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## Scientific Note

# Predators collected from balsam woolly adelgid and Cooley spruce gall adelgid in western Oregon and Washington, U.S.A., with reference to biological control of hemlock woolly adelgid (Hemiptera: Adelgidae)

As part of a comprehensive study to survey predators associated with hemlock woolly adelgid, *Adelges tsugae* Annand, 1928 in the Pacific Northwest (PNW), U.S.A. (Kohler et al. 2008), predators of balsam woolly adelgid, *Adelges piceae* (Ratzeburg, 1844) and Cooley spruce gall adelgid, *Adelges cooleyi* (Gillette, 1907) (all Hemiptera: Adelgidae) were sampled on nine dates from June 2005 to October 2006 on a small number of trees. Samples were collected every 6–8 weeks. Predators were collected from two *A. piceae* infested grand fir, *Abies grandis* (Douglas ex David Don) Lindley, and one *A. cooleyi* infested Engelmann spruce, *Piceae engelmanii* Parry ex Engelmann, on the Oregon State University campus in Corvallis, Oregon, and two *A. cooleyi* infested Douglas-fir, *Pseudotsuga menziesii* (Mirbel) Franco (all Pinaceae). One Douglas-fir was an ornamental tree in Corvallis, Oregon and the other was in a seed orchard on Whidbey Island, Washington. *Adelges cooleyi* predators were collected by striking an infested branch four times over a plastic tub with an area of 0.16 $m^2$. *Adelges piceae* predators were collected by brushing adelgid wool on the bole of infested trees with a 2-inch wide paintbrush over a beat sheet. Predators were collected from the tub and beat sheet with an aspirator. Adult insects were killed in a sealed 9-dram plastic vial containing a small piece of Hot Shot No-Pest Insecticide Strip (Spectrum Brands Inc., Atlanta, Georgia). Immature insects were killed in KAAD mixture (10 parts 95% ethanol, 1 part kerosene, 2 parts glacial acetic acid, and 1 part dioxane) and preserved in 70% ethanol (Borrer et al. 1989). Adult specimens were identified either by taxonomic specialists or by comparison to previously identified museum specimens. Voucher specimens were deposited in the Oregon State Arthropod Collection, Department of Zoology, Oregon State University, Corvallis, Oregon.

Nine predator families representing four orders were collected from *A. cooleyi*. Eleven species were identified as adults, all of which were also found associated with *A. tsugae* (Table 1) (Kohler 2007). One alate *A. cooleyi* was collected. Only two predator families, Reduviidae and Chamaemyiidae, were collected from *A. piceae* (Table 1). The one species of Reduviidae collected, *Empicoris rubromaculatus* (Blackburn, 1888) (Hemiptera: Reduviidae), has also been collected from *A. tsugae* (Kohler 2007). Four of the chamaemyiid larvae were reared to adults in the lab and identified as *Neoleucopis tapiae* (Blanchard, 1864) [=*Leucopis tapiae*] (Diptera: Chamaemyiidae), a native species. This species has not been found associated with *A. tsugae*.

The species of predators that were not found in this sampling are significant with respect to the ongoing biological control program for *A. tsugae* in the eastern U.S. In the more comprehensive survey of *A. tsugae* predators, three species of adelgid specialist predators were identified, *Laricobius nigrinus* Fender, 1945 (Coleoptera: Derodontidae), *Leucopis argenticollis* Zetterstedt, 1848 (Diptera: Chamaemyiidae), and *Leucopis piniperda* Malloch, 1921 (Diptera: Chamaemyiidae) [misidentified as *Leucopis atrifacies* Aldrich, 1925 (Diptera: Chamaemyiidae), see Grubin et al. 2011] (Kohler et al. 2008). Adults or immatures of *L. nigrinus* were collected at all 16 of the sample tree locations, and adults or immatures of one or both *Leucopis*

Table 1. Abundance of predatory species identified from infestations of *Adelges piceae* and *Adelges cooleyi* in the Pacific Northwest, U.S.A., June 2005 through October 2006.

| | prey species: | *Adelges piceae* | *Adelges cooleyi* | *Adelges cooleyi* | |
|---|---|---|---|---|---|
| | host species: | *Abies grandis* | *Pseudotsuga menziesii* | *Picea engelmannii* | |
| | # samples: | 16 | 19 | 9 | |
| Order | Species | | Number of adults and (immatures) | | OSAC accession ID[a] |
| Hemiptera | Miridae | | (1) | (16) | |
| | *Ceratocapsus apicatus* Van Duzee | | 2 | 5 | 000028966 |
| | *Deraeocoris brevis* (Uhler) | | 2 | 3 | 000028967 |
| | Nabidae | | | | |
| | *Nabis alternatus* Parshley | | | 1 | 000028968 |
| | Reduviidae | (1) | (3) | | |
| | *Empicoris rubromaculatus* (Blackburn) | 1 | (1) | 5 (5) | 000028969 |
| Neuroptera | Coniopterygidae | | (3) | | |
| | *Conwentzia californica* Meinander | | 2 | | 000028970 |
| | *Semidalis angusta* (Banks) | | 1 | | 000028971 |
| | Hemerobiidae | | (5) | (1) | |
| | *Hemerobius* spp. | | 1 | 1 | 000028972 |
| Neuroptera | Chrysopidae | | | (2) | |
| Coleoptera | Coccinellidae | | (2) | | |
| | *Harmonia axyridis* (Pallas) | | | (2) | 000028973 |
| | *Mulsantina picta* (Randall) | | 5 | | 000028974 |
| | *Rhyzobius lophanthae* (Blaisdell) | | 2 | | 000028975 |
| | *Stethorus punctillum* Weise | | 4 | | 000028976 |
| Diptera | Syrphidae | | (4) | (2) | |
| | Chamaemyiidae | (21) | (1) | | |
| | *Neoleucopis tapiae* (Blanchard)[b] | 1 | | | 000028977 |

[a] Voucher specimens deposited at the Oregon State Arthropod Collection (OSAC), Department of Zoology, Oregon State University, Corvallis.
[b] Determined by S. D. Gaimari, California Department of Food & Agriculture.

species were found at 15 of the 16 sample tree locations in the survey of *A. tsugae* predators. *Laricobius nigrinus* is restricted in distribution to the PNW and has been reported to be a specialist on *A. tsugae* (Zilahi-Balogh et al. 2002, 2003a, 2003b). However, *L. nigrinus* has occasionally been collected from *Pineus similis* (Gillette, 1907) (Hemiptera: Adelgidae) on western white pine, *Pinus monticola* Douglas ex David Don (Pinaceae), *Adelges lariciatus* Vallot, 1836 (Hemiptera: Adelgidae) (Patch) on western larch, *Larix occidentalis* Nuttall (Pinaceae), and *A. cooleyi* on Douglas-fir and Engelmann spruce in British Columbia, Idaho, and Washington (Mausel et al. 2011a, Havill et al. 2012). It has been suggested that there are two strains of *L. nigrinus*, a coastal strain and an inland strain, that could explain this behavioral difference (Mausel et al. 2011b). However, there is evidence of gene flow between these two populations that contradicts this hypothesis (see Figure 2A, Havill et al. 2012) and suggests that the behavioral differences are instead due to phenotypic plasticity. Both of the *Leucopis* species are reported from other parts of North America but are not found associated with *A. tsugae* anywhere outside of the PNW (see citations in Ross et al. 2011). Although the number of trees and sites sampled in this study was small, the data we report here supports the hypothesis that the two *Leucopis* species of specialist predators found associated with *A. tsugae* in the PNW are restricted in their distribution to that one species. Furthermore, the geographically isolated populations of *L. argenticollis* and *L. piniperda* found in the PNW are not only likely specialists on *A. tsugae*, but are distinct from populations of both species found in other parts of North America. Although both species of *Leucopis* collected in the PNW are capable of feeding and developing on other adelgid species in the laboratory (Grubin et al. 2011), there are to date no collection records to suggest that they come in contact with these other species under field conditions. In a survey of predators associated with *A. piceae* in British Columbia, only two introduced species of chamaemyiids were collected, *Cremifania nigrocellulata* Czerny, 1904 (Diptera: Chamaemyiidae) and *Leucopis atratula* (Ratzeburg, 1844) (Diptera: Chamaemyiidae) (Humble 1994). It is likely that individuals of both *L. argenticollis* and *L. piniperda* have a searching behavior that involves response to odors from the hemlock hosts of *A. tsugae* (Wallin 2011). *Laricobius nigrinus* has been studied for biological control of *A. tsugae* in the eastern U.S. for over 15 years. Since 2003, several hundred thousand adults and eggs of *L. nigrinus* have been released at hundreds of sites in 14 eastern states (Mausel et al. 2011). Both *Leucopis* species have been released in the eastern U.S. under experimental conditions (Motley et al. 2017), but no attempts have yet been made to establish populations in that region. The apparent fidelity of individuals of both *Leucopis* species to *A. tsugae* under field conditions in the PNW, based on results reported here and elsewhere in the literature, adds to the growing body of evidence (Kohler et al. 2016, Motley et al. 2017) that suggests they could be successful biological control agents for *A. tsugae* where it has been introduced in the eastern U.S.

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