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NOTE

Vertical distribution of Pale-winged Gray moth (*Iridopsis ephyraria*) defoliation on eastern hemlock trees in Nova Scotia

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Many studies of feeding patterns by tree-feeding insects examine among-tree feeding patterns within a host species (e.g., Alonso and Herrera 1996) or among different hosts (e.g., Barbosa and Greenblatt 1979; deBoer and Hanson 1984). Although feeding can vary just as much within as among trees, studies of within-tree feeding patterns are much less common (Rowe and Potter 1996; Alonso and Herrera 1996; Wallin and Raffa 1997; Fortin and Mauffette 2002; Yamasaki and Kikuzawa 2003; Johns and Quiring 2010). Although insects might feed more in some crown levels rather than others, vertical feeding patterns are often not documented due to the practical difficulty of accessing tree canopies in large trees. Uneven vertical feeding patterns among insect defoliators may be due to differences in foliage nutritional quality (e.g, White 1984), or alternatively, due to hygrothermal stress in sun-exposed areas. Here, we describe results of field studies carried out to determine if defoliation by the pale-winged gray moth, *Iridopsis ephyraria* (Walker) (Lepidoptera: Geometridae) varies among crown levels of mature and understory eastern hemlock (*Tsuga canadensis* L. Carr.) (Pinaceae) trees.

Iridopsis ephyraria is a univoltine defoliator of *Tsuga canadensis* and other plants, overwinters as an egg, and has five larval instars (Pinault et al. 2007). To estimate defoliation in different crown levels by this insect, nine sites with a range of insect densities were selected for study over three years (2004: 3 sites, 2005: 4 sites, 2006: 2 sites), during the decline of an outbreak. All sites were located in or within 15 km of Kejimkujik National Park and National Historic Site (KNP) in southern Nova Scotia. We were not able to sample sites for more than one year due to severe seasonal defoliation at most sites. Caterpillars of *Iridopsis ephyraria* severely defoliated approximately 43343 ha of hemlock forests between 2002-2006 (R. Guscott, Nova Scotia Department of Natural Resources (NSDNR), personal communication).

At each site, 10 mature (>20 m tall) eastern hemlock trees were selected along a road or path, where all crown levels were visible to observers on the ground. Defoliation was estimated using binoculars, based on Parsons et al. (2003) and as described in Pinault and Quiring (2008), using 10% defoliation classes, in each of the upper, middle and lower parts of the foliated crown. In each crown level, one branch was selected on each side of the tree bole relative to the observer, to minimize directional bias. As incident light could potentially reach the lower and middle crown branches along the road but not in the rest of a stand, observers selected branches that were not directly near or over the road. Defoliation was measured prior to egg hatch in late May and again following pupation in late July (Pinault et al. 2007), and the difference of the two (seasonal defoliation) measurements calculated. Two measurements of average defoliation are reported: defoliation of the current-year shoot, and defoliation of the entire branch (current-year foliage to 4-year-old foliage).

In 2005, defoliation of small (<4 m) hemlock trees was estimated at five of the study sites in KNP, on the current-year shoot only, as described above. Whole branch defoliation was not estimated, since older ages of foliage had been previously defoliated at all study sites (often >90%).

Defoliation among crown levels was compared using a split-plot general linear model, as estimates among crown levels were grouped by tree. In the model, site, crown level, and the interaction of site and crown level were testable

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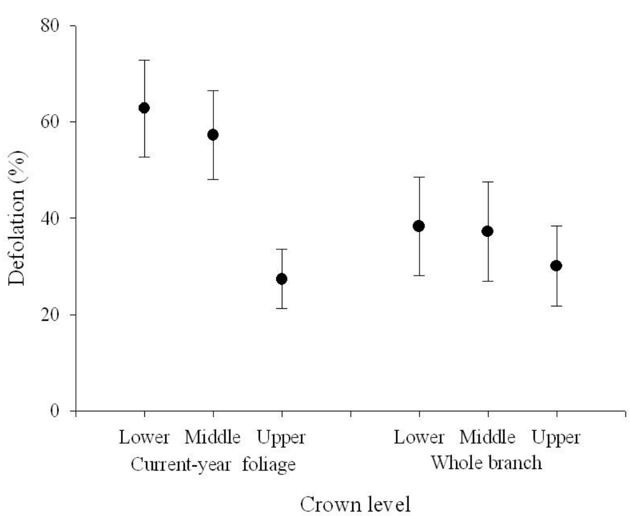
factors. When ANOVA results were significant, a Student-Newman-Keuls post-hoc test was used to determine which crown levels bore significantly different levels of defoliation.

Within the crown of mature trees, the lower and middle crowns were significantly more defoliated than the upper crown for current-year defoliation (Figure 1, Table 1, Student-Newman-Keuls post-hoc test: $q_{middle-upper} = 3.65 > q_{critical =} 3.46$; $q_{lower-middle} = 2.99 < q_{critical} = 3.46$). Whole-branch defoliation was also significantly affected by crown level (Table 1), but post-hoc tests were insignificant. Defoliation did not differ substantially between lower and middle crowns (Figure 1). Both measurements of defoliation were affected by site (Table 1), and current-year shoot defoliation was also affected by the interaction of crown level and site (Table 1), which reflected some of the natural variation among study sites. Specifically, the interaction was caused by one of the sites in 2005, where middle crown defoliation was greater than the lower and upper crown levels of defoliation.

Figure 1. Mean (±SE) percent defoliation of mature eastern hemlock trees, at 9 sites in southern Nova Scotia. Defoliation of current-year foliage only and whole branch defoliation (current year to 4-year-old foliage) is presented.



The low levels of defoliation in the upper versus middle and lower crowns probably enabled most of the large hemlock trees in the study area to survive multiple years of high defoliation. Although defoliation levels in the lower and middle crown of large mature trees were very high on all age classes of foliage at all study sites, there was very little mortality of large trees.

Among small understory trees, there was no significant difference in defoliation of current-year foliage among crown levels ($F_{2,8} = 2.02$; $P = 0.19$), although defoliation varied among sites ($F_{4,145} = 22.47$; $P < 0.001$) and small inconsistent variations in defoliation of the three crown levels among site resulted in a significant interaction between crown level and site ($F_{8,290} = 7.44$; $P < 0.001$).

Table 1. Split-plot general linear model results of differences in current-year shoot and whole branch defoliation among crown levels of mature hemlock trees in Nova Scotia, Canada.

		Current-year shoot			Whole branch		
Source of variation	df	MS	F	P	MS	F	P
Among trees							
Site	8	15015.2	12.4	<0.001	24569.7	14.6	<0.001
Error	81	1206.6			1678.8		
Within trees							
Crown level	2	32707.8	12.8	<0.001	1813.8	7.5	0.005
Site x Crown level	16	2548.9	4.3	<0.001	240.5	1.6	0.051
Error	162	587.9			141.5		

Although there was no consistent variation in defoliation among crown levels on small trees, this was not surprising given the much shorter distances required for larvae to move between crown levels. The significant interaction of crown level and site is likely due to some of the sites being more severely defoliated than others, providing less available foliage for caterpillars and thereby altering the expected feeding pattern.

Proximate mechanisms that could result in defoliation occurring primarily in the middle and lower crown of large hemlock trees include oviposition preference by adult females and feeding preference by larvae for these regions, hypotheses that are investigated in another paper (Herveux et al. 2012) in this issue.

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