once grouped in the genus *Scymnus (Scymnus)*, but species found in Japan were significantly different and a new genus was designated (Chapin 1962). The reason for the separation into two genera is that *Pseudoscymnus* species have nine-segmented antennae and a trimerous tarsal formula; while *Scymnus* have either 10 or 11-segmented antennae and are cryptotetramerous (Figure 1) (Sasaji 1971).

Concavity and length of the postcoxal line is a main character for separating genera and subgenera. The postcoxal line is directly posterior to the metasternum, on the first abdominal sternum, arching

from the anterior medial bridge in a u-shape toward the lateral anterior margin (Gordon 1976). A complete postcoxal line will reach the anterior margin of the abdominal sternum; an incomplete line ends short of the anterior margin, frequently on the posterior margin. *Scymnus* (*Scymnus*) and *Pseudoscymnus* have incomplete postcoxal lines, ending approximately one-half the distance to the anterior margin of the abdominal sternum. *Scymnus* (*Neopullus*) and (*Pullus*) have complete postcoxal lines (Figure 2) (Sasaji 1971; Gordon 1976).



Scymnus sinuanodulus *Scymnus ningshanensis* *Scymnus suturalis*

Figure 1. Habitus of adult *Scymnus* species.

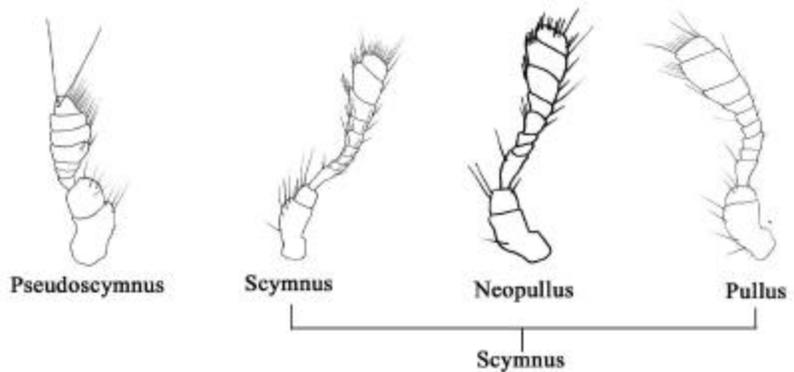


Figure 2. Adult antenna: *Pseudoscymnus*, 9-segmented; *Scymnus* (*Scymnus*), 11-segmented; *Scymnus* (*Neopullus*), 10-segmented; and *Scymnus* (*Pullus*), 11-segmented.

Species Differences

Elytron and pronotum patterning can be used to distinguish between the three similar *Scymnus* species and differentiate *Pseudoscymnus* from them and from native *Scymnus* species (Table 1, Figure 3); see Yu et al. (2000) for the variation in elytral coloration. *Pseudoscymnus tsugae* is the most easily distinguished because it is entirely black. They are entirely piceous including appendages, which is

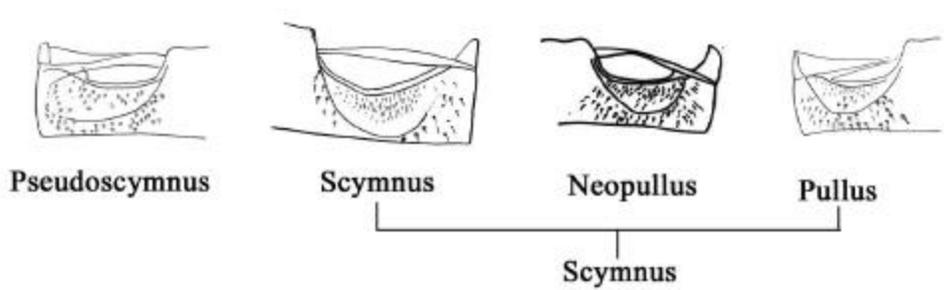


Figure 3. Adult postcoxal line: *Pseudoscymnus*, incomplete; *Scymnus* (*Scymnus*), incomplete; *Scymnus* (*Neopullus*), complete; and *Scymnus* (*Pullus*), complete.

Table 1. Characteristics of Adult Scymnini Genera.

Characteristic	<i>S. ningshanensis</i>	<i>S. sinuanodulus</i>	<i>S. suturalis</i>	<i>Pseudoscymnus tsugae</i>
Antenna	10-segmented	10-segmented	11-segmented	9-segmented
Elytra	Elytra dark orange, base black continuous with black along suture to 2/3 elytral length and black margins to 2/3 elytral length, black elongate oval 1/3 to 2/3 elytral length	Elytra dark orange, base black continuous with black along suture to 1/2 elytral length and black margins to 2/3 elytral length, black elongate oval 1/3 to 2/3 elytral length	Elytra dark orange, black at base, continuous with black along suture to 3/4 elytral length and black margins to 2/3 elytral length	Elytra black
Pronotum	Pronotum dark orange, black half circle medial and posterior, 2/3 to 3/4 dorsal surface	Pronotum dark orange black half circle medial and posterior 1/3 to 2/3 dorsal surface	Pronotum black	Pronotum black
Postcoxal line	Complete	Complete	Complete	Incomplete

very unusual and also rare among native lady beetles. The three *Scymnus* species can be separated by the markings on the elytra: *S. suturalis* has a black mark along the suture that extends three-fourths the length of the elytra and has no oval spots; *S. ningshanensis* has a black mark along the medial suture that is two-thirds the entire elytral length and has two black oval spots; *S. sinuanodulus* has a black medial suture mark only one-third the entire elytral length and two black oval spots.

Native species of *Scymnus* are represented by the subgenera *Scymnus* and *Pullus*. Additionally, there are two species native to Europe—*Scymnus (Pullus) impexus*, introduced as biological controls for the balsam woolly adelgid (Gordon 1976), and *S. (Pullus) suturalis*, introduced accidentally into the United States prior to 1915 (Gordon 1982). *Scymnus (Neopullus) sinuanodulus* and *S. (Neopullus) ningshanensis* can be separated from the native *S. (Scymnus)* and *S. (Pullus)* by the antennae; *S. (Neopullus)* are 10-segmented and *S. (Scymnus)* and *S. (Pullus)* are 11-segmented. Also, the elytral patterns of *S. sinuanodulus* and *S. ningshanensis* are distinct from all native and introduced species in the genus *Scymnus*. Generally, native *Scymnus* have black elytra with either a reddish or yellowish apical marking (Gordon 1976). *Scymnus (Pullus) loewii* and *S. (Pullus) brullei* both have varied elytra patterns, incorporating black and reddish or yellowish basal markings along the elytra (Gordon 1976). *Scymnus loewii* has a black elytral marking extending along the medial suture almost to the apex, being wide throughout (Gordon 1976). *Scymnus brullei* elytral pattern is similar to *S. loewii*, with the medial suture mark not extending to the apex and marginal black markings in some specimens (Gordon 1976). It should be recognized that newly emerged lady beetles have faint elytral patterns.

Larval Identification

The white waxy covering of Scymnini larvae is useful in identification. Other beetle larvae found on hemlock that have a waxy covering are species in the genus *Laricobius* (Derodontidae).

Laricobius larvae can be distinguished from Scymnini larvae by their longer, strongly three-segmented antennae (Lu et al. 2002) and a blanket-like, conspicuous wax covering. The wax covering on living *Scymnus* and *Pseudoscymnus* is fluffier and less dense than on *Laricobius*. Other larvae likely to be collected on hemlock in the family Coccinellidae (e.g., *Chilocorus*, *Stethorus*, or *Harmonia*) lack wax, have spiny tubercles, and usually are entirely black or mottled black (Lu et al. 2002).

Scymnus and *Pseudoscymnus* are similar in body form and behavior, making them difficult to distinguish without use of a microscope (Delucchi 1954, Sasaji and McClure 1997, Lu et al. 2002). There is a distinct difference in the color of *Scymnus* and *Pseudoscymnus* larvae. Living specimens of *Pseudoscymnus* are dark gray and *Scymnus* are lighter gray throughout their thoracic and abdominal regions; however, newly molted larvae of both genera are yellowish in color.

Larval Head Structures

Genus-level determinations rely on head structures such as antennae, maxillary palpi, and labial palpi. Some differences in these structures can be detected with careful observation using a compound or stereomicroscope. The morphologies of some structures were difficult to resolve with these methods and we used a scanning electron microscope (SEM) to examine *S. sinuanodulus*, *S. ningshanensis*, and *P. tsugae* larvae. The *Scymnus* larvae examined were from the colony maintained at the USDA Forest Service, Hamden, Connecticut, while the *P. tsugae* were from the same laboratory as well as field-collected specimens.

The number of segments of a larval antenna is a main classification character. Rees et al. (1994) has a detailed illustration of a *Scymnus* (*Pullus*) larval antenna. This illustration is very similar to our illustration (Figure 4A) and scanning electron micrographs (Figure 4B) of *S. (Neopullus) ningshanensis*. Both illustrations show three antennal segments with the apical (third) segment much smaller than the basal (first) segment and medial (second) segment. The second segment has

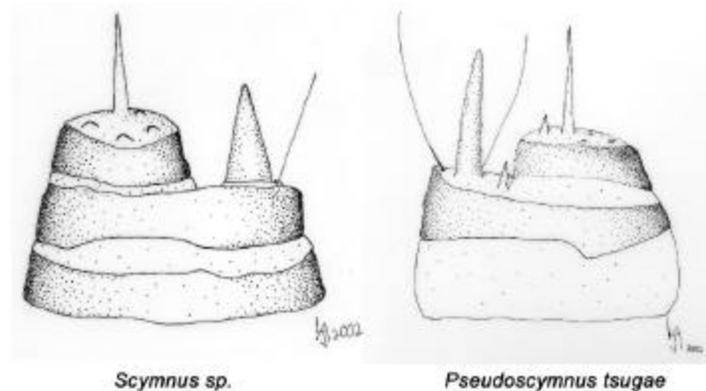


Figure 4. *Scymnus ningshanensis* larval antennae: (A) illustration; (B) scanning electron micrograph; (a) first segment (basal); (b) second segment (medial); (c) third segment (apical); (d) thin sensory structure on apical segment; (e) thick sensory structure on second segment.

a large conical structure extending approximately twice the height of the third segment and a thin conical structure on the third segment. Our observations of *S. (Neopullus) ningshanensis* are consistent with the description by Rees et al. (1994) of *S. (Pullus)* except that the third segment of *S. (Neopullus)* appears slightly larger in diameter.

The larval antenna of *Pseudoscymnus* has been described as two-segmented in *P. sylvaticus*, *P. hareja* (Sasaji 1968), and *P. amplus* (Sasaji 1998), and as three-segmented in *P. pilicrepus* (Sasaji and Tsubokawa 1983). *Pseudoscymnus tsugae* antennae are illustrated and described by Sasaji and McClure (1997) as one-segmented, with a thick seta and a few thin, long setae located at the apex. Our observations (Figures 5 A and B) of *P. tsugae* larval antennae question this description. We see a basal segment (Figure 5a) on a raised membranous base that has a raised portion (Figure 5b) with sclerotization that may be a second segment. Arising from the apex of the basal segment is a large conical structure (Figure 5c) similar to that seen on the second segment of *Scymnus* larval antennae. Arising from the apex of *P. tsugae* antennae is a thin conical structure (Figure 5d) similar to the one located on the apex of the third segment of *Scymnus* antennae.

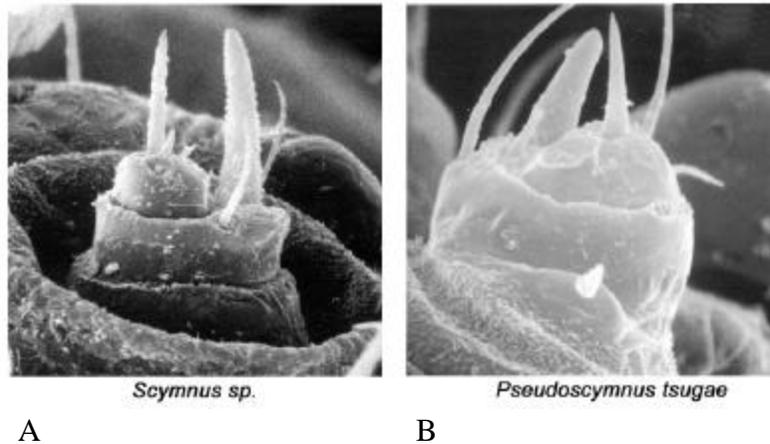


Figure 5. *Pseudoscymnus tsugae* larval antennae: (A) illustration; (B) scanning electron micrograph; (a) first segment (basal); (b) raised portion of basal segment or second segment; (c) thick sensory structure on basal segment; (d) thin sensory structure on apical segment.

The number of segments of the maxillary palpi is also difficult to define. Rees et al. (1994) described maxillary palpi of *Scymnus* in their key as three-segmented, with the segments sharply defined and a terminal palpifer. The maxillary palpi of *P. tsugae* are described as four-segmented (Sasaji and McClure 1997). The scanning electron micrograph of *P. tsugae* maxillary palpus is similar to *S. ningshanensis* (Figure 6) — the segmentation appears the same in both.

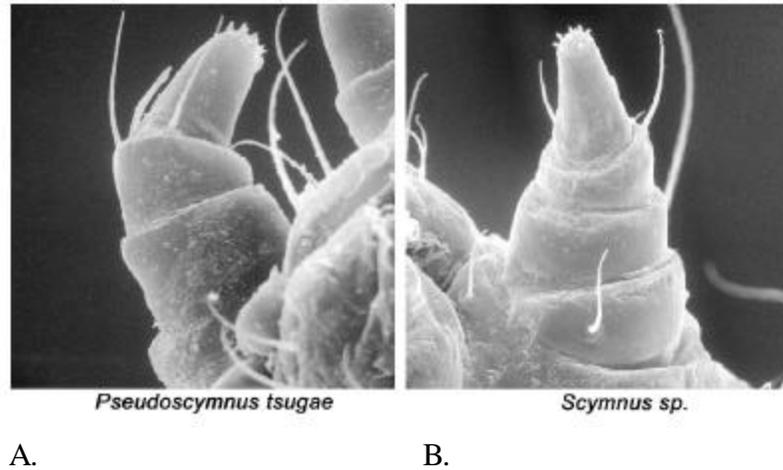


Figure 6. Larval maxillary palpi: (A) *Pseudoscymnus tsugae*; (B) *Scymnus ningshanensis*.

The scanning electron micrographs of *S. ningshanensis* (Figure 7A) indicate that the labial palpus is two-segmented. The labial palpus of *P. tsugae* is described as minute and one-segmented (Sasaji and McClure 1997). The labial palpus of *P. tsugae* appears two-segmented in SEM examination (Figure 7B). Labial palpi are probably not a useful identification tool to distinguish *Pseudoscymnus* from *Scymnus* larvae.

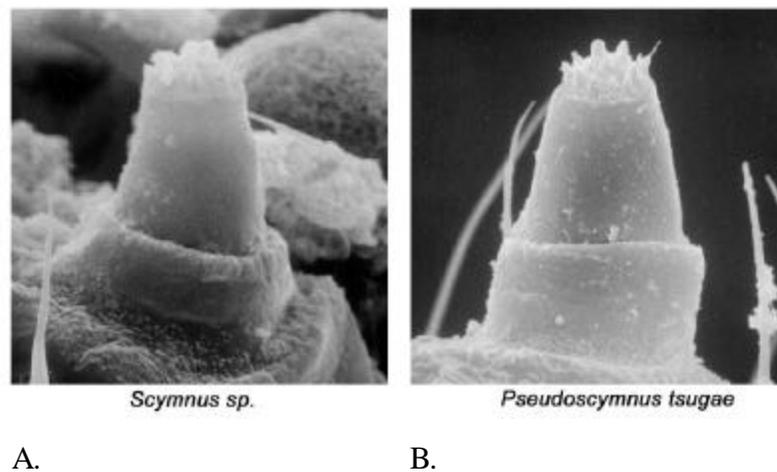


Figure 7. Larval labial palpi: (A) *Scymnus ningshanensis*; (B) *Pseudoscymnus tsugae*; (a) first segment; (b) second segment.

Conclusion and Future Research

Identification of adult lady beetles by genera can be accomplished using external characteristics, antennal segments, and length of the postcoxal line. Adult beetles found on hemlock in the genus *Scymnus* can be identified using elytra patterns. *Pseudoscymnus tsugae* is the only member of the genus in North America, and is entirely black (Sasaji and McClure 1997). All other *Scymnus* with black elytra have head, pronotum, or legs of variable color (Gordon 1976).

Larval identification is more difficult. Mature *Laricobius* are very waxy, without tubercles, and yellowish in color. *Scymnus* and *Pseudoscymnus* are lightly waxy and are light gray and dark gray, respectively.

Separation of Scymnini larvae even to the genus level is difficult and probably not practical for general field work. Our preliminary microscopic examinations of the antennae and palpi indicate a need for comprehensive morphological study of the larvae in the tribe Scymnini.

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