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Lilith K. M. Fisher

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Contact:
epress@unitec.ac.nz
www.unitec.ac.nz/epress
Unitec
Private Bag 92025, Victoria Street West
Tāmaki Makaurau Auckland 1142
Aotearoa New Zealand

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Post-border detection of the highly invasive *Lycorma delicatula* (White 1845) (Fulgoridae: Hemiptera) in Aotearoa / New Zealand: Implications for the biosecurity of Aotearoa

Lilith K. M. Fisher

Affiliation: School of Environmental and Animal Sciences, Unitec, Private Bag 92025, Victoria Street West, Auckland 1142, New Zealand
Correspondence: lfisher@unitec.ac.nz
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Abstract

A deceased adult *Lycorma delicatula* (White 1845) (Fulgoridae: Hemiptera) or spotted lanternfly (SLF hereafter) is reported in Aotearoa / New Zealand for the first time from a residential home in Kirikiriroa / Hamilton. SLF, indigenous to southwestern China, is a highly invasive polyphagous phloem-feeder introduced to Korea, Japan and the United States of America, and is considered a significant economic pest due to its wide host range and high reproductive output. Although the individual found in Kirikiriroa was deceased, its post-border detection underlines the potential accidental introduction of SLF to Aotearoa. The economic burden attributed to establishment of SLF is significant and would severely impact the agricultural and horticultural sectors of Aotearoa. It is advised that a revision of the current risk assessment regarding SLF in Aotearoa should be considered.

Keywords

Lycorma delicatula (White, 1845), spotted lanternfly, biosecurity, Aotearoa / New Zealand

Introduction

Lycorma delicatula (White, 1845) (Fulgoridae: Hemiptera), or spotted lanternfly (SLF hereafter) is a highly polyphagous phloem-feeder native to southwestern China (Figure 1) (Du et al. 2021; Kreitman et al. 2023). SLF has been accidentally introduced to the Republic of Korea (2004), Japan (2013) and the United States of America (2014) (EPPO 2016; Du et al. 2021; Urban & Leach 2023). Introduction of SLF is primarily through anthropogenic vectors, mainly from the importation of agricultural material (plant material and nursery stock), forestry material (timber and associated timber products), machinery and vehicles containing ootheca (Jones et al. 2022; Ladin et al. 2023).

Due to its wide range of host plants and high proliferation rates, the species is considered an economically significant pest, particularly for horticultural and agricultural industries (Harper et al. 2019; Urban & Leach 2023). Previously, no interceptions of SLF at any life stage (either pre- or post-border) had been reported within the Australasian region (Mauchline & McKenna 2019; Burne 2020).

In December 2021, an image was posted by Nor Uy to the Facebook group "NZ Bug Identification – Spiders, Insects etc." of a deceased, intact adult *L. delicatula*, requesting an identification (Figures 2–3). The organism was immediately identified by members within the Facebook group as an SLF and they advised the author to contact the Ministry of Primary Industries (MPI) to submit a report of the incursion. Further information was provided, stating that the SLF had been found in a new duffel bag, which had recently been imported, at Uy's home in Kirikiriroa / Hamilton, Te Ika-a-Māui / North Island). No ootheca (egg masses) or other individuals were found in the bag, and further images (Figures 3b–3d) were provided to the author to confirm species identification (Nor Uy, personal communication, November 2, 2023).

This is the first record of SLF being detected in Aotearoa, and the incursion underlines the risk of undetected introduction of SLF that could lead to an establishment of populations in this country.

Figure 1. *Lycorma delicatula* adult (left) and fourth instar juveniles (right). From 20180720-ARS-SRA-d4020-20, Stephen Ausmus, 2018, https://www.flickr.com/photos/usdagov/30776344448/

Figure 2. Original image of the deceased *Lycorma delicatula* adult found in a recently imported duffel bag in Kirikiriroa / Hamilton, Aotearoa, posted to the Facebook group "NZ Bug Identification – Spiders, Insects etc." by Nor Uy on 8 December 2021. Photo: Nor Uy.

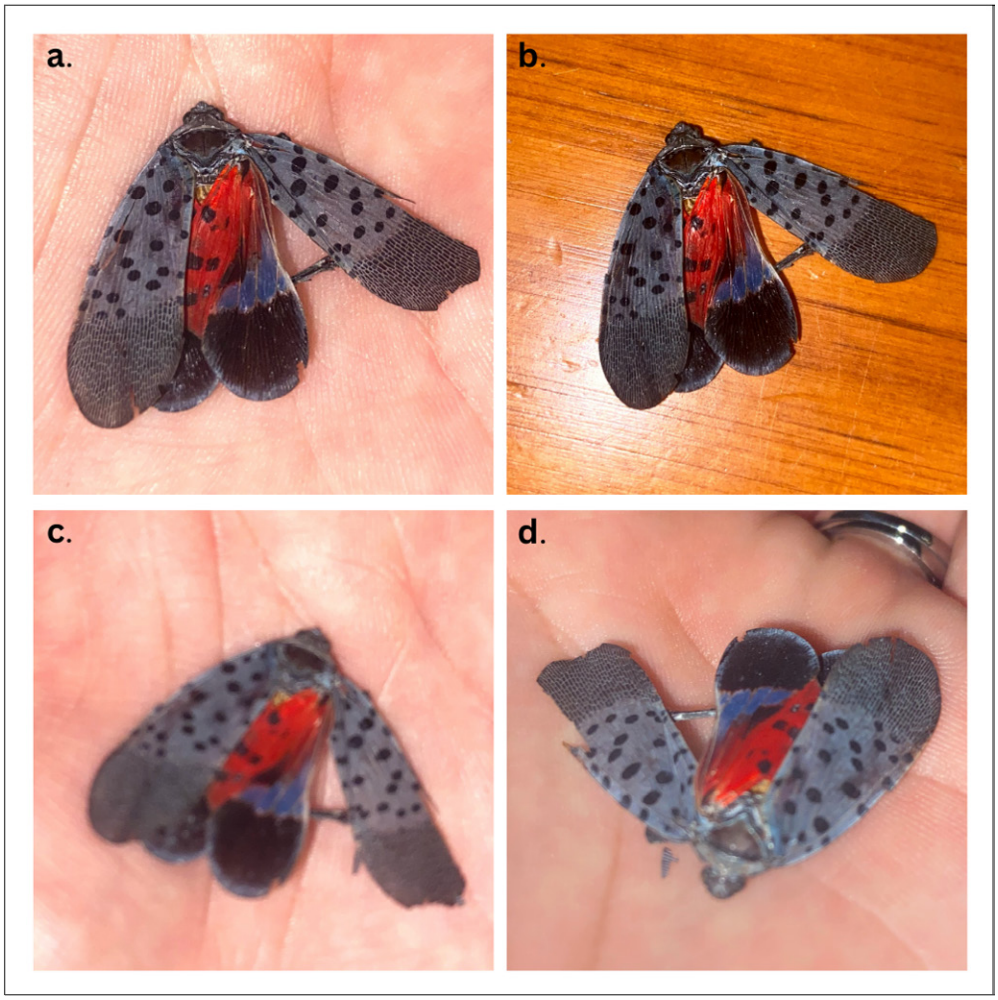

Figure 3. a. Enlarged and cropped image from the original post from Nor Uy in 2021; b–d. Further images provided by Uy to the author of the same adult *Lycorma delicatula* specimen found in December 2021. Photos: Nor Uy.

Taxonomy

Order: Hemiptera L., 1758
Family: Fulgoridae Latreille, 1807

Genus: *Lycorma* Stål, 1863

Lycorma (Hemiptera: Fulgoridae) is a phytophagous planthopper genus native to the Indomalayan region and temperate China (Bartlett 2020), and contains three valid species: *L. delicatula* (White 1845), *L. imperialis* (White 1846) and *L. meliae* Kato, 1929 (Bourgoin 2023). Two subspecies of *L. delicatula* are currently accepted: *L. delicatula jole* Stål, 1863, and *L. d. operosa* (Walker 1858); however, the validity of these subspecies requires revision, and differentiation between subspecies using morphology is not achievable (EPPO 2016; EPPO 2020).

Species: *Lycorma delicatula* (White 1845)

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

Adults lay 30–60 individual eggs, approximately 3 mm in length, 1.5 mm in width and 0.5 mm in height, which are laid in c. 25 mm vertical rows on upright surfaces (i.e., tree branches and plant stems) (Zhang et al. 2023). Following oviposition, the rows of eggs are covered with a creamy, off-white wax that hardens into a dark grey/brown ootheca resembling concrete (EPPO 2020). Eggs hatch after approximately four to six months, and remaining egg cases when exposed are ovoid or seed shaped (Figure 4a) (EPPO 2020; Zhang et al. 2023). The first three nymphal instars have black bodies with small, dorsal white spots and range between c. 0.5–1 mm in length (Figure 4b). The fourth instar is predominantly red,

with a central longitudinal black bar extending from the anterior proximal edge of the thorax to the distal edge of the abdomen (Figure 4c). Yellow/white spots present on the dorsal surface of abdominal and thoracic segments but are absent from the cephalic region. Nymphal instar stages from hatching to adulthood last approximately four months, with the adult stage lasting c. 4–6 months; egg laying occurs c. 2 months after adult emergence (Zhang et al. 2023).

Adult *L. delicatula* (Figures 1, 2, 4e–f) range in length (head to distal wing edge when folded) from c. 20–23 mm (males) and c. 24–27mm (females) (EPPO 2016; EPPO 2020). The head is black/dark grey with short, rounded red antennae protruding below compound eyes towards the anterior tip of the cephalic region. Forewings are a warm grey/brown with sparsely distributed black spots with distal tips reticulated (EPPO 2016). The proximal two-thirds of the hindwings are crimson in colour with black spots, the distal third portion is black, separated from the crimson by a bluish-white panel with variable degrees of reticulation. The ventral abdominal region has yellow and black/brown horizontal stripes separating abdominal segments. Females have a set of red valvifers on the distal margin of the abdomen (EPPO 2020).

Two subspecies have been described, including *L. delicatula jole* Stål, 1863, and *L. d. operosa* Walker, 1858; however; the validity of these descriptions requires revision due to a lack of clear distinguishing characteristics between the two subspecies (EPPO 2016) needed for identification. Further research is needed to confirm the validity of these subspecies.

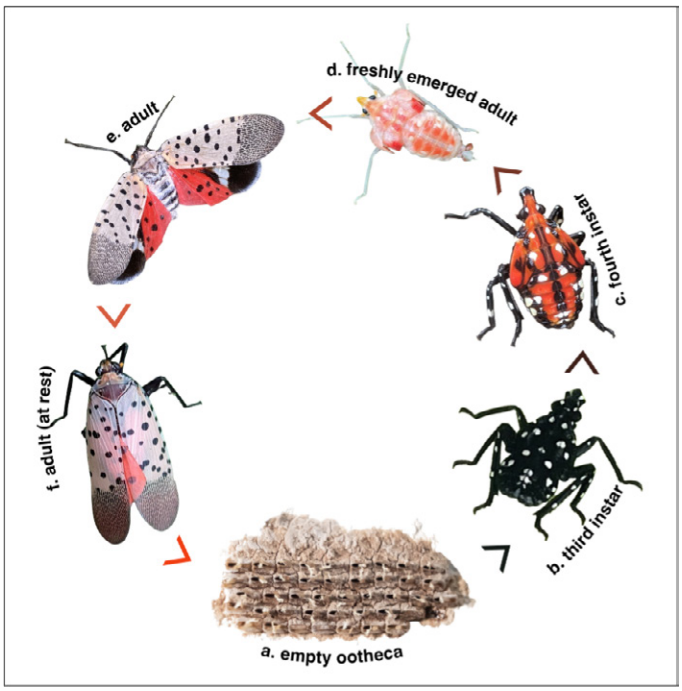

Figure 4. Life cycle of *Lycorma delicatula* from emergence to adulthood. Scale not to size, first and second instar omitted due to similarity in appearance to third instar phase (Figure 4.b). Images **a–f** adapted from: Photo 205218820, Mirko Schoenitz, 2022 (https://inaturalist.nz/photos/205218820); Photo 294837199, Andy Wilson, 2023 (https://inaturalist.nz/photos/294837199); Photo 301029840, Tom August, 2023 (https://inaturalist.nz/photos/301029840); Photo 213324828, spellecchias, 2022 (https://inaturalist.nz/photos/213324828); Photo 318722897, Zinogre, 2023 (https://inaturalist.nz/photos/318722897); and Photo 214612508, Hamilton Turner, 2022 (https://inaturalist.nz/photos/214612508).

Discussion

Impact

Following initial detection in 2014 in Berks County, Pennsylvania, USA, SLF has established populations in 130 counties within nine states (Ladin et al. 2023). The annual population growth with no implementation of control techniques in the US is estimated to be as high as 5.47, or an increase of 447% annually (Strömbom & Pandey 2021). SLF has a wide host-plant range; as of 2020 the species has been found to feed on 103 plant taxa within 33 families across their native and introduced range (Dara et al. 2015; Barringer & Ciafré 2020). Numerous host species are of economic importance, including agricultural export species such as stone fruit (*Prunus sp.*), grapes (*Vitis sp.*), apples (*Malus sp.*) and kiwifruit (*Actinidia chinensis var. deliciosa* (A.Chev.) A.Chev.) (Lee et al. 2019; Barringer & Ciafré 2020). Nymph host-preference has been identified as more broad; however, adults have been identified as having more specific host preferences depending on time of year, crop availability, host-plant health and the period of time since SLF establishment within the area (Biddinger et al. 2023).

Since its introduction to several countries, SLF has caused severe economic and ecological damage, necessitating extensive financial efforts to eradicate or control the species (Harper et al. 2019; Uyi et al. 2021). A 2019 report suggested that the worst-case scenario of SLF spread in Pennsylvania alone could cost US$554 million and result in nearly 5000 jobs being lost across agricultural and forestry sectors (Harper et al. 2019).

Reflecting on the financial and societal damage of recent biosecurity incursions such as *Pseudomonas syringae* pv. *actinidiae* Takikawa et al. 1989 (Psa) in the kiwifruit industry, which is estimated to have equated to a total loss of over NZ$2 billion, the establishment of SLF in Aotearoa would incur severe economic loss across multiple sectors (Vanneste 2017). Spotted lanternfly adults and nymphs are known to feed on wine grapes (*Vitis vinifera* L.); monitoring of vine productivity in vineyards with known infestations in Pennsylvania during 2018–19 revealed reduced crop production in the following spring, and SLF activity was suspected to impact overall vine health and pathogen susceptibility (Biddinger et al. 2023). Considering the wine industry export alone in Aotearoa generated NZ$2.45 billion in 2023, the impact of SLF establishment would bring severe financial strain to our agricultural sector (New Zealand Winegrowers 2023).

Establishment risk of SLF in Aotearoa

A risk assessment was produced in 2020 for Ministry of Primary Industries (MPI) to determine the probability of SLF establishment through various vector pathways, as well as the monitoring, management strategies and impacts following establishment (Burne 2020). SLFs utilise a diapause overwintering strategy for embryonic development, requiring a period of cold exposure (diapause development) followed by elevated temperatures (post-diapause development) (EPPO 2016).

The estimated developmental cycle cited by Burne (2020) includes an estimate of 355.4 degree days for peak egg development using the lowest developmental threshold of 8.14 °C. Burne (2020) identified three separate lowest development thresholds from separate studies: 8.14 °C (Choi et al. 2012), 11.3 °C (Park 2015) and 12.75 °C (Song 2010). The MPI report also included variation of egg mortality from three separate provinces in South Korea, which varied from c. 93% to 17%; however, the inclusion of lowest temperatures and respective duration attributed to the mortality rates was omitted in the MPI SLF report (Lee et al. 2011; Burne 2020).

Furthermore, Burne (2020) states the previously identified LTemp100 to be between -3.44 °C and -12.72 °C, based on the results from Song (2010) and Lee et al. (2011); however, the observed LT100 by Park (2015) ranged between c. -16.5 °C and -20.0 °C, and only resulted in 100% mortality when temperatures remained between these averages for prolonged periods.

A recent study of SLF peak egg-development estimates from Pennsylvania identified the lowest threshold for development at 7.39 °C, and eggs held at constant temperatures of 10 °C, 15 °C and 20 °C required 635, 715 and 849 DD7.39, respectively (Keena & Nielsen 2021). Furthermore, a biological strategy that increases the establishment success rates of SLF is the winter-adapted diapause following deposition of eggs (Maino et al. 2022). This allows for eggs laid towards the end of the summer period to overwinter, with hatching of nymphs occurring in the following warmer period to maximise nymph survivability. The diapause strategy therefore increases the likelihood of ootheca survivability during both long and short periods, such as international dispersion via anthropogenic pathways (such as private luggage, cargo, horticultural imports, etc.).

A recent publication investigating the potential for SLF to disperse via hitch-hiking on the exteriors of vehicles identified satellite populations of SLF throughout the United States (Elsensohn et al. 2024). The establishment of these satellite populations were attributed to the presence of transportation corridors, particularly highways and cargo rail lines. Elsensohn et al. (2024) tested the extent of SLF's ability to hitchhike and determined the prevalence of anthropogenic-assisted spread of SLF throughout novel environments. The methodology involved placing individuals of SLF at varying growth stages (first instar to late adult) on vehicles and exposing these individuals to windspeeds up to 100 ± 5 km h–1. They found that two areas on vehicles, the wiper blades and scuttle panel, allowed for high adhesion of SLF at all growth stages (48% and 60% respectively). This underlines further potential for assisted dispersal of SLF following the establishment of SLF in a novel environment, particularly within developed areas with transport corridors such as rail and motorways or highways.

Considering that the estimates for the developmental temperature requirements being reported have a seemingly broad range, which may be attributed to source population, caution should be taken regarding the risk of SLF establishment in Aotearoa. The Port of Auckland processed 818,810 standard 20-foot shipping containers in 2023 alone, and this figure does not include vehicle imports or passenger cargo within cruise ships (Port of Auckland 2023). The high volume of goods imported into Aotearoa opens numerous pathways for unwanted organisms to enter the country and increases the chances of establishment. Post-border incursions such as this deceased adult SLF should be considered a

serious incident for Aotearoa's biosecurity, and a revision of the risk assessment assigned to SLF in Aotearoa is recommended.

Data Accessibility Statement

No additional database.

Author Contributions

Lilith K. M. Fisher: Conceptualisation (lead); data curation (lead); validation (lead); visualisation (lead); writing – original draft (lead); writing – review and editing (lead).

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Author

Lilith Fisher is a lecturer at the School of Environmental and Animal Sciences, Unitec. Lilith is an arachnologist taxonomist with an interest in endemic orbweaver (Araneidae) taxonomy, and also teaches mātauranga Māori. She is the lead curator of Unitec's Galbraith Zoological Collection and an associate editor for *Perspectives in Biodiversity*. lfisher@unitec.ac.nz

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