Lycorma delicatula

Scientific Name
Lycorma delicatula (White, 1845)

Synonyms:
Aphaena delicatula White, 1845
Lycorma delicatulum (White, 1845)

Common Name(s)
Spotted lanternfly, spot clothing wax cicada, tropical cricket

Type of Pest
Phloem feeder

Taxonomic Position
Class: Insecta, **Order:** Hemiptera, **Family:** Fulgoridae

Reason for Inclusion
PPQ Pest of Concern (New Pest Advisory Group)

The SLF emergency response program in Pennsylvania is currently underway. The datasheet will be updated as new information becomes available.

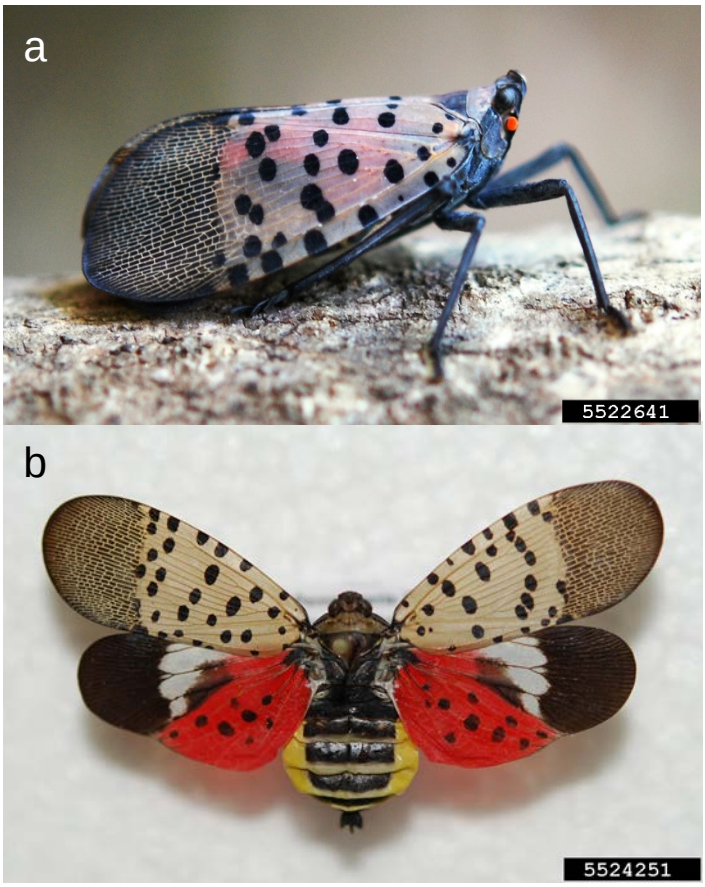

Figure 1. *Lycorma delicatula* adult at rest (a) and wings spread (b) (Lawrence Barringer, Pennsylvania Department of Agriculture, Bugwood.org).

Pest Description
Eggs: Eggs are laid masses that contain 30 to 50 brown seed-shaped eggs, deposited in parallel rows, and covered with a yellowish-brown or grey secretion that hardens into an ootheca (Park et al., 2009; Yoon et al., 2011; Dara et al., 2015). The egg mass is about 25 mm (approx. 1 in.) long and may resemble a smear of mud. After emergence, egg masses may remain on trees for a year or more. The secretion deteriorates over the course of the year, leaving columns of empty, small, brown eggs, similar in appearance to tire tread (Fig. 2) (Dara et al., 2015). For additional information and images, see the Egg Mass Identification Tips presentation developed by the Pennsylvania Department of Agriculture (PDA).

Nymphs: There are four instars. The first to third instars are black-bodied with white spots on the head, body, and legs (Fig. 3a). The fourth instar is mostly red with black legs, white spots, and distinct red wing pads (Fig. 3b) (Park et al., 2009; Dara et al., 2015). The early instar nymphs are 3.6 to 9.4 mm (approx. $^{1}/_{8}$ to $^{3}/_{8}$ in.) long and fourth instar nymphs are 10.9 to 14.8 mm (approx. $^{7}/_{16}$ to $^{9}/_{16}$ in.) long (Dara et al., 2015).

Adults: From Barringer et al. (2015), "*L. delicatula* is 17-25 mm (approx. $^{11}/_{16}$ to 1 in.) long (females 20-25 mm (approx. $^{13}/_{16}$ to 1 in.), males 17-20 mm (approx. $^{11}/_{16}$ to $^{13}/_{16}$ in.)) with grey forewings adorned with black spots and reticulated tips (Fig. 1a). The hindwings have strikingly contrasting blocks of red and black with a white stripe partially dividing them. The head and body are black with a yellow abdomen incompletely divided by black bands (Fig. 1b)." Females can be distinguished from males by the red color of the postero-caudal end of the abdomen (see Identification section) (Dara et al., 2015). For additional information, the original description can be found in White (1845).

Figure 2. New (right) and hatched (left) egg mass of *Lycorma delicatula* (Miriam Cooperband, USDA APHIS).

Biology and Ecology

Lycorma delicatula produces a single generation per year (Park et al., 2009; Dara et al., 2015). Eggs are typically laid on the smooth surface of the host trunk (Kim et al. 2011b), but have also been found on branches, as well as other smooth surfaces including: stone and manmade items like vehicles, campers, yard furniture, and farm equipment (Dara et al., 2015). In Pennsylvania, egg masses have been found beneath loose bark on tree trunks and the underside of rocks. The number of egg masses per tree can vary greatly. In South Korea, an average of 3.4 egg masses per tree were observed (Kim et al., 2014), while the average number per tree has been much higher in Pennsylvania, with as many as 197 egg masses reported from one tree (Dara et al., 2015).

Egg mass oviposition begins in the fall and continues to the onset of winter. In Pennsylvania, the first egg masses have been found in late September to October (Dara et al., 2015). *Lycorma delicatula* overwinter in the egg stage (Park et al., 2012). Choi et al. (2012) conducted a study to describe the relationship between temperature and rate of development

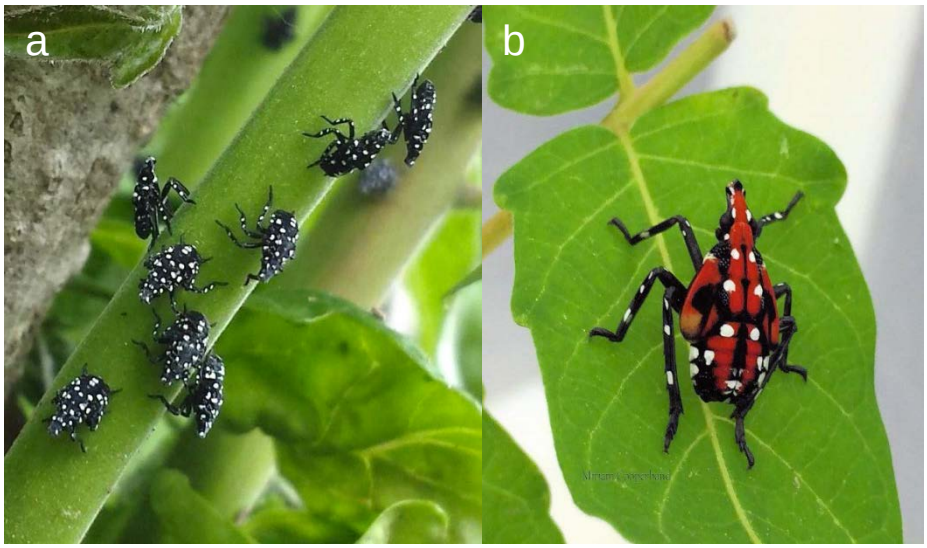

Figure 3. *Lycorma delicatula* early instars (a) and fourth instar (b) (Miriam Cooperband, USDA APHIS).

in an effort to predict hatching times in South Korea. They reported that: “Eggs hatched 55.9, 26.8, 21.6 days after incubation at 15, 20, 25°C (59, 68, and 77°F) with 14L:10D condition and the hatching rates of egg were 61.9, 57.8, 30.4%, respectively. At high temperature conditions, egg development periods were shorter and the hatching rate was lower.” … “The low temperature threshold of eggs was 8.14°C (46.7°F) and the thermal constant required to reach larva (sic) was 355.4 DD.” In Pennsylvania, eggs are reported to hatch early in the day and successful hatch rate is reported from 60-90% (Dara et al., 2015).

After hatching, nymphs climb upwards until they reach the leaves where they feed by piercing petioles and young stem tissue (Kim et al., 2011b). The nymphs engage in a cyclic behavior in which they ascend to the leaves of the trees and then fall to the ground (reviewed in Kim et al., 2011b). The basis for the falling-ascending behavior requires further study. One hypothesis is that younger nymphs are more easily dislodged by wind or other means because their arolia are not as well developed as the arolia of later instars and adults. *Lycorma delicatula* have arolia (tarsal adhesive pads) that allow them to stick to surfaces and aid in climbing and jumping. The falling-ascending cycle becomes longer as nymphs develop, suggesting that as the arolia become bigger and stronger with each instar, nymphs are able to hold onto surfaces more firmly (Kim et al., 2011b). The falling-ascending behavior may also be a dispersal or host selection strategy (Kim et al., 2011b; Park, 2015) or a strategy to avoid intense midday heat.

Lycorma delicatula undergoes four nymphal instars. In Korea and Pennsylvania, first instar nymphs have been observed emerging in May and molt from fourth instar to adult beginning in late July (Park et al., 2012; Dara et al., 2015). Adults live 3 to 4 months (Tomisawa et al., 2013). Upon molting, adults feed for up to two month before mating and oviposition begins (Park, 2015). In Japan, copulation and oviposition was observed occurring in the evening from mid-September to November (Tomisawa et al., 2013). In Beijing and Anhui Province, China, all life stages appear about a month earlier than observed in Pennsylvania populations (Wickham and Cooperband, unpublished data).

Adults are not strong fliers, often moving by jumping or walking if their path is obstructed or when crowded or disturbed (Kim et al., 2011b; Choi et al., 2012). Adults can jump up to 1 to 3 m (approx. 3 to 10 ft) (Chou, 1946). In Pennsylvania, adults have been observed flying 20 m (approx. 66 ft) under ideal conditions (L. Donovall, pers. Communication as cited in the EPPO, 2016). In 2017, preliminary research found that adults can cover 10 to 80 m (approx. 32 to 262 ft) in a single flight by climbing toward the top of vertical structures (e.g., trees, poles, buildings) and launching themselves into the wind (Baker, 2018).

Early instar nymphs feed on leaves and small stems, and as they develop, begin to feed on woodier plant material, like woody stems and branches. Adults feed on woody plant parts, like branches and trunks. *Lycorma delicatula* aggregate as nymphs and adults and can be found in large numbers on individual host plants (Ding et al., 2006). Nymphs can be found on a wide variety of host plants. In late August and September, adults,

especially females, begin to demonstrate a strong preference for tree of heaven (*Ailanthus altissima*). In Korea, Kim et al. (2011b) found that the number of different trees *L. delicatula* was collected from decreased from July to November and the total number of *L. delicatula* on non-*A. altissima* trees began to decrease in July. The number of *L. delicatula* individuals on *A. altissima* trees increased by 80 to 100% after August 30th and there were 10 to 20 times more individuals on *A. altissima* than any other tree in the survey. In September, adults were collected only on *A. altissima* and *Tetradium daniellii* trees, and by November, adults were found exclusively on *A. altissima* trees. Similar observations were made in Pennsylvania. As SLF developed into fourth instar nymphs and then into adults, the numbers of individuals captured on non-*A. altissima* trees decreased and numbers captured on *A. altissima* increased (Dara et al., 2015).

Unlike the first three instars, the fourth instar nymph is mostly red. This coloration is also present on the wings of the adults. When attacked by a predator, the adult will either jump away or suddenly open its hindwings to show its conspicuous red, white, and black markings. The aposematic coloring serves as a signal to predators that the insects are unpalatable due to the cantharidin likely sourced from host plants like tree of heaven, which cause avian predators to vomit after consumption (Anderson et al., 1983, Kang et al., 2011 and 2016). *Ailanthus altissima* contains concentrations of cytotoxic alkaloid chemicals (Anderson et al., 1983). Using gas chromatography, Feng et al. (1988) confirmed that nymphs (0.13-0.17%) and adults (0.05-0.07%) contain cantharidin. However, the authors refer to the numbers as “levels” without explaining what the percentages represent (e.g. percent body weight). Further chemical analysis is needed to test whether there is a significant difference between the defensive alkaloid concentration in different life stages, including early and late season adults (Kang et al., 2016).

Damage

Both nymphs and adults feed on the phloem of host plants in large aggregations (Kim et al., 2013). Damage by this species is two-fold. Feeding by aggregations of early instar nymphs creates a large amount of honeydew that covers the host plant and all surfaces and plants below it (Ding et al., 2006; Dara et al., 2015). Honeydew leads to sooty mold growth (Fig. 4), which can cause reduced growth or death of seedlings or plants in the understory (Ding et al., 2006) due to disrupted photosynthesis. The accumulation of honeydew and sooty mold is also a nuisance in urban areas. Aggregations of later instar nymphs and adults, especially in large numbers, cause weeping wounds on the trunk (Fig. 5) and can result in wilting of branches or death of the plants (Jang et al., 2013; Dara et al., 2015). Disrupted photosynthesis is the biggest contributor to the decline in the quality and yield of grapes (Kim et al., 2013).

Figure 4. Sooty mold on Concord grape leaf (Erica Smyers, Pennsylvania State University).

Pest Importance

Both nymphs and adults of this species feed on *Ailanthus altissima* (tree of heaven). This is an invasive plant that has spread throughout most of the United States. It is considered a noxious weed in Connecticut, Massachusetts, New Hampshire, and Vermont (USDA-NRCS, 2014).

According to Park et al. (2012) this species is becoming an important pest in Korea. It has become an important pest on some fruit trees (Park et al., 2012) and caused substantial economic losses to grapevine (Lee et al., 2011). In Korea, both economic and environmental damage caused by this species has grown annually (Han et al. 2008; Lee et al. 2009; Park et al. 2009). In Korea, this species can be found in urban areas due to high densities of one of its hosts, tree of heaven (*Ailanthus altissima*) (Kim et al., 2011b). *Lycorma delicatula* can be a nuisance in urban environments due to the honeydew (liquid secretion from the insect) accumulation from nymph and adult feeding (Jang et al., 2013).

Figure 5. Damage caused by *Lycorma delicatula* on tree of heaven (Erica Smyers, Pennsylvania State University).

Since the pest's detection in the United States, there is concern about the potential to impact the grape, fruit tree, and logging industries (Dara et al., 2015).

Known Hosts

Lycorma delicatula is reported to have a wide host range; however, the nymph and adult stages have different host ranges (Park et al., 2012). Nymphs are polyphagous, feeding opportunistically on plants in close proximity (Park et al., 2009). Adults, especially females, are found only on a few hosts, including tree of heaven (*Ailanthus altissima*) and grape (*Vitis vinifera*) (Fig. 6) (Park et al., 2012), indicating that the reproductive host range is much more restricted (Dara et al., 2015). Further research is required, but it is hypothesized that tree of heaven is a required host (Park et al., 2009).

Other than *Vitis*, the preferred host plants recorded for adults contain toxic secondary metabolites. It is hypothesized that *L. delicatula* adults may select hosts containing toxic alkaloids as part of their predator defense strategy (Kim et al., 2011b; Tomisawa et al., 2013; Kang et al., 2016).

The *L. delicatula* host list is expansive (Park et al., 2009; EPPO, 2016). Many host records in the literature do not provide evidence of feeding or damage, making it difficult to differentiate between a true host and associated plants. Host range studies are currently underway to identify true host plants, specifically which species can support the development of reproductively viable *L. delicatula*. In this datasheet, we will use the

following categories to clarify host status: Major (preferred hosts), Feeding Recorded (hosts with confirmed feeding records), and Associated (nymphs and adults have been reported on the plant but no evidence of feeding observed/reported).

Major hosts
Ailanthus altissima (tree of heaven), *Melia azeradach* (Chinaberry), and *Vitis vinifera* (grape) (Lee et al., 2009; Tomisawa et al., 2013).

Feeding Recorded
Acer palmatum (Japanese maple), *Acer saccharum* (sugar maple), *Actinidia chinensis* (kiwi), *Betula platyphylla* (Asian white birch), *Juglans hindsii* (Hind's walnut), *Juglans major* (Arizona walnut), *Juglans microcarpa* (little walnut), *Juglans nigra* (black walnut), *Mallotus japonicus*, *Malus pumila* (paradise apple),*Phellodendron amurense* (Amur corktree), *Prunus armeniaca* (apricot), *Punica granatum* (pomegranate), *Salix matsudana* (Peking willow), *Salix udensis* (Sachalin willow),*Styrax japonica* (Japanese snowbell), *Tetradium daniellii* (= *Euodia danielii*) (Korean euodia), *Toona sinensis* (Chinese toon), *Toona sinensis* 'Flamingo,' and *Vitis vinifera* (grape) (Barringer et al., 2015; Dara et al., 2015 Hou, 2013; Kim et al., 2011b; Ma et al., 2010; Park et al., 2009; Tomisawa et al., 2013; Zhai et al., 2014; Zhang, 2001; Zheng et al., 2009)

Associated
Nymphs:
Alnus hirsuta (Manchurian alder), *Angelica dahurica* (fragrant angelica), *Aralia cordata* (udo), *Aralia elata* (Japanese angelica tree), *Arctium lappa* (greater burdock), *Cedrela fissilis* (Brazilian cedarwood), *Firmiana simplex* (Chinese parasoltree), *Juglans mandshurica* (Manchurian walnut), *Juglans regia* (=*Juglans sinensis*) (English walnut),*Maackia amurensis* (Amur maackia), *Magnolia kobus* (Kobus magnolia), *Magnolia obovata* (Japanese bigleaf magnolia), *Metaplexis japonica* (rough potato), *Morus alba* (white mulberry), *Morus bombycis*, *Parthenocissus quinquefolia* (Virginia creeper), *Philadelphus schrenckii* (mock orange), *Picrasma quassioides* (nigaki), *Prunus serotina* (black cherry), *Pterocarya stenoptera* (Chinese wingnut), *Quercus aliena* (Oriental white oak), *Rhus chinensis* (=*R. javanica*) (Chinese sumac), *Rosa hybrida* (rose), *Rosa multiflora* (multiflora rose), *Rosa rugosa* (rugosa rose), *Rubus crataegifolius*, *Sorbaria sorbifolia* (false spiraea), *Sorbus commixta*, *Styrax obassia* (fragrant snowbell), *Toxicodendron vernicifluum* (=*Rhus verniciflua*) (Chinese lacquer), and *Vitis amurensis* (Amur grape) (Barringer et al., 2015; Chou et al., 1985; Dara et al., 2015; Park et al., 2009).

Adults:
Acer rubrum (red maple), *Cedrela fissilis* (Brazilian cedarwood), *Juglans mandshurica* (Manchurian walnut), *Parthenocissus quinquefolia* (Virginia creeper), *Picrasma quassioides* (nigaki), *Populus koreana* (Korean poplar), *Prunus serotina* (black cherry), and *Vitis amurensis* (Amur grape) (Barringer et al., 2015; Dara et al., 2015; Park et al., 2009)

Pathogens or Associated Organisms Vectored

This species is not known to vector any pathogens or associated organisms. Sooty mold can develop on honeydew produced by *L. delicatula*, leading to disrupted photosynthesis. This can cause reduced tree growth, death of seedlings, as well as a decline in the quality and yield of grapes (Kim et al., 2013).

Figure 6. *Lycorma delicatula* adults on chardonnay grapes (Erica Smyers, Pennsylvania State University).

Known Distribution

This species is thought to be native to China (Park et al., 2012).

Asia: China, India,[1] Japan, Korea, Taiwan,[1] and Vietnam.[1] **North America:** Pennsylvania (Park et al., 2012; Dara et al., 2015; Ding et al., 2016).

Pathway

Lycorma delicatula has spread throughout parts of Asia. It was first reported in South Korea in 1932, but was not detected again until 2004 (Han et al., 2008). By 2006, it was considered common in western Korea and had spread across most of the country within 5-7 years of the 2004 detection (Han et al., 2008; Park et al., 2013). Based on the rapid range expansion observed in South Korea, it is thought that movement occurs through short-range expansion, likely influenced by host plant availability, and long-distance dispersal. Long-distance dispersal ability and migration patterns are not well known, but was found to be associated with ground transportation and human activity in Korea (Park et al., 2013). It is unclear how it was introduced into Korea; however, according to Park et al. (2012) “its establishment may be associated with global climate change and increasing winter temperatures that allow it to successfully overwinter.” It was found in Honshu, Japan in 2008 and may have been introduced on planting materials or wood packing materials from China (Hong et al., 2012).

This species was added to the AQAS database in 2014. Since then, there have been three interceptions recorded at U.S. ports of entry. One interception was on miscellaneous cargo from an unknown origin and the other two were in general cargo from South Korea (AQAS, 2016, queried October 14, 2016).

This species was found in Pennsylvania in 2014. This species may have been introduced on imported stone from China (Spichiger, 2014). Currently, Pennsylvania

[1] *Lycorma delicatula* is known to occur in India, Taiwan, and Vietnam, but it is not clear how common or widely distributed it is within each country.

has a quarantine in place with the intent of restricting the movement of this pest (PDA, 2016).

This species can lay eggs on a variety of smooth surfaces (in addition to its main host, tree of heaven) including: stones, manmade items like vehicles, campers, yard furniture, and farm equipment, and other smooth vertical surfaces (Dara et al., 2015).

In Pennsylvania, the following items are regulated and are not to be moved out of the quarantine area (PDA, 2016):

- Any life stage of the pest,
- Brush, debris, bark, or yard waste,
- Landscaping, remodeling, or construction waste,
- Firewood of any species,
- Grapevines for decorative purposes or nursery stock,
- Nursery stock,
- Crated materials,
- Outdoor household articles including recreational vehicles, lawn tractors and mowers, mower decks, grills, grill and furniture covers, tarps, mobile homes, tile, stone, deck boards, mobile fire pits, any associated equipment and trucks or vehicles not stored indoors.

The pathway section will be updated as new information becomes available.

Potential Distribution within the United States

This species was found in Berks County, Pennsylvania in 2014. The initial population was found feeding on both tree of heaven and wild grapevine (Barringer et al., 2015). It is believed that the population in Pennsylvania had been present for more than one season, as the population was well established upon detection (Spichiger, 2014). Currently, it is only known to occur in southeastern Pennsylvania (Dara et al., 2015). The predicted range for *L. delicatula* based on habitat suitability includes 8 USDA plant hardiness zones (6-13).

The economically important host density map for *Lycorma delicatula* developed by USDA-APHIS-PPQ-CPHST (Fig. 7) identifies areas of high host acreage based on the acreage of commercially grown grape varieties only. The map does not include the acreage for wild grape species or tree of heaven, due to the absence of reliable distribution data. The map includes bearing and non-bearing host acreage from the National Agricultural Statistics Service (NASS). Bearing acreage includes: 1) acres of vines that produced a fruit crop for the NASS census year or in previous years, and 2) acreage where fruit was present but was not harvested (e.g., market issues, damaged fruit). For non-bearing acreage, the host was not at the proper age or maturity to produce fruit when the data was collected. Because grape acreage data was not available for Hawaii, a host map for Hawaii has not been included in the datasheet.

Agricultural host distribution maps are based on county level data. To combine host data for pest-specific analyses, CPHST normalizes the data by dividing the total host

present in a county by overall county area (acres of host in county/ total acres of county). This yields host by county area and allows CPHST to properly combine host distributions without the skewing effects of overall county size. For example, 100 acres of grapes grown in Suffolk County, NY can now be compared to 100 acres of grapes grown in Napa County, CA. Please note, maps are created using the most current NASS point data available. Actual acreage may have changed since the point data was collected.

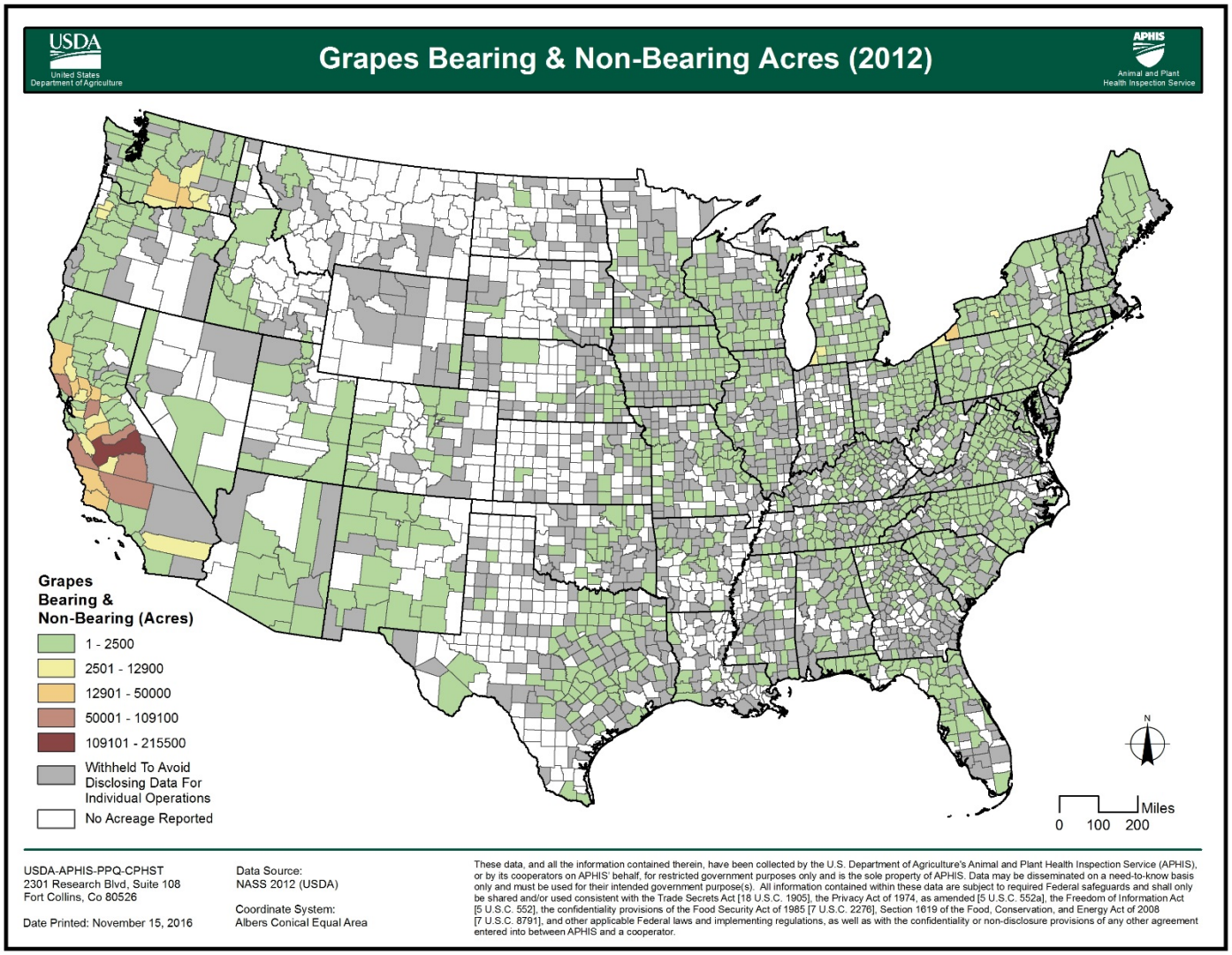

Figure 7. Economically important host density map for *Lycorma delicatula* within the continental United States. Values represent host acreage low to high (commercially grown grapes). Map courtesy of USDA-APHIS-PPQ-CPHST.

A map representing known tree of heaven (*Ailanthus altissima*) distribution in the United States is in development. In the meantime, contact Heather Moylett (heather.moylett@aphis.usda.gov) for additional maps, including host maps and nymph emergence maps.

Survey

CAPS-Approved Method*:

The CAPS-approved method is visual inspection for the organism. Note that surveying for egg masses only, for instance when conducting gypsy moth surveys, is not sufficient for negative data reporting. Negative data may be reported if fourth instar nymphs or adults are not found and no feeding damage symptoms are observed when host material is inspected between July and November.

The survey section will be updated as new information becomes available.

Visual survey for organism

Nymphs (Fig. 8a) and adults (Fig. 8b) are typically found in aggregations on the branches and trunk of a host plant. Early instar nymphs are not host specific and can be found on woody and non-woody plants (Dara et al., 2015). As the nymphs mature to fourth instars and adults, the host range narrows significantly and the majority of individuals migrate to tree of heaven (Dara et al., 2015). The fourth instar nymphs (red nymph) and adults are the most distinct and easily detected life stages. Identifying symptoms of feeding damage may be useful in areas of low density.

Visual survey for feeding damage

If feeding damage symptoms are observed, additional visual inspections should be conducted in the area to locate eggs, nymphs, or adults. Detection of an SLF individual or egg mass is required for a positive detection. Look for symptoms on host plants including: wilting of plants, weeping wounds of sap on trunks, and honeydew (liquid insect secretion), and mold growth (Kim et al., 2013; Jang et al., 2013). Heavy honeydew secretions can build up at the base of the plant, leading to the growth of saprophytic fungal mats (Fig. 9), and on the plants in the understory, leading to sooty mold growth (Dara et al., 2015). The honeydew secreted by the species can also lead to increased activity of wasps, hornets, bees, and ants which feed on the secretions. Reliably recognizing damage symptoms may require some additional training/in-field experience.

Survey site selection

Surveys should be conducted in grape vineyards; tree fruit orchards; and high-risk areas, including wholesale and retail distributors of natural and artificial outdoor products, utility and transportation right-of-ways, construction companies and contractors, landscapers, and loggers and firewood dealers. Tree of heaven is the preferred host of SLF and, as an edge species, is commonly found growing along the margins of agricultural fields, industrial areas, and right-of-ways. For these reasons, tree of heaven is the sentinel plant for visual survey and should be principal host inspected for SLF.

Site inspection

- In grape vineyards, inspect the vines for aggregations of nymphs and adults. Nymphs may also be found on the underside of leaves.

- Identify tree of heaven along the margins of the vineyard, industrial area, or right-of-way.
- Inspect the tree from the base up into the canopy for life stages appropriate to the time of year. Use binoculars to inspect branches, upper trunk, and canopy.
- Be on the lookout for egg masses as they can remain on trees, rocks, and other smooth vertical surfaces throughout the year.
- Inspect the surrounding plants growing below trees (including non-tree of heaven) for early nymphs or feeding damage symptoms, including honeydew accumulation, sooty mold growth, and fungal mats.
- Inspect tree of heaven for feeding damage, including wilting, flagging, weeping sap wounds, honeydew accumulation, sooty mold growth, and fungal mats found at the base of the tree.
- If only feeding damage is observed, increase the frequency of visual survey and inspect more tree of heaven trees in the area.

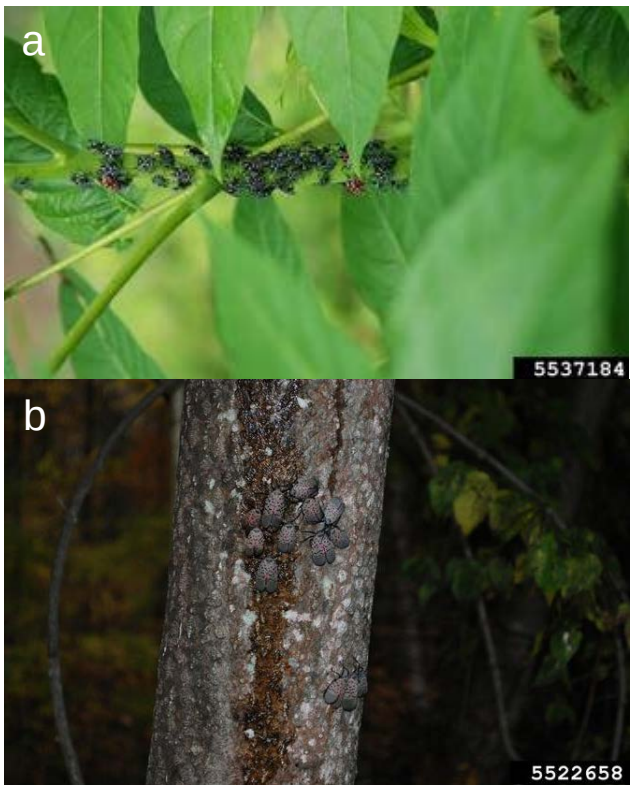

Figure 8. Aggregations of *Lycorma delicatula* nymphs (a) and adults (b) on *Ailanthus altissima.* (a. Lawrence Barringer, b. Pennsylvania Dept. of Agriculture)

Figure 9. Mold growth at the base of tree of heaven. (Erica Smyers, Pennsylvania State University)

Time of year to survey:

The life stage present will depend on the season (Fig. 10). Egg masses can be found throughout the year. In Pennsylvania, early instar nymphs begin to emerge in April to May (Dara et al., 2015), but are inconspicuous and polyphagous, making them difficult to detect. Fourth instars (red nymph) and adults are more readily detected. The start date of the visual survey (July) coincides with the emergence of fourth instar nymphs

(red nymph) and terminates once the majority of adults die off (late November or following first freeze). However, all life stages may be surveyed for: egg masses, nymphs (early (1st – 3rd) and 4th instar), and adults.

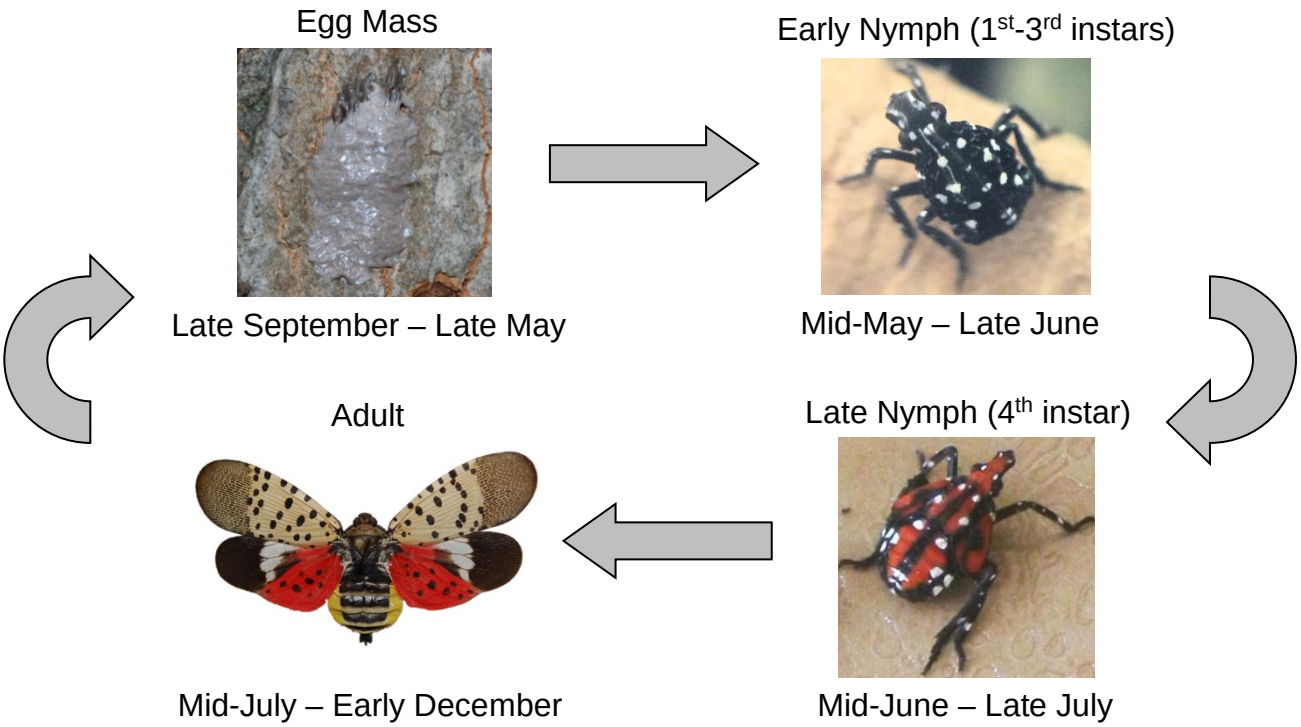

Figure 10. Seasonal phenology of *Lycorma delicatula*, spotted lanternfly (SLF). Photos: egg mass, late nymph, and adult courtesy of Penn. Dept. of Ag.; early nymph courtesy of Miriam Cooperband (USDA-APHIS-PPQ-CPHST).

Egg mass survey:

Spotted lanternfly egg masses may be surveyed for in combination with Asian gypsy moth surveys. It is difficult to reliably find egg masses, so only positive finds should be recorded in NAPIS. Negative data can only be entered for nymph and adult visual surveys. If spotted lanternfly egg masses are found, biweekly visual survey for nymphs and adults should be initiated. If the egg mass is found over the winter, begin surveys in the area in mid-May.

Egg masses can be found on any vertical surface, including trees, stones, fence posts, vehicles, and buildings (Barringer et al., 2015) (see Pathway section for additional locations). Egg masses may look similar to a smear of mud. When surveying, scrape mud away from the surface and look for eggs below the plaster layer (Fig. 11) or, if eggs are not visible, look for characteristic tire tread pattern (Fig. 12) (PDA, 2014).

Figure 11. Hatched egg mass of *Lycorma delicatula* (Lawrence Barringer, Pennsylvania Dept. of Agriculture, Bugwood.org).

Figure 12. *Lycorma delicatula* egg mass. Scraped egg mass with characteristic tire tread pattern (Pennsylvania Dept. of Agriculture).

Tree bands:

There is currently no approved trap or lure for this species. Visual survey is considered the most effective method of detection for SLF. Field trials testing the efficacy of brown, sticky tree bands and a methyl salicylate (high-release) lure are ongoing. The band and lure combination are in use as part of the spotted lanternfly emergency response program in Pennsylvania and states with recent detections. The band and lure combination will be considered for inclusion as a CAPS approved method for pest surveillance based on the outcome of field trials and observations from the SLF program.

*For the most up-to-date methods for survey and identification, see Approved Methods on the CAPS Resource and Collaboration Site, at https://caps.ceris.purdue.edu/approved-methods.

Tree of heaven identification resources

Tree of heaven is an invasive exotic tree that grows in dense thickets (Fig. 13a) and is commonly found in recently disturbed areas, including roadsides, forest edges, fencerows, and fields (Swearingen and Pannill, 2009). “Mature trees can reach 80 feet in height. Ailanthus has smooth stems with pale gray bark and twigs which are light chestnut brown, especially in the dormant season. Its large compound leaves are 1-4 feet in length, alternate, and composed of 10-41 smaller leaflets (Fig. 13b). Each leaflet has one or more glandular teeth along the lower margin…Flowers occur in large terminal clusters and are small and pale yellow to greenish (Fig. 13c). Flat, twisted, winged fruits each containing a single central seed (Fig. 13d) are produced on female trees in late summer to early fall and may remain on the trees for long periods of time…All parts of the tree, especially the leaves and flowers, have a nutty or burned nut odor (Swearingen and Pannill, 2009).” For additional information on identification, easily confused species, and winter identification please see the links below.

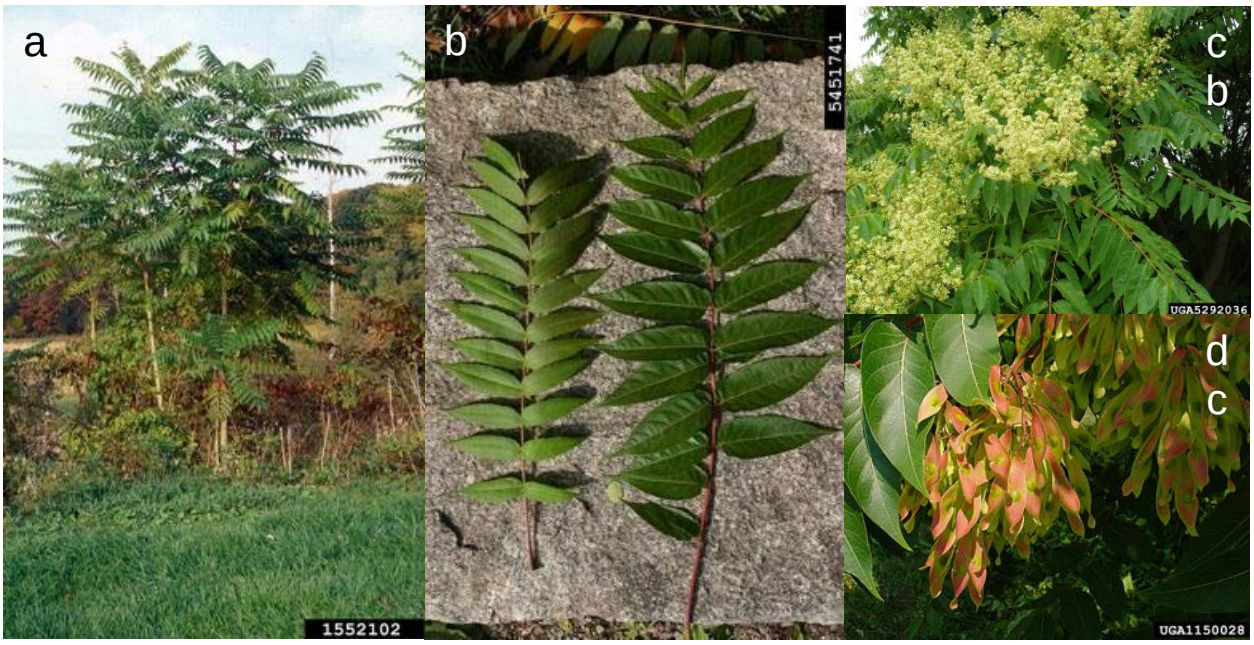

Figure 13. (a) Tree of heaven thicket, (b) leaves, (c) flowers, and (d) and seeds. (All photos from Bugwood.org: (a) Catherine Herms, The Ohio State University, (b) Leslie J. Mehrhoff, University of Connecticut, (c) Jan Samanek, Phytosanitary Administration, (d) Chuck Bargeron, University of Georgia).

Identification and easily confused species:
http://www.nybg.org/files/scientists/rnaczi/Mistaken_Identity_Final.pdf, pg. 12-13

Fact sheet and identification:
http://articles.extension.org/pages/62664/ailanthus-altissima-tree-of-heaven

Literature-Based Methods:

Trapping: Work has been carried out in Korea to determine effective trapping methods for this species. Choi et al. (2012) tested three different colors of sticky traps and found that brown sticky traps were the most attractive to nymphs and adults over a two week trapping period and least attractive to non-targets. In South Korea, Kim et al. (2011b) found that the best location to set traps for adults was at the base of the preferred host species (including *Ailanthus altissima*, *Betula platyphylla, Evodia daniellii*, and *Phellodendron amurense*) from August to October. Insect nets have been used to catch *L. delicatula* when populations are high. They can also be collected by hand due to their large size (Kang et al., 2011).

The Pennsylvania Department of Agriculture is conducting a large-scale tree-banding program to mitigate populations in areas known to be positive (S.-E. Spichiger, personal communication, 2016a). Brown, sticky tree bands are placed on *Ailanthus altissima* trees at 5 feet above the ground and replaced every two weeks (as described in the PDA Spotted Lanternfly 2016 Survey/Control Protocols). CAPS is considering adding brown sticky tree bands as an approved method but requires further field testing before it can be approved for reporting negative data.

Second to fourth instar nymphs and female adults have also been shown to be attracted to spearmint oil, with fourth instar nymphs and adults showing the greatest attraction (Moon et al., 2011). However, the attraction to spearmint oil was not observed in laboratory and field experiments conducted by CPHST (Cooperband, personal communication, 2016b). *Lycorma delicatula* was also attracted to a methanol extract from *Ailanthus altissima* (Lee and Park, 2013).

Research on the visual orientation of this species may be useful in developing a trapping method in the future. According to Jang et al. (2013), this species shows a strong positive phototaxis toward UV and blue lights. However, this species is diurnal, so the use of artificial lights to attract this species may not work well during the day (Jang et al., 2013).

Visual survey: Following the initial detection, the Pennsylvania Department of Agriculture (PDA) conducted a visual delimiting survey on publicly accessible property from October to December 2014 (G. Parra, 2016, personal communication). Surveyors looked for this species through egg mass surveys (similar to the gypsy moth program) on tree of heaven. Surveyors checked stands of tree of heaven when five or more trees were present. They also inspected surrounding material (rocks, logs, poles, etc.), as the females are known to lay their eggs on hard, smooth surfaces (G. Parra, 2016, personal communication). The PDA has continued to conduct surveys throughout Pennsylvania, expanding efforts to include visual survey of fourth instar nymphs and adults, tree banding, volunteer programs (banding and egg scraping), and an extensive outreach program in cooperation with Penn State Extension. For more information, please see:

PDA Spotted Lanternfly Program:
http://www.agriculture.pa.gov/Plants_Land_Water/PlantIndustry/Entomology/spotted_lanternfly/Pages/default.aspx

Penn State Extension: https://extension.psu.edu/spotted-lanternfly

Not recommended: Kim et al. (2011b) suggested placing sticky traps at the bases of trees to catch nymphs due to their cyclic behavior of ascending to leaves of host trees and then falling to the ground. However, targeting first to third instar nymphs would not be a good method for visual detection surveys as nymphs of this species are generalists (Kim et al., 2011b).

Identification

CAPS-Approved Method*:

Morphological. *Lycorma delicatula* is very distinctive. The first three instars are black with white spots and the fourth and final instar is red with white spots and red wing pads (Fig. 14). Male and female adults are very similar in appearance but can be distinguished by the female's larger size and red postero-caudal end (Fig. 15).

Figure 14. The four nymphal instars of *Lycorma delicatula* (Lawrence Barringer, Pennsylvania Dept. of Agriculture).

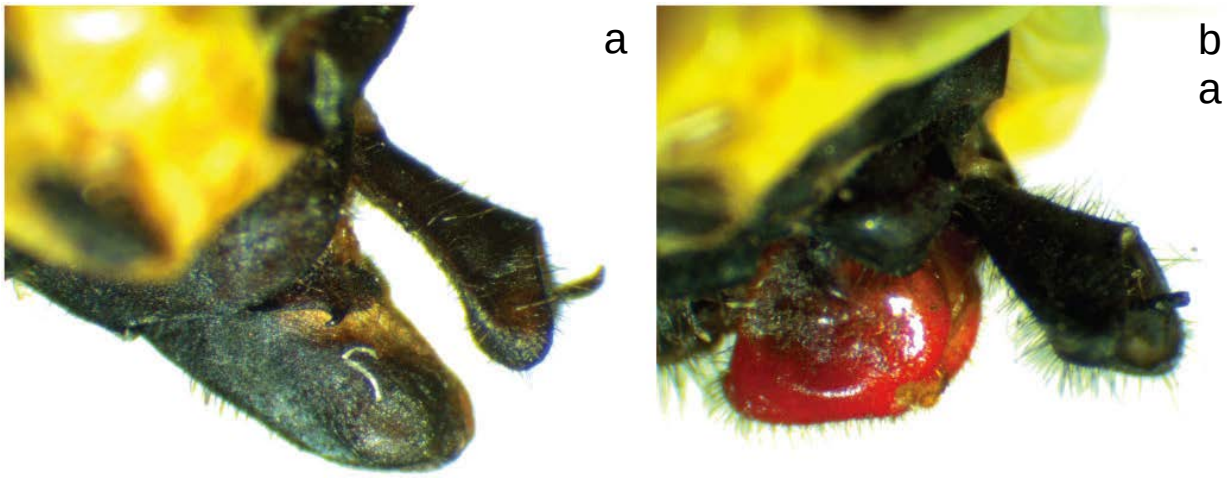

Figure 15. The male (a) and female (b) postero-caudal end of *Lycorma delicatula* (Lawrence Barringer, Pennsylvania Dept. of Agriculture).

*For the most up-to-date methods for survey and identification, see Approved Methods on the CAPS Resource and Collaboration Site, at https://caps.ceris.purdue.edu/approved-methods.

Easily Confused Species

This species is large and striking in appearance. The fourth instar and adult stages are not likely to be confused with other species found in the United States. From a distance, the first instar nymph may resemble a tick to the untrained eye, however they can jump.

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