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Deidamia inscriptum (Lettered Sphinx Moth) Caterpillars Feeding on *Oxydendrum arboreum* (Sourwood) and Their Predation by Black Bears in Northeast Tennessee

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Abstract - An outbreak of *Deidamia inscriptum* (Lettered Sphinx Moth) caterpillars was noted in northeast Tennessee where *Oxydendrum arboreum* (Sourwood) trees were defoliated. Nearly all published literature and online resources list only plants in the grape family (Vitaceae) as larval food plants. Food-plant preference trials using fresh leaves of 3 woody plant species showed that *Deidamia* caterpillars from this region had a preference for Sourwood over *Parthenocissus quinquefolia* (Virginia Creeper), and rejected *Acer rubrum* (Red Maple), a non-host species. *Ursus americanus* (Black Bear) were feeding on the caterpillars as evidenced by bent and broken Sourwood saplings bearing claw marks and by abundant sphingid remains in bear scat.

Introduction

The geographical range of *Deidamia inscriptum* (Harris) (Lettered Sphinx Moth) encompasses much of eastern North America. Caterpillars of this species feed primarily on plants in the grape family (Vitaceae) including *Parthenocissus* spp. (creepers), *Ampelopsis* spp. (peppervines), and *Vitis* spp. (grapes) (Covell 2005, Hodges 1971, Tuttle 2007). There have been sporadic reports stating that in the southeastern US, Lettered Sphinx Moth caterpillars also feed on the leaves of *Oxydendrum arboreum* (L.) DC. (Sourwood) (Tietz 1952, 1972; Tuttle 2007; Wagner 2005; Wagner and Langdon 2006), a small tree in the Ericaceae that is distantly related to the Vitaceae.

Although Sourwood has not previously been considered a major host species for the Lettered Sphinx Moth, it appears to be a preferred host in mid-elevations of the Appalachian Mountains from West Virginia to North Carolina (Wagner 2005). The Lettered Shinx Moth is a recurrent defoliator of Sourwood stands in Great Smoky Mountains National Park (GSMNP). Larvae of a green sphingid defoliated Sourwoods in GSMNP in 1988 and 1990, but the caterpillars were not identified to species (Wagner and Langdon 2006). We could not find any published accounts of Sourwood defoliation prior to these reports, although Keith Langdon (GSMNP, Gatlinburg, TN, pers. comm.) recalls hearing mention of them in the GSMNP by Art Stupka, the Park's naturalist from 1938–1963. In 2001–2003, also in GSMNP, an outbreak of Lettered Sphinx Moth caterpillars caused widespread defoliation of Sourwoods (Wagner and Langdon 2006). During the 2001–2003 outbreak, grape

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plants growing alongside Sourwood had much lower densities of Lettered Sphinx Moth caterpillars, and showed little feeding damage compared with Sourwood. *Ursus americanus* (Pallas) (Black Bear) predation was not observed during the 2001–2003 outbreak, but Stupka had noted Black Bears feeding on green caterpillars on Sourwood during his tenure in GSMNP (Wagner and Langdon 2006; K. Langdon, pers. comm.).

In this paper, we document an outbreak of Lettered Sphinx Moth caterpillars on Sourwood in Unicoi County, TN, at a site in the Cherokee National Forest ~115 km northeast of GSMNP; demonstrate that Sourwood is a preferred food plant; and provide evidence that Black Bears commonly feed on these caterpillars at this location.

Field Site

The extent of the area of heavy infestation in 2013 was ~25 km^2 centered on the northeastern end of Little Mountain, extending south and west across the Scioto Valley to Stone Mountain. Another large outbreak occurred in the same approximate area again in 2014, but very few caterpillars and little damage were noted in 2015.

We conducted surveys for caterpillars and Sourwood tree damage along 4 km of a trail from the mid to upper slope (640 m–750 m) of Little Mountain, Unicoi County, TN. The trail traverses a mid-successional upland mixed-deciduous forest dominated by *Acer rubum* L. (Red Maple), *Nyssa sylvatica* Marsh. (Black Gum), *Quercus rubra* L. (Red Oak), and near the ridge, *Pinus rigida* Mill. (Pitch Pine), *P. virginiana* Mill. (Virginia Pine), *Q. montana* Willd. (Chsestnut Oak), and *Q. coccinea* Munchh. (Scarlet Oak). In the understory, *Acer pensylvanicum* L. (Striped Maple) and *Cornus florida* L. (Flowering Dogwood) are common and Sourwood is abundant. *Vitis aestivalis* Michx. (Summer Grape) occurs sporadically throughout, while *Parthenocissus quinquefolia* (L.) Planch. (Virginia Creeper) and *Smilax glauca* Walter (Cat Greenbrier) and *S. rotundifolia* L. (Common Greenbrier) are more common near edges and openings.

Methods

On 3 June 2013, we measured 5 groups of 10 Sourwood trees spaced along the trail at intervals of 0.4 km. We determined tree height, diameter at breast height (dbh), and degree of defoliation. We visually estimated defoliation and classified the damage to each tree using 4 categories: <25%, 26%–50%, 51%–75%, and >75% defoliation.

We conducted food-preference trials using entire, undamaged leaves of 3 plant species: Sourwood, chosen because it was the apparent preferred food plant; Virginia Creeper, chosen because it was common at the site and is a known food plant; and Red Maple, chosen as a control because it is a locally common woody plant and is unrelated to known food plants (Wagner 2005). We collected plants for food-preference trials from an area with little to no caterpillar herbivory and conducted 6 trials using 7–12 caterpillars in each; trials were conducted in the field immediately after caterpillars were collected. We placed the caterpillars in plastic trays containing comparable amounts of the 3 food plants with leaves of the different species placed in an alternating arrangement (Fig. 1). Caterpillars were spaced on the tray bottom and not directly on leaves within trays. We recorded the number of caterpillars feeding on each species at 5-min intervals for 20 min. After 10–15 minutes, nearly all caterpillars had chosen a leaf and remained there feeding until the trial ended.

On 4 June 2013, we recorded the number of apparent Black Bear scats along the 4-km section of trail. We considered scats with diameters >3.8 cm or in piles >10 cm in diameter to be bear scats. We recovered and identified caterpillar casts or remains, i.e., undigested sections of the larval integument, from 2 scats. We measured and assessed stem damage apparently caused by Black Bears on trees at 3 other locations along the trail. We assumed that standing Black Bears can reach up to 2.4 m and that they cannot readily bend a tree greater than 7.5 cm dbh, and compared the frequency of trees that were bent/broken inside and outside those sizes classes.

Under the null hypothesis of no preference, i.e., equal numbers of caterpillars feeding on each host species, we employed an exact goodness-of-fit test to identify preferences among hosts. We used analyses of variance to test for differences in Sourwood height and dbh among sites and whether defoliation was dependent upon tree height or dbh. We used Fisher's exact test for heterogeneity of frequencies with defoliation as the categorical variable to test for differences among sites.

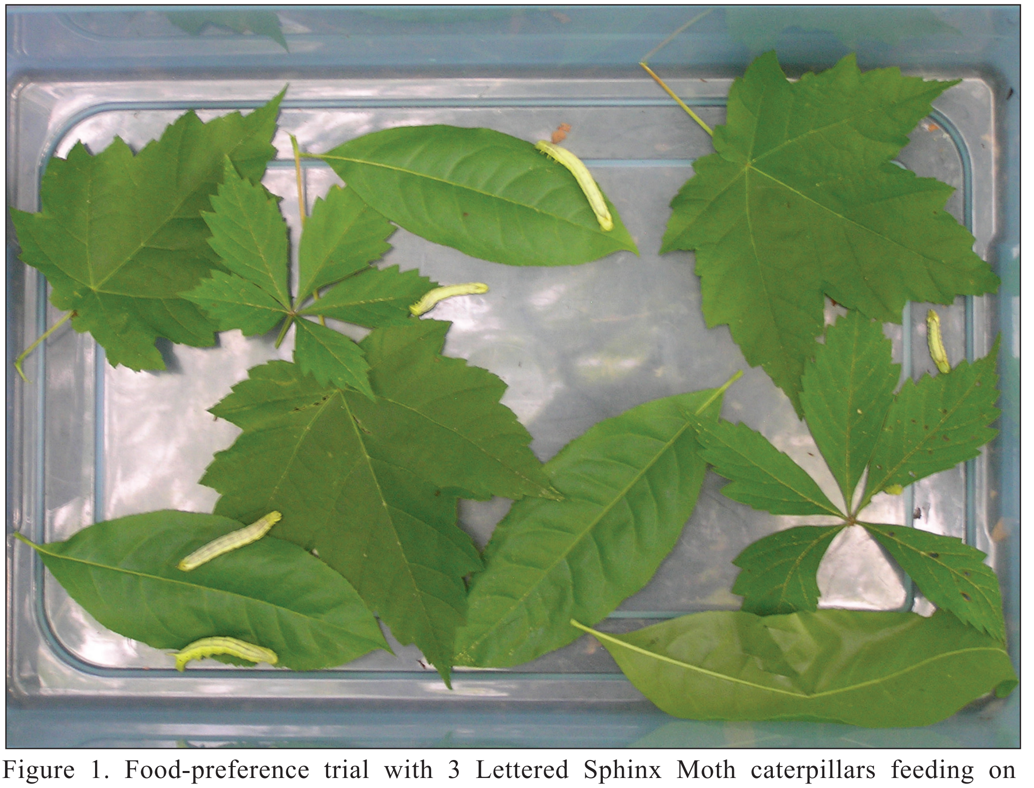

Figure 1. Food-preference trial with 3 Lettered Sphinx Moth caterpillars feeding on *Oxydendrum arboretum* (Sourwood), none on *Acer rubrum* (Red Maple), and 2 on *Parthenocissus quinquefolia* (Virginia Creeper) leaves.

Results

Tree height and dbh varied among the 5 sample sites, with significantly taller trees at Sites 1 and 5 (ANOVA $P < 0.001$) and significantly larger-diameter trees at Site 1 (ANOVA $P < 0.001$) (Table 1). Defoliation amount was not significantly dependent upon height or dbh, but was marginally significantly different among sites ($P = 0.06$; Table 1). Almost two-thirds (64%) of Sourwoods of all sizes were nearly completely defoliated, and only 14% had less than 50% defoliation.

Caterpillar feeding preference differed among all 3 food-species, with Sourwood eaten most often (31 caterpillars), Virginia Creeper eaten less often (11 caterpillars), and Red Maple never eaten. The difference in feeding among the 3 plant species was significant ($P < 0.0001$), as was the difference between Sourwood and Virginia Creeper ($P = 0.04$).

At the 3 areas of greatest apparent bear activity, 14 trees were bent or broken. Each had a dbh of <7.5 cm and a bend/break at 0.3 m–1.0 m; 4 of the 14 had claw marks, and these were located 1.0 m–1.5 m up the trunk (Figs. 2, 3). Five small trees had claw marks 0.3 m–1.2 m above ground-level on the bark, and at points where the trees had been bent or broken (Figs. 2, 3). We noted 2 bear-paw prints directly below the point at which 1 tree had been bent; the prints were ~0.5 m from claw marks above (Fig. 2 inset). Larger trees in these areas were not damaged, and the differences in the frequency of damage among smaller and larger trees was significant ($P < 0.0001$; Table 2).

We observed 7 separate presumed bear scats. The 2 freshest scats had abundant caterpillar casts; for one scat, the cast volume was ~80–90% of the total (Fig. 4). A green hue resulted when we placed ~20% of this scat in 4 L of water. We identified insect remains from these 2 scats as Lettered Sphinx Moth catarpillars.

Discussion

Historically, the Lettered Sphinx Moth has been considered a specialist on Vitaceae (Covell 2005, Hodges 1971). Our observations and those reported previously for the Appalachian Region as well as more recent anecdotal reports from websites

Table 1. Mean tree height (m), mean dbh (cm), and frequencies of *Oxydendrum arboretum* (Sourwood) trees in different defoliation categories at 5 sites. Sites are numbered sequentially according to location along the monitoring trail. Means followed by the same letter were not significantly different from each other.

			Defoliation			
Site	Mean height	Mean dbh	<25%	26%–50%	51%–75%	>75%
1	9.00^{A}	11.7^{A}	0	1	0	9
2	3.02^{B}	2.9^{B}	2	1	4	3
3	3.08^{B}	2.4^{B}	0	1	1	8
4	3.66^{B}	3.8^{B}	1	1	4	4
5	7.56^{A}	6.9^{B}	0	0	2	8
Total	5.26	5.5	3	4	11	32

(e.g., http://www.mindenpictures.com/search/preview/caterpillar-larva-of-lettered-spinx-moth-deidamia-insripta-on-sourwood/0_90369747.html, http://www.humnature.com/blog/tivebackyard.com/2014/05/invasion-of-unidentified-moths.html, https://www.reddit.com/r/whatsthisbug/comments/3728lt/weve_always_called_these_sour_wood_worms_because/) show that Sourwood is a regionally favored host species. As would be expected for a univoltine, spring-active hawkmoth (Tuttle 2007), Lettered Sphinx Moth caterpillar densities spiked and then declined over a period of ~5 weeks. Our observations suggest that Sourwood is a viable host; we noted fully mature caterpillars and wandering prepupae at several of our sampling sites (including locations where no Vitaceae were present).

Figure 2. *Oxydendrum arboretum* (Sourwood) tree broken ~1 m from ground. Arrow in inset points to *Ursus americanus* (Black Bear) footprint.

Table 2. Contingency table showing *Oxydendrum arboretum* (Sourwood) trees with and without damage to the main stem based on whether or not they were within the height (ht) accessible to Black Bears standing on the ground and within the diameter (dbh) range that Black Bears could be expected to bend or break.

	Main stem damage	
	None	Bent/broken
Trees >2.5 m in ht and <7.5 cm dbh	20	14
Trees not as above	40	0

Host-plant preference trials demonstrated that Lettered Sphinx Moth caterpillars preferred Sourwood to Virginia Creeper, a known host species. These observations suggest that a host shift occurred such that caterpillars (as well as ovipositing

Figure 3. Claw marks (arrows) on bent *Oxydendrum arboretum* (Sourwood) tree. Inset shows a close-up of a claw mark.

females) from northeast Tennessee and perhaps throughout the Appalachian Region utilized Sourwood as a host. Feeding trials using caterpillars and, more importantly, oviposition trials with gravid females from different parts of the range could shed light on the geographic nature of Sourwood use and relative preferences

Because Sourwood is rather distantly related to the traditional Lettered Sphinx Moth host species in the grape family, Wagner and Langdon (2006) commented on the "taxonomic jump" and further speculated that "it is odd that what is reported in the literature as a grape-feeder would be so common on an ericaceous tree. One wonders if there is a unique secondary chemical shared by members of the grape family and sourwood." Recent phylogenetic studies of the Sphingidae (Kawahara and Barber 2015) support the contention that feeding on Sourwood is an evolutionarily derived trait for the Lettered Sphinx Moth. All 3 members of *Deidamia*'s sister genus *Acosmeryx* feed on *Vitis*, and none of the recorded hostplants of *Acosmeryx* are members of the Ericaceae (Robinson et al. 2016). The sister group to *Deidamia* + *Acosmeryx* in Kawahara and Barber (2015) includes 20 genera of sphingids. Hostplants are documented for 15 (75%) of these genera by Robinson et al. (2016). Of the 15, ten (50%) of the genera include species that feed on Vitaceae; Ericaceae were not listed for any of the 15 genera in the sister taxon for which hostplant data are available.

Malacosoma neustria testacea L. (Japanese Tent Caterpillar Moth), a species unrelated to the Lettered Sphinx Moth, have been documented to acquire oxalic acid from their diet and secrete oxalate crystals into their Malpighian tubules

Figure 4. *Ursus americanus* (Black Bear) scat with caterpillar casts.

(Takahashi et al. 1969), presumably as an anti-predator mechanism (Finley 1999). Oxalates are known to accumulate in Vitaceae (Franceschi and Horner 1980), and Sourwood derives its name from the relatively high concentrations of oxalic acid (Coder 2011). While speculative, it is possible oxalic acid or oxalate crystals in leaves of both Vitaceae and Sourwood may be involved in the unusual host-usage pattern exhibited by the Lettered Sphinx Moth.

Several lines of evidence demonstrate that Black Bears were feeding on Lettered Sphinx Moth caterpillars on Sourwood trees. The height at which tree stems were bent or broken was above that expected for *Meleagris gallopavo* L. (Wild Turkey) or smaller mammals (*Procyon lotor* [L.] [Raccoon], *Didelphis virginiana* Kerr. [Opossum], *Marmota momax* [L.] [Groundhog]), and damaged stems were of a size that probably exceeded the strength of these other potential predators of Lettered Sphinx Moth larvae. Moreover, claw marks were often associated with the bends/breaks, and in some instances we observed Black Bear footprints at the base of bent/broken stems. Most conclusively, we found abundant integumental remains of a hornworm in Black Bear scat collected at sites where caterpillars were defoliating Sourwood. While admittedly speculative, we wonder if oxalates facilitated the host-plant shift from Vitaceae to Sourwood, and if Black Bear tolerance to oxalates may allow them to consume large numbers of caterpillars when caterpillar densities are high, as was the case in the outbreaks we report.

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