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LETTER TO THE EDITOR

Victims or perpetrators: contribution and response of insects to forest diebacks and declines

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Abstract

• ***Key message*** **Unprecedented forest declines and diebacks are expected worldwide in response to global change. Insects can trigger or contribute to these disturbances, which can in turn have either beneficial or detrimental retroactive cascading effects on insect communities. However, we are still unsure of the effects that pests will have on these disturbances in the future, and new biodiversity and pest management strategies still need to be put into place. Several recent contributions to Annals of Forest Science address these issues.**

Forest ecosystems worldwide are currently facing increasing amounts of biotic and abiotic environmental stress, which severely challenges both their acclimation and adaptation capacities (Allen et al. 2010; Carnicer et al. 2011). As a result, extended forest diebacks, or declines, are becoming escalating global phenomena (Allen et al. 2010). The two terms have been used interchangeably (Ciesla and Donaubauer 1994), but it seems that "decline" more generally refers to multifactorial and progressive loss of tree vigor (Sinclair 1967; Manion 1981; Ciesla and Donaubauer 1994), while "dieback" refers to rapid tree mortality, driven by a major biotic or abiotic agent, such as the ash dieback (Pautasso et al. 2013).

Insects are key components of forest biota. From a functional standpoint, they play major roles in several forest ecosystem processes, such as wood decomposition due to the numerous saproxylic species (Grove 2002), and in trophic webs as key prey, predators, and herbivores (Yang and Gratton 2014). In addition to their animal biomass, they also make a major contribution to the tremendous biodiversity found in forests (Stork 2018). Within the frame of global change, forest insect populations are currently undergoing major shifts in their geographical range and population dynamics. In this context, forest insects can act as major drivers of diebacks or as inciting factors of declines (e.g., Thomas et al. 2002; Biedermann et al. 2019). Bark and wood boring species can also take advantage of the weakening of trees and act as contributing factors of declines (Sallé et al. 2014). Both dieback and decline dramatically alter the organization and functioning of forest ecosystems (e.g., Šťursová et al. 2014; Hoven et al. 2020), and can consequently have cascading effects on forest insect communities, potentially over large spatial and temporal scales (e.g., Winter et al. 2015). All these situations are illustrated in the topical issue "Entomological issues during forest diebacks" and recent publications in *Annals of Forest Science*.

Climate change can promote thermophilous species through direct selective effects of warming on developmental and behavioral traits (Bale et al. 2002), and also through direct and indirect effects on forest health (Seidl et al. 2017). Several recent contributions to the journal deal with insects (often Mediterranean species) showing a recent increase in damage levels, or an extension of their geographical range (Bellahirech et al. 2019; Poole et al. 2019; Sánchez-Osorio et al. 2019; Torres-Vila et al. 2019; Sallé et al. 2020).

Ever-increasing import rates and trade volumes foster the introduction and establishment of invasive forest species,

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which can be major drivers of forest diebacks (Roy et al. 2014; Liebhold et al. 2017). On this subject, the paper by Coleman et al. (2019) provides a preliminary susceptibility assessment of two invasive ambrosia beetles, *Euwallacea whitfordiodendrus* (Schedl) and *Euwallacea kuroshio* Gomez and Hulcr, for both native and ornamental trees in North America. The paper by Orlova-Bienkowskaja et al. (2020) describes the population of *Agrilus planipennis* Fairmaire recently introduced in the Moscow area, as well as the insect's westward progression through Europe, and commonly infested host tree species.

Interestingly, most recent contributions to *Annals of Forest Science* regarding climate change effects on forest pests and invasive species deal with either Buprestidae (Orlova-Bienkowskaja et al. 2020; Poole et al. 2019; Torres-Vila et al. 2019; Sallé et al. 2020) or ambrosia beetles (Bellahirech et al. 2019; Coleman et al. 2019). This reflects growing concerns worldwide surrounding these two groups of wood borers. Both groups include several prominent invasive species (e.g., Orlova-Bienkowskaja et al. 2020; Coleman et al. 2019) and also some thermophilous secondary pests, in particular buprestids, which are favored by both direct and indirect impacts of climate change (Bellahirech et al. 2019; Poole et al. 2019; Torres-Vila et al. 2019; Sallé et al. 2020).

The management of these growing issues requires tools to monitor damage distribution and evolution. Torres-Vila et al. (2019) propose a novel method, using Google Street View, to detect and map oak shoot browning at a regional scale. Oak shoot browning is a potential inciting factor of oak decline in the Iberian Peninsula and is caused either by a pathogen, or *Coraebus florentinus* Herbst. The investigations conducted by Bellahirech et al. (2019) and Sánchez-Osorio et al. (2019) could allow us to identify the stands or trees at risk of colonization by *Platypus cylindrus* Fabricius and *Cerambyx welensii* Küster, respectively. The investigation concerning the chemical ecology of *C. welensii* may improve the management of this pest and could, for instance, facilitate the development of efficient lures.

There is accumulating evidence that insect diversity is undergoing a significant decline (e.g., Hallmann et al. 2017; Seibold et al. 2019) and that this trend also affects forest insect communities (Homburg et al. 2019; Seibold et al. 2019). Both forest declines and diebacks are disturbances that may affect some critical resources. However, they also generate biological and/or structural legacies such as snags and logs (Franklin et al. 2002), thereby creating novel colonization opportunities for forest species, and in particular saproxylic species, which depend on dead or weakened trees and associated resources (Grove 2002). This may result in short- or long-lasting biodiversity pulses, depending on the disturbance frequency, spatial extent, and intensity (e.g., Winter et al. 2015; Kozák et al. 2020). In their paper, Sallé et al. (2020) show that an oak decline can have contrasting impacts on canopy-dwelling beetles, depending on their trophic guild. Although it favors saproxylic beetles in general, it may negatively affect some leaf-eating species.

Overall, these papers call for further studies to better predict, monitor, and manage the damage caused by both invasive and increasingly aggressive native pests. A worldwide multidisciplinary research agenda in order to fill lingering knowledge gaps could also focus on comparative studies of (i) large-scale effects of forest dieback/decline in forest landscapes on regional dynamics of insect pests and biodiversity, (ii) long-term or cumulative effects over time of dieback/decline on pest and biodiversity dynamics, (iii) the potential occurrence of response thresholds for insect diversity metrics or ecosystem functions to a forest dieback gradient (Evans et al. 2017), and (iv) feedback and non-linear interactions between climate-induced declines and other climate-related disturbance processes, such as insect outbreaks. We need to better assess the functional outcomes of the unprecedented level of forest decline expected to affect forests worldwide, and to propose management strategies which include declining areas when planning conservation networks.

Data availability Data sharing is not applicable to this article (no dataset).

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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