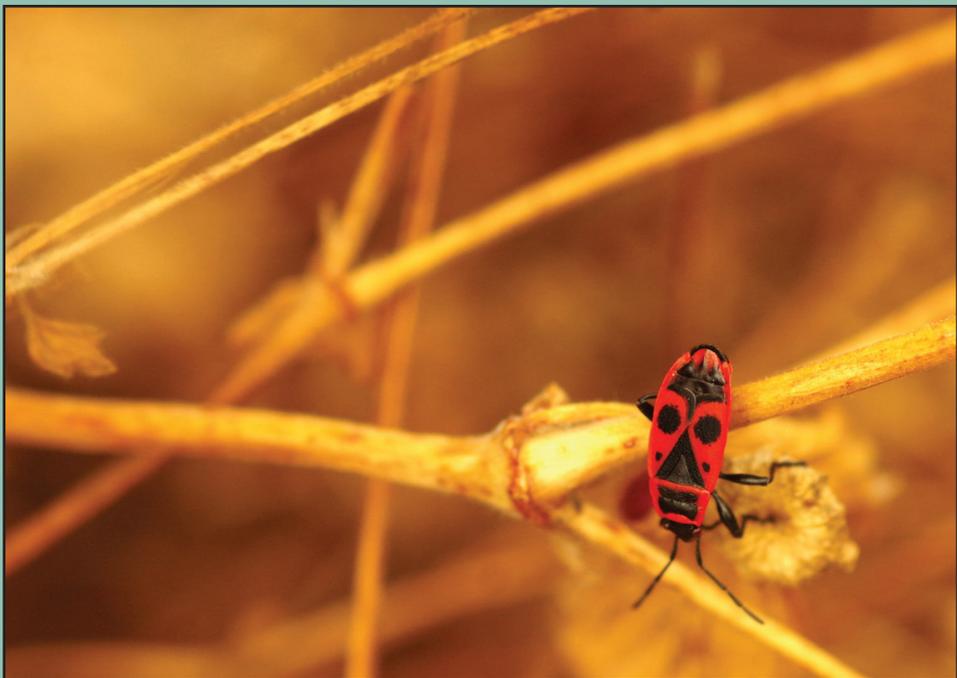


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Luis Mata, Blythe Vogel,
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Cover Photograph: European Firebug in Westgate Park (Melbourne, Australia). Photograph © Luis Mata.

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The Arrival and Spread of the European Firebug (*Pyrrhocoris apterus*) in Australia as Documented by Citizen Scientists

Luis Mata^{1#*}, Blythe Vogel^{2#}, Estibaliz Palma¹ and Mallik Malipatil^{3,4}

Abstract - We report the recent introduction and spread of the European Firebug (*Pyrrhocoris apterus*) in Australia, as documented on the citizen science platform iNaturalist. The species was first observed in December 2018 in the City of Brimbank (Melbourne, Victoria) and has quickly expanded into 15 adjacent municipalities, including areas in Metropolitan Melbourne and regional Victoria. Records of the European Firebug in Victoria are rapidly rising, with a current tally of almost 100 observations, as of July 31, 2021.

The case of the European Firebug in Australia showcases the key role that citizen scientists are playing in the early detection of introduced species and in documenting their expansion across their non-native range. Citizen science presents an exciting opportunity to complement biosecurity efforts carried out by government agencies, which often lack resources to sufficiently fund detection and monitoring programs given the overwhelming number of current and potential invasive species.

While the European Firebug has the potential to become a nuisance pest, negatively impacting both ornamental and indigenous plants, the ecological consequences of the rapid range expansion of the species in Australia and other parts of the world are currently unknown. We propose that future studies should be conducted to understand and quantify the effects of the species on Australian ecological communities and production industries.

Given the range expansion patterns of the European Firebug worldwide, their adaptation ability, and future climate scenarios, we suspect the European Firebug will continue to expand its range beyond Victoria to other urban environments and regional areas of Australia, New Zealand, and the South Pacific. We believe that most of the knowledge about how this expansion continues to unfold will be provided by citizen scientists contributing observations in or around urban areas.

Pyrrhocoris apterus Linnaeus (European Firebug) [Hemiptera: Pyrrhocoridae] is an herbivorous, gregarious, and vividly aposematic species (Fig. 1). European Firebugs present distinct wing polymorphism, with most individuals expressing the brachypterous (Fig. 1) over the macropterous form (Socha 1993). The European Firebug diet is mainly associated with seeds of Linden Trees (genus *Tilia*); however, the species is known to be widely polyphagous, feeding on plant species in the families Asparagaceae (Asparagus), Betulaceae (Birch), Boraginaceae (Borage), Cupressaceae (Cypress), Asteraceae (Daisy), Cornaceae (Dogwood), Ulmaceae (Elm), Malvaceae (Mallow), Lamiaceae (Mint), Fagaceae (Oak), Fabaceae (Pea), Rosaceae (Rose), and Sapindaceae (Soapberry) (Kristenová et al. 2011). The species occurs in a wide array of terrestrial habitats (including on leaf litter, rock crevices, under bark, and on vegetation) and has been documented extensively in urban environments (Endrestøl and Roth 2020, Hodgson 2008, Mata et al. 2013, Oviedo Rojas and Jackson 2018). The species is well adapted to cold climates and presents adaptations that allow it to survive freezing temperatures (Košťál and Šimek 2000). European Firebugs normally develop one generation per year, but may also produce a second generation under warmer conditions (Saulich and Musolin 1996). Easily reared under experimental conditions, Euro-

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pean Firebugs have been widely used as model organisms in a wide range of morphological, developmental, ecological, ethological, physiological, biochemical, genetic, and evolutionary studies (Kristenová et al. 2011, Socha 1993).

The European Firebug has been traditionally known as a Palearctic species, ranging from central and southern Europe to western China (Kerzhner 2001). Ample evidence, however, shows that it has been rapidly spreading outside its traditional native range (Fig. 2; Gardiner 2020). While, in some instances, it might be difficult to disentangle natural from anthropogenic expansion—for example, in the Azores (Cardoso et al. 2011), Malta (Casar 2019), and northern Europe (Endrestøl and Roth 2020)—it is evident that the European Firebug has reached the American (Hodgson 2008, Oviedo Rojas and Jackson 2018) and Australian continents, assisted by humans.

Here, we report the arrival and spread of the European Firebug in Australia. On 10 March 2019, the first authors were facilitating a citizen science outdoor activity targeted at documenting ecological interactions between indigenous plants and insect pollinators in urban environments. The activity was part of a research and community engagement project entitled “Pollinator Observatories”, which took place in Westgate Park (Melbourne, Victoria, Australia), between April 2017 and March 2019 (Mata et al. 2020, Vogel 2019). During the activity, a citizen scientist asked for assistance to identify an insect they had observed on the ground. To our surprise, the insect was the European Firebug, a species that one of the first authors had researched in its native range in the Iberian Peninsula and had experience in surveying and identifying (Mata et al. 2013). We, therefore, had no difficulties in recognizing the species as non-native to Australia.

We set to assess whether we had documented the first record of the European Firebug in Australia. We began by searching the literature for evidence of the European Firebug occurring in Australia but could not find any references documenting this. We then searched the Atlas of Living Australia for European Firebug records but found none. Next, we asked



Figure 1. The European Firebug *Pyrrhocoris apterus* (Westgate Park, Melbourne, Victoria, Australia). Photo by Luis Mata.

colleagues across our networks whether they had any relevant information on the European Firebug and used this as an opportunity to communicate the discovery to the relevant biosecurity authorities. We learned the European Firebug had, indeed, been previously recorded in Melbourne’s western suburbs as early as April 2018 by the Border Surveillance Group of the Australia Government’s Department of Agriculture and Water Resources (Adam Broadley pers. comm., later published in DAWE [2019]). Finally, having experienced first-hand how straightforward it had been for a citizen scientist to find the European Firebug, we consulted the online biodiversity citizen science platform iNaturalist (<https://www.inaturalist.org/>) hoping to find further evidence of the arrival and potential spread of the species in Australia.

We found that, at the time of our inquiry (April 2019), 4 citizen scientists had contributed 6 iNaturalist observations of the European Firebug in Australia. The earliest was from 21 December 2018, the latest from 9 March 2019; all were from the suburb of Sunshine in the City of Brimbank (Melbourne, Victoria). We monitored subsequent iNaturalist observa-

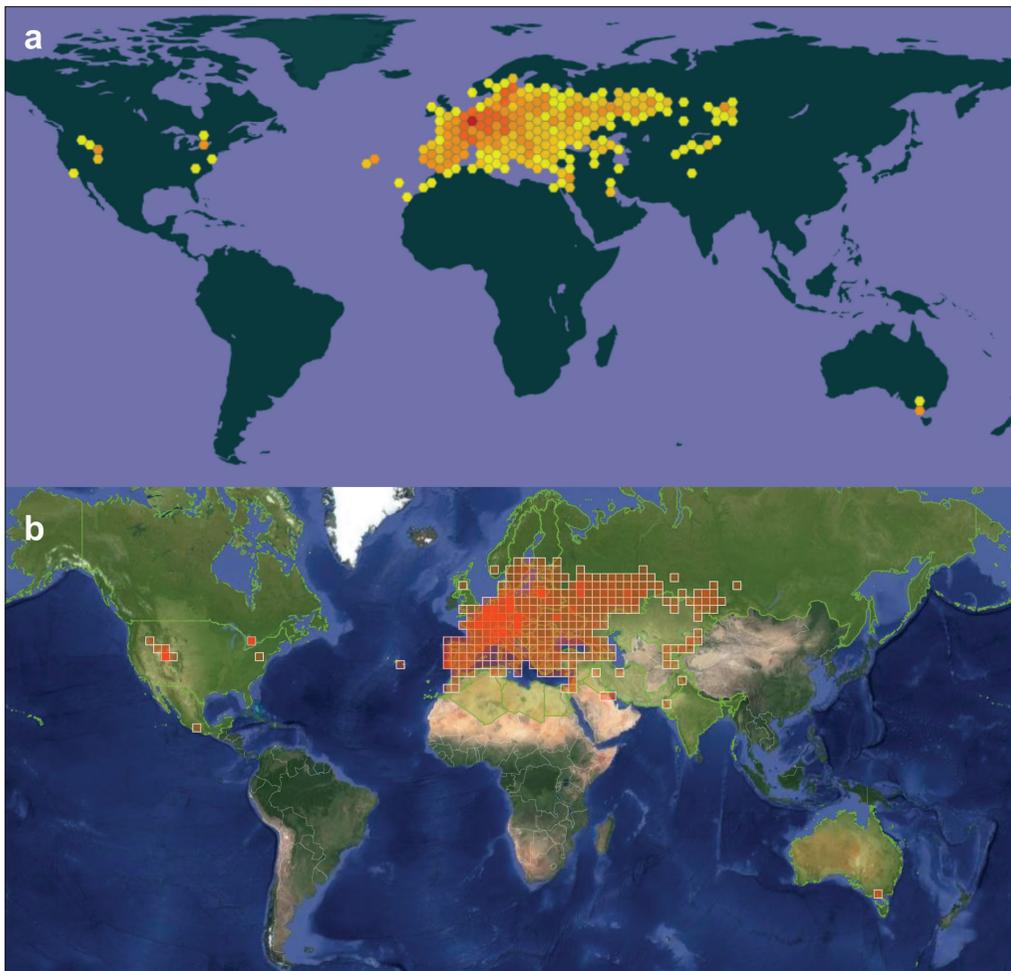


Figure 2. Current biogeographical distribution of the European Firebug *Pyrrhocoris apterus* based on data provided by (a) the Global Biodiversity Information Facility (<https://www.gbif.org/>) and (b) iNaturalist (<https://www.inaturalist.org/>). The species was, until recently, restricted to the Palearctic but has now expanded its range to the African, Australian, and American continents. The colored cells in each map represent the occurrence and density of European Firebug records.

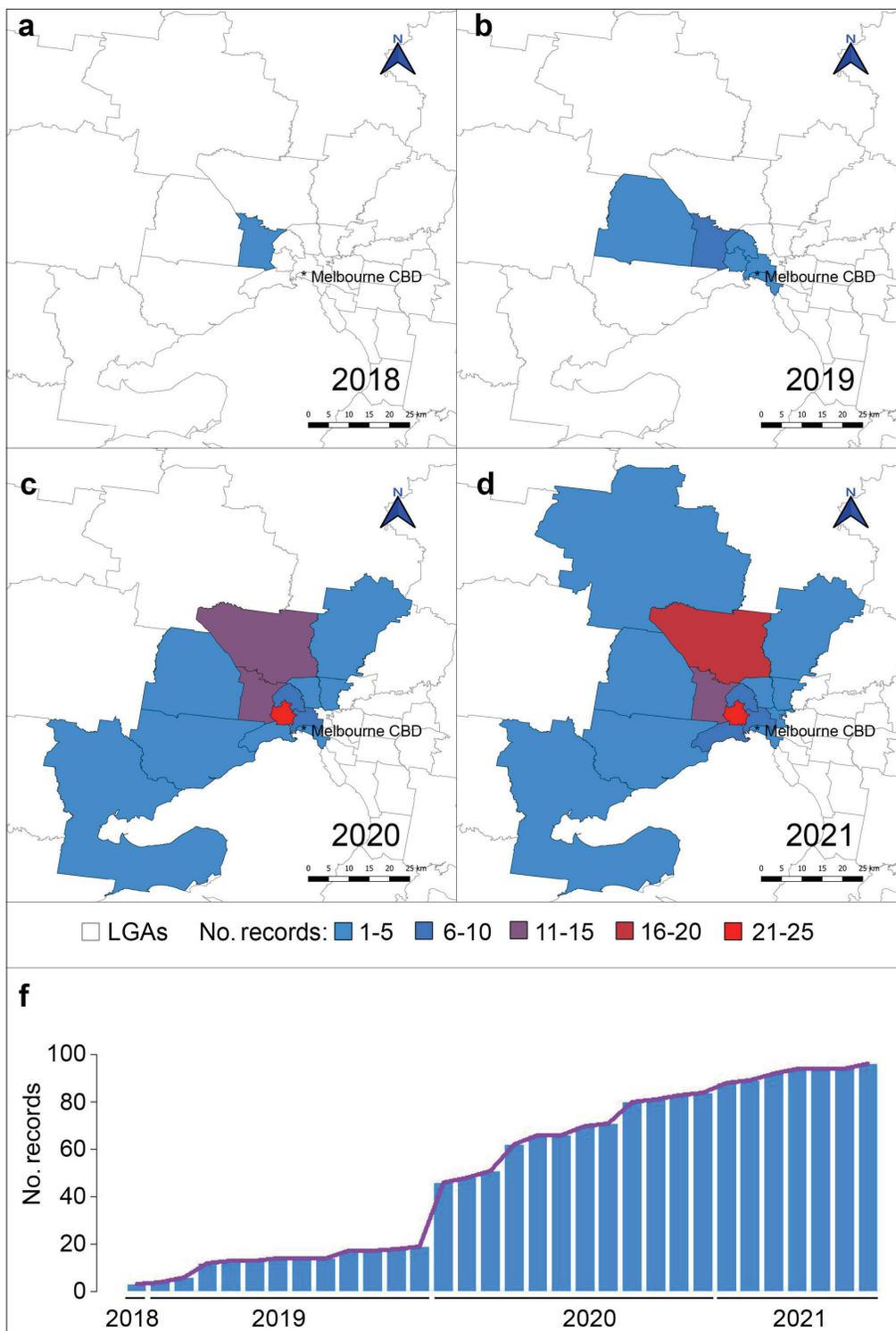


Figure 3. (a-d) Past and current distribution of the European Firebug *Pyrhocoris apterus* in Australia. The heat maps highlight the Local Government Areas (i.e. municipalities and shires) across the Melbourne Metropolitan Area and regional Victoria in which the species has been documented by citizen scientists through iNaturalist as of 31 July 2021. (f) Number of accumulated observations by month of the European Firebug in Australia from December 2018 to July 2021. CBD: Central Business District; LGA: Local Government Area.

tions to track the potential spread of the species throughout Melbourne, regional Victoria, and likely other urban and regional areas across Australia. We found that, as of July 2021, over 30 citizen scientists have contributed approximately 100 observations of the European Firebug in Australia (Fig. 3f). These observations distinctly indicate that the species has been expanding its range, spreading from its original introduction enclave in the City of Brimbank (Fig. 3a) to 15 municipalities and shires in the Melbourne Metropolitan Area and regional Victoria (Fig. 3d) in less than 3 years.

Taken together, our findings highlight the key role that citizen scientists—whether prompted by academic-led activities, government-initiated programs, or personal enthusiasm—are playing in detecting newly introduced species and documenting their establishment and expansion in their non-native ranges. The engagement of citizen scientists can effectively complement government-funded detection and monitoring programs, ensuring that introductions or outbreaks of potentially harmful species do not remain undetected (Ricciardi et al. 2017, Turrini et al. 2018). With careful project design, volunteer training, and professional validation, citizen science observations can be as reliable and robust as those undertaken by professional scientists (Kosmala et al. 2016). Citizen scientists around the world have successfully detected invasive species early, significantly contributing to the rapid management of potential pest species (Azzurro et al. 2013, Cohen et al. 2011, Eritja et al. 2019, Scyphers et al. 2015, Walther and Kampen 2017). Citizen scientists, who can cover much larger areas and longer time periods than experts alone can (Turrini et al. 2018), have also made critical contributions in the ongoing monitoring of invasive species following their detection, documenting their long-term spread and impacts on native species and ecosystems, and in informing management plans and actions (Maistrello et al. 2016, Pyšek et al. 2020, Ricciardi et al. 2017, Weed and Schwarzländer 2014). Citizen scientists participating in national, continental, and global projects (e.g. eButterfly, eBird, iNaturalist) often excel at detecting range expansions or shifts of both native and introduced species much earlier than professional scientists do (Crall et al. 2015, Chandler et al. 2017, Prudic et al. 2017). These and other examples emphasise the ability for citizen scientists to reliably study species of interest—including actual or potential threats—across wide geographical ranges.

We argue that the contributions of citizen scientists are highly valuable, as they complement efforts of biosecurity agencies in charge of detecting and monitoring introduced species during their early invasion stages or during outbreaks. This is particularly relevant for species with documented detrimental impacts in their non-native regions, if left unmanaged. While Oviedo Rojas and Jackson (2018) note that the European Firebug could become a nuisance pest in Canada, negatively impacting both ornamental and indigenous plants, the potential ecological consequences, whether detrimental or beneficial, of the rapid range expansion of the European Firebug in Australia and other parts of the world are currently unknown. Future studies on the current topic are therefore recommended in order to understand and quantify the potential detrimental impacts of the European Firebug on Australian ecological communities, as well as on its grains, horticultural, and nursery industries.

Given the global range expansion patterns of the European Firebug, the reported feeding and thermal adaptations of the species, and future climate scenarios, we would like to put forward the following two ideas about the future spread of the European Firebug across Australia and beyond. First, we believe that, if left unmanaged, the species will likely continue to spread across metropolitan Melbourne and regional Victoria, eventually reaching other urban and rural areas across continental Australia, and also Tasmania, New Zealand, and other South Pacific islands, and likely, in the not-too-distant future,

the Antarctic continent. Second, we are convinced that the majority of the future range expansion of the European Firebug across Australia and beyond will be documented by citizen scientists contributing observations in or around urban areas. As such, we would like to thank them in advance for their efforts and call for biosecurity and other related agencies to continue to support their invaluable contributions to science and society.

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Data and Code Accessibility Statement

The data and codes to reproduce the analysis shown in Fig. 2 are already published and publicly available in Zenodo: <https://doi.org/10.5281/zenodo.5355347>

Author Contribution Statement

Luis Mata: Conceptualization (co-lead); Investigation (equal); Writing-original draft (co-lead); Writing-review and editing (equal). **Blythe Vogel:** Conceptualization (co-lead); Investigation (equal); Writing-original draft (co-lead); Writing-review and editing (equal). **Estibaliz Palma:** Data curation (lead); Formal analysis (lead); Investigation (equal); Writing-review and editing (equal). **Mallik Malipatil:** Investigation (equal); Writing-review and editing (equal).

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