Establishment and Distribution of *Laricobius* spp. (Coleoptera: Derodontidae), a Predator of Hemlock Woolly Adelgid, Within the Urban Environment in Two Localities in Southwest Virginia

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Abstract

Hemlock woolly adelgid (HWA), *Adelges tsugae* Annand, is a highly destructive non-native pest lethal to eastern hemlock, *Tsuga canadensis* (L.) Carrière, and Carolina hemlock, *T. caroliniana* Engelmann. Fifty years following the first observation of HWA in eastern North America, a predatory beetle, *Laricobius nigrinus* Fender, was evaluated, approved, and released as a biological control agent. Efforts were made to mass rear *L. nigrinus* with the goal of redistributing the beetles on public lands, typically in forest ecosystems, as a secondary option to silvicultural and chemical controls. The majority of *L. nigrinus* releases has occurred on public lands. Herein, we report the observation of *L. nigrinus* within the urban environment outside of known release locations. Two towns, Blacksburg and Radford, were divided into 0.40 km² grids. A total of 27 and 19 grids were randomly selected from each town, respectively. Hemlocks were present in 44 and 42% of the grids surveyed in Blacksburg and Radford, respectively. In Blacksburg and Radford, 86 and 100% of the grids with hemlocks were infested with HWA, and of those infested hemlocks, *Laricobius* spp. was present in 100 and 75% of grids, respectively. A total of 154 *Laricobius* spp. (98% *L. nigrinus* and 2% *Laricobius rubidus*) adults were collected between each town. While it is unclear the level of control *L. nigrinus* has on reducing HWA’s impact, the establishment of this biological control agent in the urban environment is an additional level of predation, that would otherwise not be present, for homeowners with HWA-infested trees.

**Key words:** *Adelges tsugae*, hemlock, biological control

*Adelges tsugae* Annand (Hemiptera: Adeilgidae), commonly known as the hemlock woolly adelgid (HWA), is a destructive invasive, non-native pest of eastern hemlock, *Tsuga canadensis* (L.) Carrière, and Carolina hemlock, *T. caroliniana* Engelmann (Jenkins et al. 1999, Havill et al. 2006). *Adelges tsugae* was first reported in the urban environment in the early 1950s in Richmond, Virginia on ornamental hemlock (Gouger 1971, Souto 1996), presumably imported from Japan (Havill et al. 2006). Since then, HWA has spread into the indigenous hemlock distribution across 20 states and portions of Canada, covering over half of the extant range of eastern hemlocks (USDA Forest Service 2019). The continued spread of HWA into urban and forest landscapes jeopardizes the health and integrity of ecosystems that depend on these keystone species (Ellison et al. 2014), as well as threatens the aesthetic nature of these ecosystems (Stadler et al. 2005).

*Laricobius nigrinus* Fender (Coleoptera: Derodontidae) and *Laricobius rubidus* LeConte (Coleoptera: Derodontidae) are native predacious species of Adelgidae, occupying the western and eastern portions of the United States, respectively (Zilahi-Balogh et al. 2002; Onken and Reardon 2011). *Adelges tsugae* is the preferred prey of *L. nigrinus* and following its introduction in the eastern United States, has become secondary prey of *L. rubidus*. The primary prey of *L. rubidus* is the pine bark adelgid (PBA), *Pinus strobi* (Harrig) (Wantuch et al. 2017). *Laricobius osakensis* Shiyaake and Montgomery (Coleoptera: Derodontidae) is native to Japan and was imported into the United States under quarantine in 2006, approved for release in 2010, and subsequently released in the eastern United States beginning in 2012 (Vieira et al. 2011; Fischer et al. 2014, Mooneyham et al. 2016). Both *L. nigrinus* and *L. osakensis* are now established in Virginia (Mausel et al. 2010, Toland et al. 2018).
Following the approval for release of *L. nigrinus*, the University of Tennessee and Virginia Tech initiated a robust mass rearing effort (Lamb 2002, Jubb 2011). The goal was to supply public land managers with biological control agents as an additional control option, where chemical insecticide treatments are not feasible due to ecological and/or economical issues. Since the approval for release of *L. nigrinus* in 2003, releases have been made from Georgia to Maine, totaling over 400,000 beetles (Jubb 2019). Establishment and subsequent recoveries have occurred within every release state. The majority of releases have occurred within forest settings. For homeowners, there is only a handful of effective registered insecticides that can safeguard individual infested trees from succumbing to HWA infestations (Vose et al. 2013). Chemical control options are more plausible for homeowners and municipalities targeting individual trees than for land managers targeting trees at the ecosystem level. Insecticide application also requires a base knowledge of how to apply the insecticides (e.g., foliar sprays, soil drench, or trunk injections), requires reapplication every 4 to 7 yr, and costs may limit the number of trees that can be treated (Cowles et al. 2006, Benton et al. 2016). In spite of these limitations, chemical control is the principal tactic employed in urban environments. Beetles produced by laboratories or collected by government employees are destined for release on public lands. The only case of a focused effort to release beetles in communities or on private lands was done through consultants. In that situation over 14,000 *L. nigrinus* collected from the Seattle, WA area were released in the area surrounding Boone, NC (McDonald et al. 2011). Other than this example, no other known intentional releases of *Laricobius* spp. in urban environments have been reported.

The goal of this study was to determine whether *Laricobius* spp. have become established at nonrelease sites within the urban environment in two localities in southwest Virginia: Blacksburg, and Radford. The two towns were divided into 0.40 km² grids (Fig. 1). Individual grids that did not completely fall within each respective town limits were excluded. A total of 27 and 19 grids were randomly selected from the two towns, respectively. Each town was surveyed between 21 February and 12 March 2019. Each individual grid was surveyed for the number of hemlocks, number of hemlocks with HWA, and the number of hemlocks with HWA and *Laricobius* spp. *Laricobius* adults were sampled using the beat sheet method for a collection time of 5 min, and if beetles were present, they were manually aspirated and collected. While this method historically underestimates the population of *Laricobius* adults (Mausel et al. 2010), it is quick and easy to employ. Species determination was based on morphology using a dissection microscope (Leschen 2011). *Laricobius* adults sampled within surveyed grids were mapped using GIS (ESRI 2018). The National Land Cover Database (NLCD) 2016 land cover raster layer, was used to visualize forest composition and development intensity at each survey site.

Fig. 1. Randomly selected survey grids (0.40 km²) sampled in the town of Blacksburg (*n* = 27) and Radford City (*n* = 19), VA. Selected grids were surveyed for the presences of hemlocks, HWA, and *Laricobius* spp. in 2019. Color of each grid represents mean adult *Laricobius* sampled per hemlock tree. The National Land Cover Database (NLCD) 2016 land cover raster data layer illustrates forest composition and development intensity at each survey site.
development intensity within surveyed grids (Fig. 1) (Yang et al. 2018).

Hemlocks were present in 44 and 42% of the grids surveyed in Blacksburg and Radford, respectively. In Blacksburg and Radford, 86 and 100% of the grids with hemlocks were infested with HWA, and of those infested hemlocks, Laricobius spp. was present in 100 and 75% of grids, respectively. A total 154 Laricobius spp. (98% L. nigrinus and 2% L. rubidus) adults were collected from Blacksburg and Radford. This is the first documentation of L. nigrinus in the urban environment in the eastern United States where beetles have not been intentionally released. During the initial scouting for biological control agents of HWA in the Pacific Northwest, a common, reliable, and convenient location to collect L. nigrinus is in the urban environment which includes neighborhoods, parks, and cemeteries (McDonald et al. 2011). The relatively high rates of recovery suggest that L. nigrinus can successfully establish in the urban environment within its newly introduced range. This supports our hypothesis that once released, L. nigrinus can disperse, locate its prey, and establish in environments outside of the forest setting. Following emergence, L. nigrinus uses a combination of olfactory cues, visual cues, and semiochemicals from infested trees to locate its prey (Mausel et al. 2011, Wallin et al. 2011).

The source of L. nigrinus found in each respective town is unknown. The closest release sites of L. nigrinus were at two locations in 2003. One site was located at Price’s Fork (37.2121 N, −80.4894 W), 6.9 km from Blacksburg and 11.8 km from Radford. The second release site was Kentland Farm in Blacksburg, VA (37.2075 N, −80.5895 W) located 15 km from Blacksburg and 9.3 km from Radford. Laricobius nigrinus adults may have dispersed to these adjacent towns 16 yr after their initial release. Another source of L. nigrinus collected in Blacksburg may have been the Virginia Tech’s mass rearing facility located in the town limits of Blacksburg (37.2206 N, −80.4234 W). Hemlock branches infested with HWA are collected from other localities in Virginia and further south, and bought to Virginia Tech’s rearing facility for mass rearing of Laricobius spp. These HWA-infested branches may have been collected from sites that supported L. nigrinus and L. rubidus populations, and adults may have been present on the branches. These branches were kept outside the rearing facility and adults present on the branches may have flown from them and dispersed into Blacksburg. The ubiquity of L. nigrinus throughout both towns, their relative location to the closest known releases, and their univoltine life cycle suggest the beetles had been established for many years.

The establishment and distribution of L. nigrinus in the urban environment is an added level of protection for homeowners who have HWA-infested hemlocks. After learning about biological control, homeowners often ask, ‘How do I get beetles for my trees?’ Due to the apparent ability of L. nigrinus to successfully disperse over reasonably long distances, other urban areas close to L. nigrinus release sites may already have this species established, or will, soon. Monitoring for this predator in urban habitats can help homeowners and municipalities determine how best to address the presence and potential impact of HWA-infested hemlocks.

References Cited


