Invasive species threat to New Zealand: The Spotted lanternfly (*Lycorma delicatula*)

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The Spotted lanternfly, *Lycorma delicatula* (Hemiptera: Fulgoridae), is a highly polyphagous phloem feeding plant hopper, native to China, Japan, and Vietnam (although this range could be larger) (Dara et al. 2015). A known key host of *L. delicatula* is *Ailanthus altissima* (Han et al. 2008), yet due to the species expanding global distribution, it has been found that *L. delicatula* is associated with over 103 plant taxa, across 33 families and 17 orders (Barringer and Ciafré 2020) These known host pants include grapes and other specialty agricultural crops, trees and plants in urban habitats, managed and natural forested areas (Urban and Leach 2022). *Lycorma. delicatula* has spread and established throughout most of Southeast Asia (Kim et al. 2013), and in 2014 was discovered in Pennsylvania, USA, and has since expanded its range into five other north-eastern states (Harper et al. 2019). Agricultural impacts alone in Pennslyvania are estimated to be $13.1 million (US dollars) annually, with the potential for that figure to increase to $29.6 million (US dollars) (Harper et al. 2019). In 2020, the Ministry for Primary Industries (MPI) stated that *L. delicatula* is not present in New Zealand (Burne 2020), and to date there have been no observations of this species in the country.

Figure 1. *L. delicatula* nymphal instars. The first three instars (left to right) are black with white spots. The fourth instar develops red patterning on the dorsal side, covering the head, thorax, and abdomen. Spotting becomes white to yellowish. Photo Credit: Lawrence Barringer (Dara et al. 2015).

Figure 2. Dorsal view of an adult female *L. delicatula*. Photo Credit: Lawrence Barringer. (Daraet al. 2015)

Lycorma delicatula develops through four nymphal instars (Fig. 1) over approximately three months (Dara at al. 2015). Observations have shown that the broadest host range is in the early first to third instars, feeding on fleshy herbaceous plants, whereas fourth instar nymphs narrow their host range and primarily feed on woody plant tissues (Mason et al. 2020). Nymphs and adults feed on phloem tissues using their piercing and sucking mouthparts, and during population booms, can cause extensive damage, resulting in the wilting and death of the host (Ding et al. 2006). As *L. delicatula* feeds, large amounts of honeydew are excreted, promoting a build-up of sooty mould on the vegetation below, inhibiting photosynthesis and reducing plant growth, and in extreme cases, thick mats of fungal growth accumulate around the host plants base (Tedders and Smith 1976). Volatile chemicals found in honeydew attract large numbers of Hymenoptera and other insects. In *L. delicatula's* native range, these chemicals attract notable species such as egg parasitoid *Anastatus* *orientalis*, which is considered a significant biocontrol in China, with parasitism rates reaching 80% in some regions (Choi et al. 2014).

The ecological impacts of *L. delicatula* are poorly studied, and it is not clear how this species may affect ecosystem composition in non-native regions. A risk analysis of *L. delicatula* by Burne (2020) on behalf of MPI, concluded that economic consequences of *L. delicatula* establishing in New Zealand to be moderate to high (with moderate uncertainty), and the environmental consequences were considered to be low (with high uncertainty). Environmental conditions have been found to be favourable (Fig. 3.), and the likelihood of establishment and spread is considered high (Burne 2020).

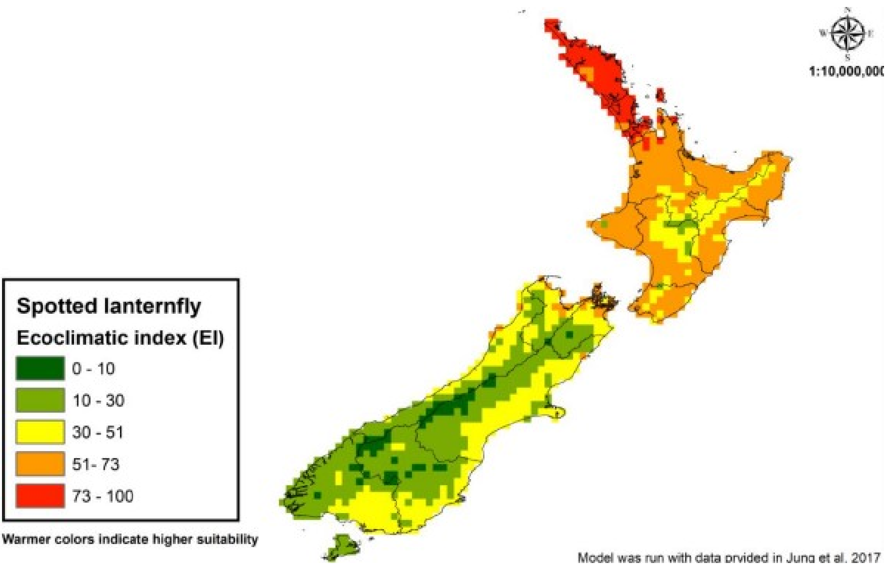

Figure 3. The potential distribution of *L. delicatula* based on parameters modelled in CLIMEX by Jung et al. (2017) Higher Ecoclimatic index value, indicate more suitable areas. Values below 5 are marginal for establishment.

The highest likelihood of entry is believed to be on pathways such as forest products and inbound passengers' luggage, as overwintering egg masses. (Burne 2020).

The population growth of many invasive species has been shown to follow an expected trajectory, including a lag phase during initial establishment, followed by a stage of exponential growth, a population peak, and then fluctuating patterns of equilibrium which can often exceed the carrying capacity of the new environment (Fig 4.). Equilibrium is reached when populations of the invasive species are limited by factors such as food availability, competition with native species, space, and abiotic factors such as temperature (Morris 2012).

The eradication and containment of introduced species is best done when populations are small (Kelly et al. 2021), therefore, monitoring must occur at an intensity that will allow early detection (Larson et al. 2011). Given the high costs of invasive species control once equilibrium has been achieved, it is more cost-effective to invest in preventing invasion than it is to control established populations (Yokomizo et al. 2009). Despite the threat of *L. delicatula* entering New Zealand being low, the suitability of the environment is favourable, and therefore post-boarder strategies should be implemented. The removal of key host species, such as *Ailanthus altissima*, may limit the ability of *L. delicatula* to establish (Kang et al. 2011). The association between *A .altissima* and *L. delicatula* is understood to be through the sequestration of alkaloids for defence, limiting predation by birds (Kim et al. 2011).

There are no commercially available monitoring tools for *L. delicatula* in New Zealand, and post boarder checks are reliant on visual inspection (Burne 2020). However, MPI have noted several potential monitoring tools which could be of use detecting *L. delicatula*:

- *L. delicatula* is attracted to short wavelength blue light. Light trapping may be suitable for exploitation as a monitoring tool (Lee et al. 2019).
- Adhesive bands placed round the base of host trees have proven as an effective means of monitoring and capture. In colour preference tests conducted in South Korea, brown coloured bands have been demonstrated to be more effective than blue or yellow and

captured *L. delicatula* across nymph and adult phases (Choi et al. 2012).

- Chemical attractants for *L. delicatula* have been identified, which have potential for use as monitoring tools or kill traps (e.g. sticky traps).
- Repellent testing by Yoon et al. (2011) showed that certain oil extracts act as a repellent against *L. delicatula*, which could be used as a deterrent across areas identified as favourable areas for initial establishment.

If *L. delicatula* was to become fully established in New Zealand, controlling large populations would prove to be extremely difficult. Many insecticide applications have been shown to be ineffective, with low (< 50%) egg mortality, and significant damage to non-target species in the application of spraying (Dara et al. 2015). Three potential Hymenoptera biological controls have been identified for *L. delicatula*, each showing high levels of parasitism across egg and nymph stages (Choi et al. 2014).

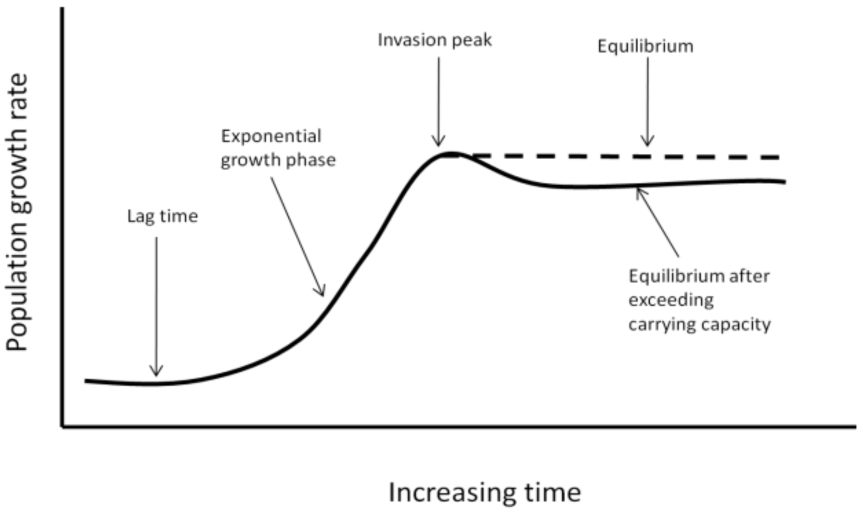

Figure 4. Simplified theoretical line-plot of population growth curve and phases for invasive species. (Morris 2012)

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