

# Description and Distribution of *Pseudoscymnus tsugae* sp. nov. (Coleoptera: Coccinellidae), an Important Predator of Hemlock Woolly Adelgid in Japan

HIROYUKI SASAJI<sup>1</sup> AND MARK S. MCCLURE<sup>2</sup>

Valley Laboratory, Connecticut Agricultural Experiment Station, P.O. Box 248, Windsor, CT 06095

Ann. Entomol. Soc. Am. 90(5): 563-568 (1997)

**ABSTRACT** *Pseudoscymnus tsugae* sp. nov. is described. In Honshu, Japan, it has been collected between 34°11' and 36°50'N latitude and from sea level to 1,980 m. The adult and the mature larva are illustrated. The beetle may be a good candidate for the biological control of hemlock woolly adelgid, *Adelges tsugae* Annand, in North America.

**KEY WORDS** *Pseudoscymnus tsugae* sp. nov., *Adelges tsugae*, *Tsuga* spp., biological control, predator, hemlock.

THE HEMLOCK WOOLLY adelgid, *Adelges tsugae* Annand, native to Japan, is a destructive pest of eastern hemlock, *Tsuga canadensis* (L.) Carriere, in parts of the eastern United States (McClure 1987, 1989, 1991, 1996). In 1992 the junior author explored Honshu, Japan, for natural enemies of *A. tsugae* that could be used as biological control agents in North America (McClure 1995a, 1995b). Among them was an undescribed coccinellid of the genus *Pseudoscymnus*. This beetle was widespread and killed 86-99% of all adelgids wherever it occurred (McClure 1997).

This newly discovered species of *Pseudoscymnus* is now being cultured and released into hemlock forests in Connecticut, where initial studies have revealed some potential for biological control of *A. tsugae* (Cheah and McClure 1996). It has become, and will likely remain, the focus of biological control efforts against hemlock woolly adelgid in the eastern United States. It also will continue to be of interest to researchers in western North America and in China, where the adelgid was also introduced, and in its native Japan. This paper establishes the identity of *Pseudoscymnus tsugae* sp. nov. and provides the means for distinguishing it from other closely related species.

The genus *Pseudoscymnus* (Scymninae: Scymnini) was established by Chapin (1962) to include some species of Oriental *Scymnus* (s. lat.). Currently, 37 species of *Pseudoscymnus* have been described from Asia, Oceania, and Africa (Sasaji 1967). Members of the genus typically are small (3 mm) and specifically eat such homopteran pests as adelgids, aphids, mealybugs, and scale insects

(Pang and Gordon 1986). They characteristically have very short, 9-segmented antennae, a carinate prosternal process, a prosternum with a very narrow basisternum, the 1st abdominal sternum with an incomplete femoral line, and 3-segmented tarsi (Sasaji 1971). A key to the 9 species of *Pseudoscymnus* previously known from Japan was provided by Sasaji (1971).

## *Pseudoscymnus tsugae* Sasaji & McClure, new species

**Adult. Body.** Oblong-oval, relatively strongly convex above, 1.5 times as long as wide, measuring 1.57-1.80 (1.60) by 1.05-1.23 (1.05) mm (Fig. 1A) (holotype measurements in parentheses). Both dorsum and venter, including appendages, entirely black, although antennae slightly brownish. Dorsal pubescence silvery white, very fine; elytral hairs smoothly arranged toward the posterior. Abdomen blackish brown laterally.

**Head.** 0.67 times width of pronotum; eyes relatively large, interocular distance 0.6 times width of head. Frons very weakly convex; very densely, strongly, uniformly punctured; interocular margins weakly arcuate. Antenna (Fig. 1B) 0.75 times as long as interocular distance, 9-segmented, terminal 4 segments forming distinct club; basal segment large, much longer than wide; segment 2 subcylindrical, 1.5 times longer than wide; segments 3-5 each nearly as long as wide; segment 6 as long as 5, strongly thickened apically; segment 7 trapezoidal, also strongly thickened apically, 1.5 times longer than 6; segment 8 nearly parallel-sided, as long and wide as 7; terminal segment (9) small, half as long as wide. Mandible (Fig. 1C) sharply bifid apically. Terminal segment of maxillary palpus (Fig. 1D) 1.5 times as long as wide, sides slightly divergent api-

<sup>1</sup> Biological Laboratory, Fukui University, College of Education, 9-1, Bunkyo 3-Chome, Fukui-shi 910, Japan.

<sup>2</sup> To whom reprint requests should be sent.

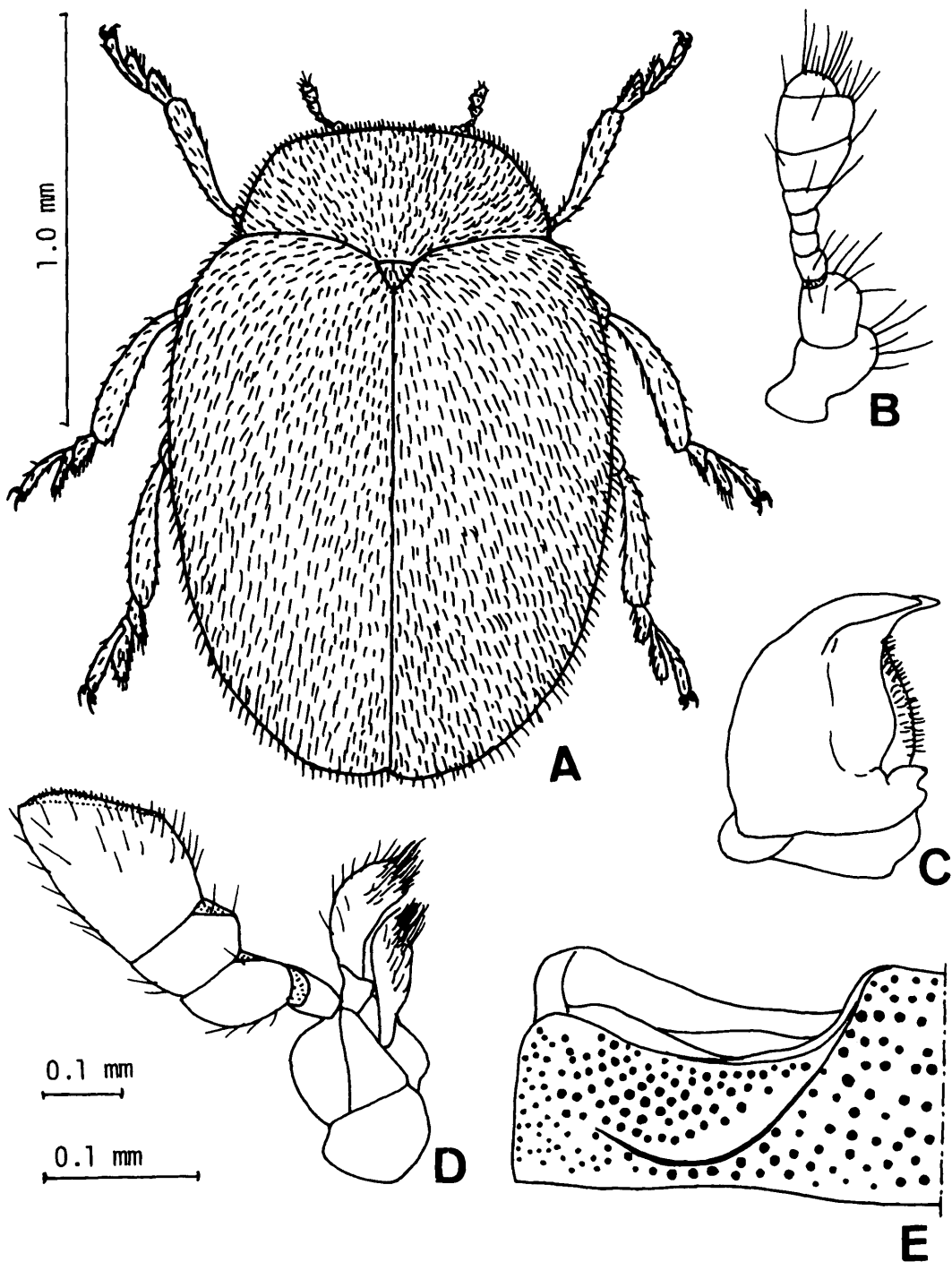


Fig. 1. Characters of adult of *Pseudoscymnus tsugae* sp. nov. (A) Dorsal habitus. (B) Antenna. (C) Mandible. (D) Maxilla. (E) Right half of first abdominal sternite. The 1.0-mm scale applies to (A), the short 0.1-mm scale applies to (B)-(D), and the long 0.1-mm scale applies to (E).

cally at basal half; apices strongly, obliquely truncate; preapical segment distinctly transverse, nearly as wide as terminal segment.

*Thorax.* Pronotum  $\approx 0.7$  times as wide as body;  $\approx 2.3$  times as wide as long and weakly convergent

apically; surface of pronotum finely and densely punctate, punctation of pronotum somewhat weaker than that of frons. Pronotum laterally weakly arcuate, very finely margined; basal corners obtusely angulate, anterior corners rectangulate.

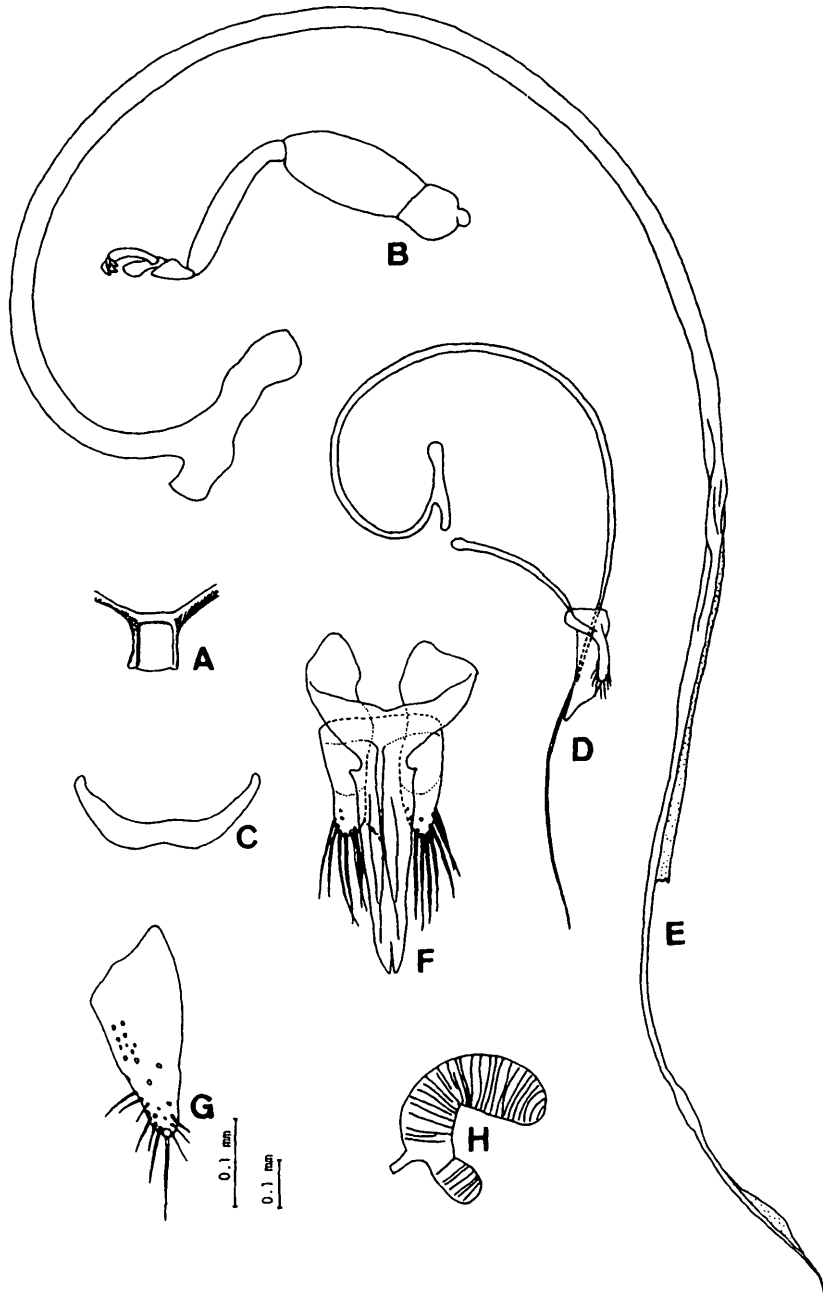


Fig. 2. Characters of adult of *Pseudoscymnus tsugae* sp. nov. (A) Median part of prosternum. (B) Middle leg. (C) Sixth abdominal sternite. (D) Male genitalia, lateral view. (E) Siphon, lateral view. (F) Tegmen, ventral view. (G) hemisternite of female. (H) Spermatheca. The short 0.1-mm scale applies to A-D; the long 0.1-mm scale applies to E-H.

Scutellum nearly regular, angulate, small,  $\approx 0.05$  times as wide as body. Elytra relatively long,  $\approx 0.75$  times as long as wide; sides weakly arcuate, widest near basal quarter. Elytral disk very densely punctate and pubescent, but pubescence distinctly sparser and coarser than on pronotum. Elytral hairs arranged in smooth arc, not in strongly curved S-form. Apex of each elytron rounded. Prosternum with longitudinally oblong median process and

very short lateral wings (Fig. 2A); median process  $\approx 0.75$  times as wide as long, lateral sides parallel, distinctly carinate. Mesosternum weakly and arcuately narrowing apically. Metasternal femoral line moderately arcuate, surface of metasternum strongly and densely punctate, more dense laterally. Legs (Fig. 2B) of moderate length and thickness with no distinct modifications; tarsi trimerous with dentate claws.

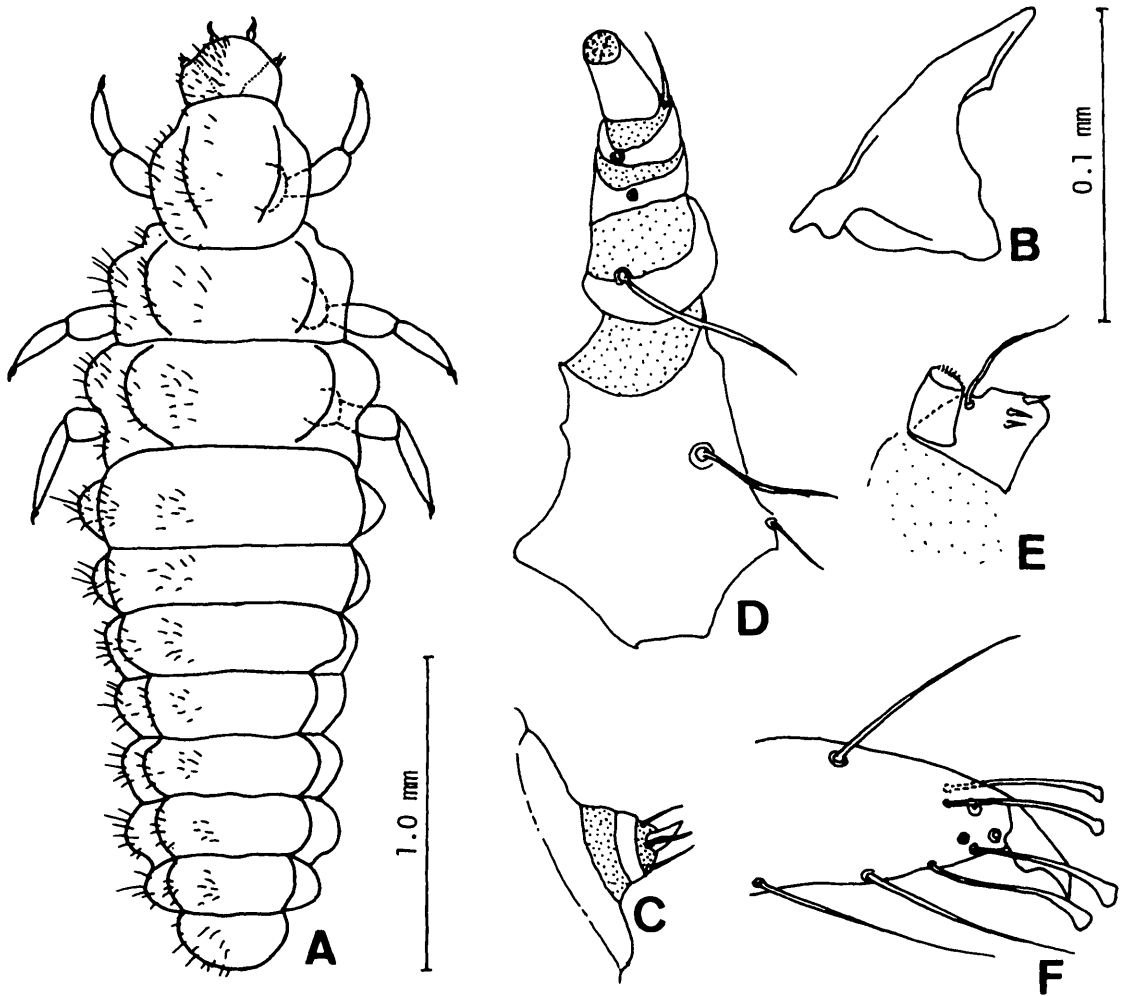


Fig. 3. Characters of mature (4th) instar of *Pseudoscymnus tsugae* sp. nov. (A) Dorsal habitus. (B) Mandible. (C) Antenna. (D) Maxillary palpus. (E) Labium. (F) Apex of front tibiotarsus. The 1.0-mm scale applies to A; the 0.1-mm scale applies to B-F.

**Abdomen.** Femoral line of first visible abdominal sternum (Fig. 1E) incomplete, weakly arcuate, relatively short, lateral, and distant from lateral margin of sternite; area delineated by femoral line strongly and uniformly punctate except for narrow smooth impunctate area near line. Preapical segment nearly flat at apical margin; apical segment (visible 6th, morphological 8th; Fig. 2C) widely and arcuately emarginate at hind margin.

**Male Genitalia** (Fig. 2 D-F). Siphon extremely long, very thin, its straight length  $\approx 1.9$  times longer than body, semicircular at basal half and weakly sinuate at apical half; apical modification barely evident at apical part of siphon. Siphonal capsule with a long inner process and a much shorter outer process. Tegmen moderately slender; median portion of tegmen very slender and weakly narrowing apically as viewed ventrally, its pointed apex deeply divided; lateral lobe of tegmen (or paramera) very short,  $\approx 0.5$  times as long as median portion.

**Female Genitalia.** Hemisternite (Fig. 2G) elongate triangular, much longer than wide, with a small but distinct stylus with thick seta. Receptaculum seminis (spermatheca) (Fig. 2H) moderately stout, weakly curved, with distinct nodulus and ramus.

**Mature (4th) Instar. Body** (Fig. 3A). Elongate fusiform, 3.02 mm long, 0.77 mm wide; gray or reddish brown, with light coating of waxy fuzz. Thoracic and abdominal dorsal sclerotized tubercles very indistinctly defined and slightly darkened.

**Head.** Transverse subpentagonal, somewhat wider than long (0.28 mm by 0.24 mm), weakly narrowing basally. Mandible as in Fig. 3B. Antenna (Fig. 3C) very small, its single segment  $>3$  times wider than long; apex of antenna with 1 thick seta and a few thin, long setae. Sclerotized segments of antenna and epicranium blackish brown, except near frontal suture. Maxillary palpus (Fig. 3D) well developed, 4-segmented, apical segment  $\approx 1.5$  times as long as thick. Labial palpus (Fig. 3E) minute, 1-segmented.

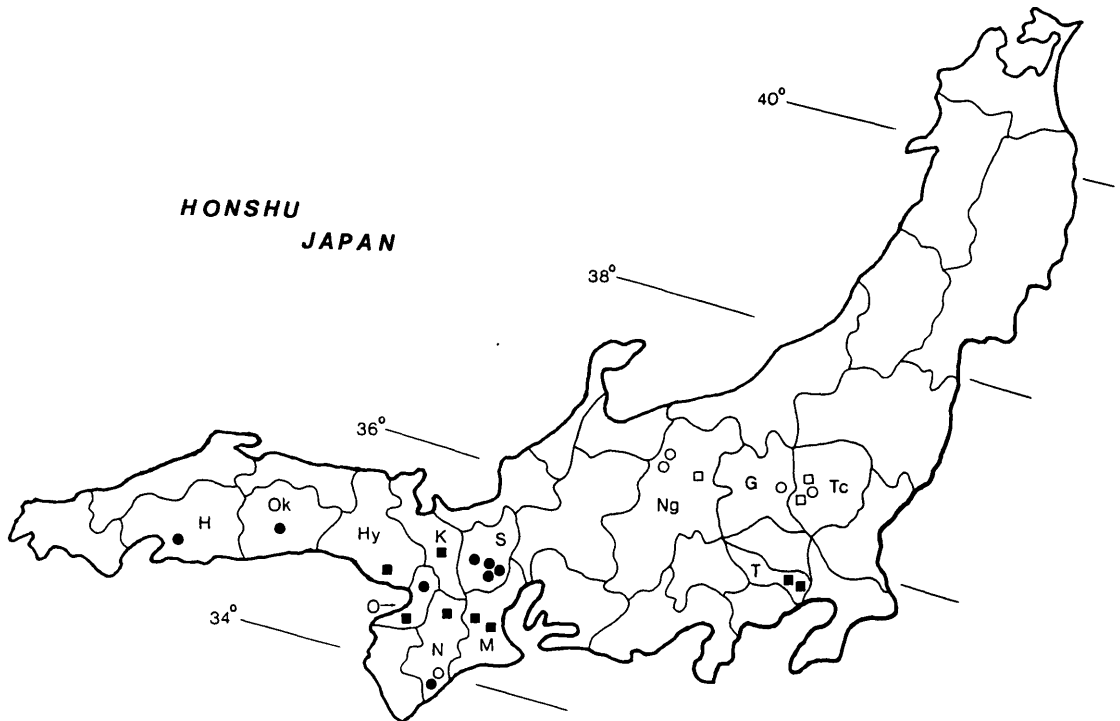


Fig. 4. Location of 24 sites in Japan where *Pseudoscymnus tsugae* sp. nov. was collected between 12 May and 23 June 1992 from forests (circles) and ornamental plantings (squares) of *Tsuga sieboldii* (shaded symbols) and *T. diversifolia* (unshaded symbols) that were infested with *A. tsugae*. Prefectures: G, Gunma; H, Hiroshima; Hy, Hyogo; K, Kyoto; M, Mie; Ng, Nagano; N, Nara; Ok, Okayama; O, Osaka; S, Shiga; Tc, Toichigi; and T, Tokyo.

**Thorax.** Prothorax subpentagonal, slightly longer than wide. Dorsal and dorsolateral areas weakly convex, with many relatively thick setae; meso- and metathoraces with anterior and posterior multiseptiferous convexities laterally. Legs dark brown to black; fore femur 0.20 mm long; fore tibiotarsus 0.19 mm, meso femur 0.22 mm, meso tibiotarsus 0.25 mm, meta femur 0.26 mm, meta tibiotarsus 0.25 mm. Tibiotarsus elongate spindle-shaped, stout, nearly as long as femur; tip (Fig. 3F) with 4 clavate adhesive apical setae. Claws thick at base.

**Abdomen.** Abdominal terga 1-7 with dorsal, dorsolateral, and lateral convexities with several strongly defined setae. Segment 8 transverse, darkened, arcuate apically.

**Type Material.** HOLOTYPE: ♂, reared from a larva collected on 7 June 1994 from *Adelges tsugae* on *Tsuga sieboldii* Carriere in Koshida, Takatsuki, Osaka Pref., T. Urano leg., preserved and deposited in the collection of the Entomological Laboratory, Kyushu University, Fukuoka. PARATYPES: 3♂♂, 4♀♀, Kitagata, Awara-cho, Fukui Pref., 22-IV-94, O. Kishimoto leg.; 1♂, 1♀, Rokuroshi, Oono-shi, Fukui Pref., 20-VIII-95, H. Sasaji leg., preserved and deposited in the collection of the Entomological Laboratory, Kyushu University, Fukuoka.

**Other Material Examined.** Six mature (4th) instars reared by M.S. McClure, and progeny of specimens collected on 7 June 1994 from *A. tsugae* on *T.*

*sieboldii* in Koshida, Takatsuki, Osaka Prefecture, by T. Urano. Specimens of larvae were preserved and deposited in the collection of the Entomological Laboratory, Kyushu University, Fukuoka. Measurements were taken from a single specimen preserved in ethanol and mounted on a microscope slide in PVA after having been cleaned with 10% KOH.

**Remarks.** Larvae of Scymnini have been little investigated at the species level. Generally, however, they have 3-segmented antennae (Kamiya 1966). Because larvae of *P. tsugae* sp. nov. and *P. hareja* (Weise 1879), described by Sasaji (1968), both have 1-segmented antennae, these species may be closely related phylogenetically among the Palearctic Coccinellidae. Larvae of *P. tsugae* sp. nov., with 4 clavate hairs on each tibiotarsus, are easily distinguishable from those of *P. hareja*, which have a single clavate hair on each tibiotarsus.

Of the 37 species of *Pseudoscymnus* described from Asia, Oceania, and Africa (Sasaji 1967), adults of 8 species resemble *P. tsugae* sp. nov. by being almost completely black dorsally. Five of them, *Pseudoscymnus kurohime* (Miyatake) (1959), *P. ammanshanus* Yang (1971), *P. amplus* Yang and Wu (1972), *P. dapae* Hoang (1978), and *P. hanoiensis* Hoang (1982) differ from *P. tsugae* sp. nov. by having female genitalia with a wide (not elongate) hemisternite and strongly curved S-form (not smoothly arcuate) elytral hairs. The other 3 spe-

cies, which occur in Japan, can be distinguished from *P. tsugae* sp. nov. as follows: *P. lewisi* (Kamiya) has a subovate (not elongate) hemisternite, *P. nagasakiensis* (Kamiya) has a tegmen with a lateral lobe that is  $\approx 4/5$  (not half) the length of the median piece (Kamiya 1961, 1966), and *P. nakanei* (Araki) (1963) has strongly curved S-form (not smoothly arcuate) elytral hairs. Sasaji (1971) provides other characters for distinguishing the Japanese species of *Pseudoscymnus*.

**Distribution in Japan.** Adults of *P. tsugae* sp. nov. were collected between 12 May and 23 June 1992 by M. S. McClure from *A. tsugae*-infested *Tsuga diversifolia* Masters and *T. sieboldii* Carriere in 13 of 37 forests and at 11 of 37 ornamental sites in 12 prefectures of Honshu, Japan (Fig. 4). These sites ranged from 34° 11' to 36° 50' N latitude and from sea level to 1,980 m elevation. Adults from these 24 sites were similar and appeared to be identical to others that were collected from *A. tsugae*-infested *T. sieboldii* on 7 June 1994 by T. Urano at Koshida, Takatsuki, Osaka Prefecture and subsequently examined by H. Sasaji. Adults of *P. tsugae* sp. nov. were collected later by sweeping grasses and shrubs at 2 marshy sites in Fukui Prefecture.

#### Acknowledgments

We are grateful to Kensuke Ito, E'ichi Shibata, and Fumio Yamada for organizing the visit of M.S.M. to Japan; to the Forestry and Forest Products Research Institute (FFPRI) for providing research facilities, personnel and equipment; and to Tadahisa Urano (Kansai Research Center, FFPRI, Kyoto Prefecture) and Osamu Kishimoto (Takefu High School, Fukui Prefecture) for providing specimens of the type series. We thank Robert Gordon for identifying coccinellid specimens, Robert Ballinger, Beth Beebe, and Mary Klepacki for valuable technical assistance, and Carole Cheah for reviewing an early draft of the manuscript. This research was supported in part by funds provided by the Horticultural Research Institute (Washington, DC); Steep Rock Association, Inc. (Washington, CT); Finch, Pruyn & Company (Glens Falls, NY); Connecticut Tree Protective Association (Rocky Hill, CT); and the U.S. Forest Service through the Northeastern Area State and Private Forestry, Forest Health Technology Enterprise Team, and the Northeastern Forest Experiment Station.

#### References Cited

- Araki, M. 1963. Description of four new species of the genus *Scymnus* from Japan (Coleoptera: Coccinellidae). Sci. Rep. Kyoto Prefect. Univ. Agric. 3(5)A: 251-255.
- Chapin, E. A. 1962. *Pseudoscymnus*, a new genus of Asiatic Scymnini (Coleoptera: Coccinellidae). Psyche 69: 50-51.
- Cheah, C. A. S.-J., and M. S. McClure. 1996. Exotic natural enemies of *Adelges tsugae* and their potential for biological control, pp. 103-112. In S. M. Salom, T. C. Tigner, and R. C. Reardon [eds.], *Proceedings, First Hemlock Woolly Adelgid Review*, 1995, Charlottesville, VA. U.S. For. Serv., FHTET 96-10.
- Hoang, D. N. 1978. Genre *Pseudoscymnus* Chapin (Coccinellidae, Coleoptera) au Viet-nam. Tapp. San Sinh Vat—Dia Hoc 16(4): 111-115.
1982. Coccinellidae of Viet Nam (Insecta: Coleoptera), (vol. 1).
- Kamiya, H. 1961. A revision of the tribe Scymnini from Japan and the Loochoos (Coleoptera: Coccinellidae), part I. J. Fac. Agric. Kyushu Univ. 11:275-302, pl. 32.
1966. On the Coccinellidae attacking the scale insects and mites in Japan and the Ryukyus. Mushi 39: 65-93.
- McClure, M. S. 1987. Biology and control of hemlock woolly adelgid. Bull. Conn. Agric. Exp. Stn. 851.
1989. Evidence of a polymorphic life cycle in the hemlock woolly adelgid, *Adelges tsugae* (Homoptera: Adelgidae). Ann. Entomol. Soc. Am. 82: 50-54.
1991. Density-dependent feedback and population cycles in *Adelges tsugae* (Homoptera: Adelgidae) on *Tsuga canadensis*. Environ. Entomol. 20: 258-264.
- 1995a. Using natural enemies from Japan to control hemlock woolly adelgid. Front. Plant Sci. 47(2): 5-7.
- 1995b. *Diapterobates humeralis* (Oribatida: Ceratozetidae): an effective control agent of hemlock woolly adelgid (Homoptera: Adelgidae) in Japan. Environ. Entomol. 24: 1207-1215.
1996. Biology of *Adelges tsugae* and its potential for spread in the northeastern United States, pp. 16-23. In S. M. Salom, T. C. Tigner, and R. C. Reardon [eds.], *Proceedings, First Hemlock Woolly Adelgid Review*, 1995, Charlottesville, VA. U.S. For. Serv. FHTET 96-10.
1997. Biological control in native and introduced habitats: lessons learned from the sap-feeding guilds on hemlock and pine, pp. 31-52. In D. A. Andow D. W. Ragsdale, and R. F. Nyvall [eds.], *Ecological interactions and biological control*. Westover, Boulder, CO.
- Miyatake, M. 1959. A contribution to the coccinellid fauna of the Ryukyu Islands (Coleoptera). Mem. Ehime Univ. (IV)4: 125-162.
- Pang, X. F., and R. D. Gordon. 1986. The Scymnini (Coleoptera: Coccinellidae) of China. Coleopt. Bull. 40: 157-199.
- Sasaji, H. 1967. On the coccinellidae attacking the aphids in Japan and the Ryukyus. Mushi 40: 147-175.
1968. Descriptions of the coccinellid larvae of Japan and the Ryukyus (Coleoptera). Mem. Fac. Educ. Fukui Univ., Ser. II (18): 93-138.
1971. Fauna Japonica: Coccinellidae (Insecta: Coleoptera). Academic, Tokyo, Japan.
- Weise, J. 1879. Beiträge zur Käferfauna von Japan (fünftes Stück). Dtsch. Entomol. Z. 23: 147-152.
- Yang, C.-T. 1971. Notes on the species of genus *Pseudoscymnus* from Taiwan (Coleoptera: Coccinellidae). J. Agric. For. Taichung 20: 85-96.
- Yang, C.-T., and R.-H. Wu. 1972. Notes on some Coccinellidae of Taiwan. J. Agric. For. Taichung 21: 115-128.

Received for publication 4 March 1997; accepted 12 June 1997