



Review

Bark and wood boring insects involved in oak declines in Europe: Current knowledge and future prospects in a context of climate change



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ABSTRACT

Oak declines are multifactorial processes in which bark and wood boring (BWB) beetles can act as major inciting factors, killing the weakened trees. Nonetheless, the current knowledge on the biology, ecology of these species is scattered and no efficient management strategies are currently available. Based on the existing literature and field observations from the French forest health service, we firstly identified the prominent BWB species implicated in oak declines in Europe. Secondly we performed a state of the art on the biology and ecology of these species, with a particular reference to the interactions with their host trees. Finally considerations were made on how climate change could affect these interactions. Six species, namely *Agrilus biguttatus*, *Coraebus florentinus*, *Coraebus undatus*, *Cerambyx cerdo*, *Platypus cylindrus* and *Scolytus intricatus* are frequently implicated in oak declines in Europe. The interactions with their hosts regarding selection and resistance are generally poorly known. Likewise, these beetles are associated with a diverse microbial community, which composition and implication in the biology of insects and decline processes is unclear in most cases. Climate change will probably increase the frequency and distribution of oak declines in Europe. It will also likely modify the interactions between oaks and these beetles by promoting contributing factors of decline, modifying directly and indirectly host resistance, phenology and attractiveness, and beetles development, distribution and interaction with microorganisms. Evidences point out that the increase in temperature has already favored the distribution and development of *C. florentinus* and could enhance the development of other species. Potential research prospects are proposed, aiming at acquiring missing basic knowledge and improving the currently limited management strategies.

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1. Oak declines in Europe

In Europe, oaks have a prime ecological, economical and cultural importance as they are a major component of temperate and Mediterranean forest ecosystems. The genus *Quercus* gathers in this continent at least 17 indigenous species plus numerous subspecies, hybrids and several introduced species (Bussotti and Grossoni, 1998). Oaks are long-lived species, with forest rotation cycles up to 200 years or more, and are thus likely to be exposed to varying environmental conditions, including biotic and abiotic extreme events. During the last centuries, oak forests have regularly undergone declines throughout Europe (Delatour, 1983; Siwecki and Ufnalski, 1998; Oszako, 2000; Thomas et al., 2002; Denman et al., 2010; Nageleisen et al., 2010; Sonesson and Drobyshev, 2010). The declines frequently affect *Quercus robur* L. and, to a lesser extent, *Quercus petraea* (Matt.) Liebl., the two dominant species in Europe, with a wide distribution covering most of the continent. Yet, declines have also been reported for other oak species as *Quercus cerris* L., *Quercus dalechampii* Ten., *Quercus faginea* Lam., *Quercus frainetto* Ten., *Quercus ilex* L., *Quercus polycarpa* Schur, *Quercus pubescens* Willd., *Quercus pyrenaica* Willd. and *Quercus suber* L. (Delatour, 1983; Brasier, 1996; Oszako, 2000; Thomas et al., 2002; Nageleisen, 2008; Nageleisen et al., 2010).

Oak declines are multifactorial processes resulting from complex interactions among both biotic and abiotic factors, with prevailing factors varying across Europe (Führer, 1998; Oszako, 2000; Thomas et al., 2002; Sonesson and Drobyshev, 2010; Andersson et al., 2011). Every oak species has particular bioclimatic needs and ecophysiological specificities, and it is then generally assumed that causal factors differ among species and affected regions (Führer, 1998; Thomas et al., 2002). Factors involved in tree declines can be arranged as predisposing, contributing or inciting factors and can take place successively or simultaneously during the decline process (Sinclair, 1967; Manion, 1981; Nageleisen et al., 2010). Predisposing factors are generally related to site conditions, management strategies or endogenous tree characteristics and are constantly affecting the stands or isolated trees (Nageleisen, 1993; Führer, 1998; Thomas et al., 2002). Contributing factors trigger declines. They are intense and punctual perturbations, which can be either abiotic as severe droughts or frosts, or biotic like repeated defoliations by moths (Thomas et al., 2002; Andersson et al., 2011). If contributing factors cease, trees may recover, by producing new sprouts for example (Oszako, 2000). Yet, once a decline has been initiated, trees undergo a vigor loss resulting in an increased susceptibility to secondary pests and pathogens (Dunn et al., 1987, 1990; Wargo, 1996). These pests and pathogens are the main inciting factors, aggravating the deleterious effects of the contributing factors, and ultimately killing the trees. For instance, different *Phytophthora* or *Armillaria* can occur in declining stands and contribute to kill weakened oaks (Brasier, 1996; Thomas et al., 2002; Marçais and Bréda, 2006). Likewise, bark and wood boring (BWB) insects are considered as major inciting factors, implicated in some of the main oak declines in Europe (Kolk, 1992; Landmann, 1994;

Wargo, 1996; Moraal and Hilszczanski, 2000; Thomas et al., 2002; Evans et al., 2004).

While numerous insect species can colonize the bark and wood of oaks, just a few of them are considered as significant pests, colonizing mostly weakened trees. However, during declines these species can play a prominent role, as they prevent weakened trees from recovering and bring then the ecosystem beyond a reversibility threshold. Considering that, together with temperature, the frequency and duration of severe droughts is expected to increase (Jentsch et al., 2007; Allen et al., 2010; IPCC, 2013), both the biology and ecology of these insects will probably undergo dramatic changes. The ecological and economical importance of oak-killing insects is then likely to grow in the future. Since they are generally regarded as secondary pests, the literature dealing with the biology and ecology of European species is very scarce. However, the recent introduction of *Agrilus planipennis* Fairmaire in North America has stimulated the research on introduced and native bark and wood borers and on the resistance mechanisms deployed by host trees. The growing literature on these models offers opportunities of practical and theoretical knowledge transfer. In addition, the French forest health service (DSF) has gathered since 1989 field observations on pests and pathogens affecting the vitality of forest stands. Since France possesses wide oak forests, with different species in various bioclimatic conditions, such a database provide useful information on the relative importance and population dynamics of insects involved in damage to oaks. This review firstly identifies the prominent bark and wood boring (BWB) species implicated in oak declines in Europe. Secondly it presents a state of art of the biology and ecology of these species, with a particular reference to their interactions with their host trees. Finally considerations are made on how climate change could affect these interactions, potential research prospects are proposed and management strategies are presented.

2. Bark and wood boring species associated with oak declines

2.1. Species associated with stem damage and declines

Insects that exploit stem tissues can be separated in different guilds depending on the nature and physiological status of their host tree (Bouget et al., 2005). Among them, corticiphagous species, feeding upon the cork, cambiphagous species, feeding on inner bark tissues, xylemophagous species, feeding in the sapwood and, on occasion, insects with piercing mouthparts can cause significant damage to living oaks. Species attacking living oaks in Europe gather mostly beetles belonging to the Curculionidae, Buprestidae and Cerambycidae families (Jurc et al., 2009; Markovic and Stojanovic, 2011). Scolytinae and Agrilinae subfamilies (families Curculionidae and Buprestidae, respectively) in particular are frequently associated to damage on oaks. An overview on the data from the DSF survey indicate that approximately 75% of the insect-related damage on stems or branches can be attributed to Agrilinae, 15% to Scolytinae and the remaining records involve mostly Platypodinae and Cerambycidae (Fig. 1).

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