Cerambycidae attracted to semiochemicals used as lures for *Monochamus* spp. in the Sonian Forest, Brussels-Capital Region, Belgium (Insecta: Coleoptera)

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Abstract

The pinewood nematode (PWN), *Bursaphelenchus xylophilus*, causes pine wilt disease (PWD), the most serious introduced threat to coniferous forests worldwide. Strict import regulations and phytosanitary measures have failed to prevent its spread into southern Europe, where it is presently established in Portugal and locally present in Spain. In the context of a global survey in Europe for the nematode and its vectors, *Monochamus* species, a network of monitoring traps baited with pheromones and kairomones of *Monochamus* spp. was established throughout Belgium. Within this framework, traps were placed in four *Pinus sylvestris* stands in the Sonian Forest in Brussels. No *Monochamus* spp. were captured, however, three species, *Rhagium inquisitor* (Linnaeus, 1758), *Arhopalus rusticus* (Linnaeus, 1758) and *Spondylis buprestoides* (Linnaeus, 1758), were captured in sufficient numbers to be considered attracted to the lures, and six other species are considered incidental captures. *Arhopalus rusticus* and *S. buprestoides* were deemed rare in Belgium based on examination of collections at the Royal Belgian Institute of Natural Sciences since the 1830's and of several Belgian private collections, but were shown to have stable and homogeneous populations within the Sonian Forest. Although these three species can carry PWN, they are not considered true vectors and the risk of PWN introduction remains low. However, due diligence dictates populations should continue to be monitored.

Keywords: Coleoptera**,** Cerambycidae, Sonian Forest, *Rhagium*, *Arhopalus*, *Spondylis*, *Monochamus*, trapping.

Résumé

Le nématode du pin (PWN), *Bursaphelenchus xylophilus*, provoque le dépérissement des pins (PWD) et représente la plus grave menace pesant sur les forêts de conifères du monde entier. Les règlements d'importation stricts et des mesures phytosanitaires n'ont pas réussi à empêcher sa propagation dans le sud de l'Europe, où il est actuellement établi au Portugal et présent localement en Espagne. Dans le contexte d'une enquête mondiale en Europe sur le nématode et ses vecteurs, à savoir des espèces de Cerambycidae appartenant au genre *Monochamus*, un réseau de pièges de surveillance appâtés avec des phéromones et kairomones de *Monochamus* spp. a été installé dans toute la Belgique. Dans ce dispositif, des pièges ont été placés dans quatre peuplements de *Pinus sylvestris* au sein de la forêt de Soignes, à Bruxelles. Lors de ces collectes, aucun *Monochamus* spp. n'a été capturé. Cependant, trois autres espèces de longicornes, *Rhagium inquisitor* (Linnaeus, 1758), *Arhopalus rusticus* (Linnaeus, 1758) et *Spondylis buprestoides* (Linnaeus, 1758), ont été capturés en nombre suffisant pour être considérées comme attirées par les attractifs utilisés. Six autres espèces ont également été collectées mais ces captures peuvent être qualifiées d'accidentelles. *A. rusticus* et *S. buprestoides* sont mentionnées comme étant des espèces rares en Belgique sur la base de l'examen des collections de l'Institut royal des Sciences naturelles depuis les années 1830 ainsi que de plusieurs collections privées belges. Au contraire, nos résultats indiquent plutôt des populations stables et homogènes au sein de la

forêt de Soignes. Bien que ces trois espèces peuvent transporter le PWN, elles ne sont pas considérées comme de véritables vecteurs et le risque de l'introduction de PWN en Belgique reste faible. Cependant, une certaine prudence devrait nous inciter à continuer de surveiller ces populations.

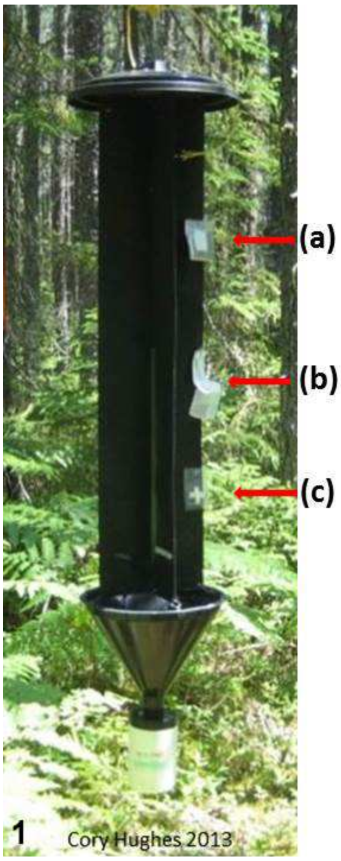
Samenvatting

De dennennematode *Bursaphelenchus xylophilus*, veroorzaakt verwelken en afsterven van dennen en is daarmee de belangrijkste bedreiging van dennenbossen wereldwijd. Een strenge importregeling en fytosanitaire maatregelen hebben echter niet kunnen vermijden dat deze ziekte zich heeft kunnen verspreiden tot in Zuid-Europa waar ze zich momenteel in Portugal heeft gevestigd alsook lokaal in Spanje. In het kader van een globale Europese opvolging van de nematode en haar vectoren *Monochamus* soorten, werd een netwerk van vallen met feromonen en kairomonen van *Monochamus* spp. geïnstalleerd, verspreid over gans België. In het Zoniënwoud werden voor dit project vallen geplaatst in vier *Pinus sylvestris* bestanden. Er werd geen *Monochamus* ingezameld, maar drie andere boktorsoorten *Rhagium inquisitor* (Linneaus, 1758), *Arhopalus rusticus* (Linneaus, 1758) en *Spondylis buprestoides* (Linneaus, 1758) werden wel in hoge aantallen gevonden want suggereert dat deze soorten door de lokstoffen worden aangetrokken. Verder werden nog zes andere boktorren ingezameld, hoogstwaarschijnlijk als toevallige vangsten. Op basis van herzieningen van de collecties op het Koninklijk Belgisch Instituut voor Natuurwetenschappen ingezameld sinds 1830 en privécollecties werden de soorten *Arhopalus rusticus* en *S. buprestoides* als zeldzaam beschouwd in ons land. Deze soorten bleken echter stabiele en homogene populaties te hebben in het Zoniënwoud. Niettegenstaande deze drie soorten dragers kunnen zijn van de dennennematode, worden ze niet beschouwd als echte vectoren en is het risico dat zij de dennennematode introduceren zeer laag. Niettemin suggereren wij deze populaties te blijven opvolgen.

Introduction

Pine wilt disease (PWD) is the most serious introduced threat to susceptible conifer forests worldwide. Its causal agent, the pinewood nematode (PWN), *Bursaphelenchus xylophilus* (Steiner & Buhrer, 1934) Nickle, is native to North America where it is a secondary pathogen of native pine species, but causes PWD in non-native species (BERGDALH, 1988; DWINELL & NICKLE, 1989). Since its introduction into Japan over a century ago, PWD has spread throughout Asia and has become the most destructive disease of pine forests (TOGASHI & JIKUMARU, 2007). The PWN is vectored almost exclusively by cerambycid beetles in the genus *Monochamus* Dejean, 1821 (LINIT, 1988) and its congeneric counterparts in each region of the world in which it has established (see HUMBLE & ALLEN, 2006). Despite the implementation of comprehensive regulations and embargoes, PWN was reported in Portugal in 1999 (MOTA *et al.*, 1999) where continuous control and containment efforts have been ineffective in preventing its spread. PWN now occupies a major part of the country and has established in Spain and on the island of Madeira (see ZHAO *et al.*, 2014).

The European Union (EU) Commission decision 2012-535-EC on emergency measures to prevent the spread of PWN within the Union requires member states to conduct annual surveys in susceptible areas in which PWN was previously not known to occur. In Belgium, the Belgian Federal Agency for the Safety of the Food Chain (FASFC) organized phytosanitary controls at import sites as well as national surveys in (natural) pine stands, public green areas, and logging and wood processing facilities since 2000. Furthermore, in 2013, Belgium initiated an experimental monitoring network for native *Monochamus* spp. as potential PWN vectors, and for exotic species that could enter the country via wood packaging material. This network employs a four-component semiochemical blend in combination with a teflon-coated cross-vane trap that have been shown to be an effective system to capture Cerambycidae, in particular *Monochamus galloprovincialis* (Olivier, 1795) (PAJARES *et al.*, 2010; BONIFÁCIO *et al.*, 2012; ALVAREZ *et al.*, 2013), the main vector of PWN in Europe (NAVES *et al.*, 2007). The blend consists of the pheromone 2-(undecyloxy)-ethanol (monochamol) produced by mature males of *Monochamus* spp. native to Asia, Europe, and North America, to which both sexes are attracted (PAJARES *et al.*, 2010; TEALE *et al.*, 2011; ALLISON *et al.*, 2012; FIERKE *et al.*, 2012), in combination with two pheromones of *Ips* spp. (ipsenol and 2-methyl-3-buten-2-ol), and the host compound α-pinene, which synergize the attractiveness of monochamol (PAJARES *et al.*, 2010).



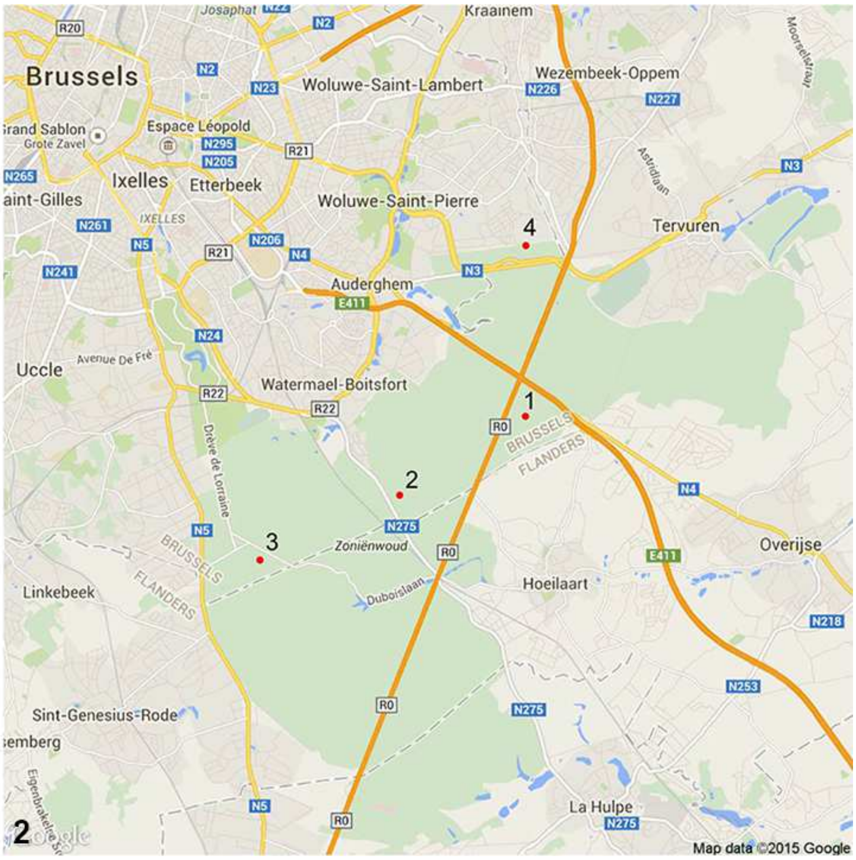


Fig. 1. European trapping system for *Monochamus* species: Crosstrap® and Galloprotect pack®. Location of various components of Galloprotect Pack: (a) monochamol, (b) α-pinene, and (c) ipsenol and 2-methyl-3-buten-1-ol).

Fig. 2. Location of the four coniferous stands sampled in the Sonian Forest in 2013 and 2014. 1) Drève du Prince; 2) Sentier des Vallons des Chênes; 3) Sentier du Grasdelle; and, 4) Chemin du tir aux Pigeons. Created by ULB-LUBIES in R (v. 3.1.2).

The Cerambycidae family arouses keen interest for coleopterists who utilize various classical collection methods, such as net swapping, threshing low tree branches, collecting or rearing from woody material, light trapping, etc. (BERGER, 2012). Consolidation of the information regarding the Cerambycidae fauna in Belgium began with LAMEERE (1894) who assembled data preserved in collections in the Royal Belgian Institute of Natural Sciences (RBINS) or maintained in private collections of his eminent contemporaries such as CANDÈZE, KERREMANS, DE MOFFARTS, DE SELYS-LONGCHAMPS, etc. In this published revision of the cerambycid beetles from Belgium, 85 species were described. Almost one century later, MUYLAERT (1990) published a new synthesis, increasing the reported number of Cerambycidae to 115. More recently, DRUMONT *et al.* (2011) developed a website for saproxylic beetles from Belgium data to compile the Cerambycidae data from these collections as well as the dormant distribution data preserved in several private collections. Recorded Cerambycidae for the Belgian fauna increased to 123 species, including established non-native species. In Belgium, the use of baited traps is less widespread than in more southern European countries, mainly due to climatic conditions; and coloured, interception, window or emergence traps are used occasionally for specific faunistic studies. The use of baited traps has mainly been devoted to bark beetle (Curculionidae: Scolytinae) studies, whose pheromones are attractive to some Cerambycidae, and facilitated the detection of a new species record for Belgian fauna, *Acanthocinus griseus* (Fabricius, 1792) (WARZÉE & DRUMONT, 2004). The current extensive monitoring network for Cerambycidae in Belgium presents a compelling opportunity to verify and expand the records for Belgian cerambycid species composition and distribution. In this paper, we characterize the assemblage of Cerambycidae attracted to semiochemicals of *Monochamus* spp. in the Sonian Forest for 2013-2014.

Material and methods

Research was conducted in the Sonian Forest (50.7756 N, 4.4228 E), located in the south-eastern area of Brussels and covers approximately 4383 ha. It is a remnant of a large forest that is believed to have covered western Europe after the last Ice Age, and a wooded area for at least 5000 year BP. The Sonian Forest was originally an oak-hornbeam forest, dominated by *Quercus robur* and *Carpinus betulus*. It is now dominated by beech, *Fagus sylvatica* (85%), with minor components of oak, *Quercus robur*, and introduced conifer stands, comprised of *Pinus sylvestris*, *Larix decidua*, and *Picea abies* (8%). The forest ranges in altitude from 65 to 130 m a.s.l. The local climate is temperate and humid with a growing season of approximately seven months (April-October). Mean annual temperature is 9.9°C and mean annual precipitation is 835 mm (GODEFROID & KOEDAM, 2003).

One Teflon-coated cross-vane trap (Crosstrap®, Econex, Muria, Spain) (Fig. 1) was deployed in each of four *Pinus sylvestris* stands (Trap 1: Drève du Prince, trap 2: Sentier des Vallons des Chênes, trap 3: Sentier du Grasdelle, trap 4: Chemin du tir aux Pigeons) within the Sonian Forest (Fig. 2) from 18 June to 4 November 2013, and 30 April to 1 October 2014. Traps were suspended by rope from a branch of a non-host tree so that the base of the collection cup was approximately 0.5 m from the ground. To prevent excessive trap disturbance, traps were secured with a cord attached to a stake in the ground. Traps were baited with a four component commercially available lure, Galloprotect Pack® (SEDQ, Barcelona, Spain). Lures consisted of an aggregation pheromone of *Monochamus* spp., undecycolxy-1-ethanol (monochamol) (release rate: 2 mg/day); and kairomones: ipsenol, a pheromone of *Ips* spp. (Curculionidae: Scolytinae) (release rate: 2.5 mg/day) and 2-methyl-3-buten-1-ol (release rate: 10 mg/day), and a host-plant compound, α-pinene (release rate: 0.32 mg/day). Each lure component was placed at a specific height on one of the cross-vanes. The aggregation pheromone was attached in the upper section, α-pinene was attached in the center, and the kairomones were attached in the lower section (Fig. 1 a-c). Lures were replaced at 6 or 8 week intervals to ensure continuous delivery of volatiles.

Insect captures were collected at approximately two week intervals. A dry collection method was employed for the first two collecting periods in 2013 and insects were stored in 96% denatured ethanol prior to processing. Due to the high number of Silphidae (and associated mites) in the samples, a wet collection method was employed for the remainder of the season in 2013 and 2014. Approximately 250 ml monoethylene glycol was added to the wet collecting cup as a preservative. After processing, insects were stored in 96% denatured ethanol until identification. Identification of the Cerambycidae was confirmed at the Royal Belgian Institute of Natural Sciences, Brussels, Belgium, and voucher specimens deposited in its collection.

Table 1. Cerambycidae captured in *Pinus* spp. stands in the Sonian Forest, 2013, 2014.

Species	**Trap 1**		**Trap 2**		**Trap 3**		**Trap 4**	
	2013	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
***Monochamus* spp.**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Rhagium inquisitor (Linnaeus, 1758)	1	11	1	41	7	35	6	73
Arhopalus rusticus (Linnaeus, 1758)	3	3	9	4	17	5	10	1
Spondylis buprestoides (Linnaeus, 1758)	3	3	8	1	3	3	5	0
Rhagium mordax (De Geer, 1775)	1	2	0	0	0	5	0	1
Rutpela maculata (Poda, 1761)	1	2	1	0	0	2	0	1
Pogonocherus hispidus (Linnaeus, 1758)	0	0	0	0	1	0	0	0
Pogonocherus hispidulus (Piller & Mitterpacher, 1783)	0	0	0	0	2	0	0	0
Clytus arietis (Linnaeus, 1758)	0	0	0	1	0	0	0	0
Stenurella melanura (Linnaeus, 1758	0	0	0	0	0	0	0	1

Results

A total of 273 Cerambycidae in nine species belonging to the subfamilies Lepturinae Latreille, 1802, Spondylidinae Audinet-Serville, 1832, Cerambycinae Latreille, 1802 and Lamiinae Latreille, 1825 were captured in the Sonian Forest in 2013 and 2014 and are listed in Table 1. Although no *Monochamus* species were captured, three species: *Rhagium inquisitor* (Linnaeus, 1758) (Lepturinae),

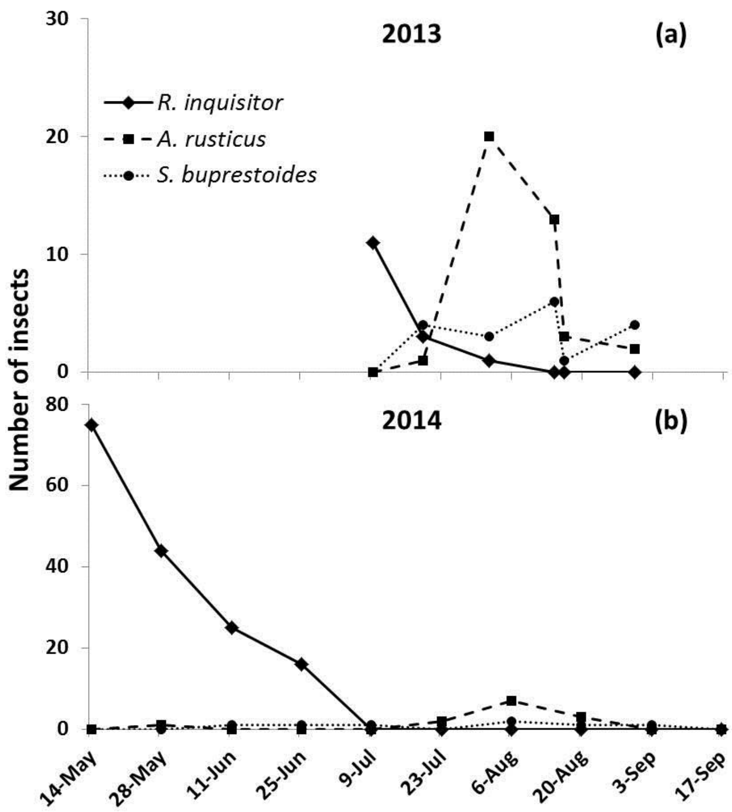


Fig. 3. Seasonal abundance of *Arhopalus rusticus*, *Rhagium inquisitor*, and *Spondylis buprestoides* in *Pinus* spp. stands in the Sonian Forest, 2013 (a) and 2014 (b).

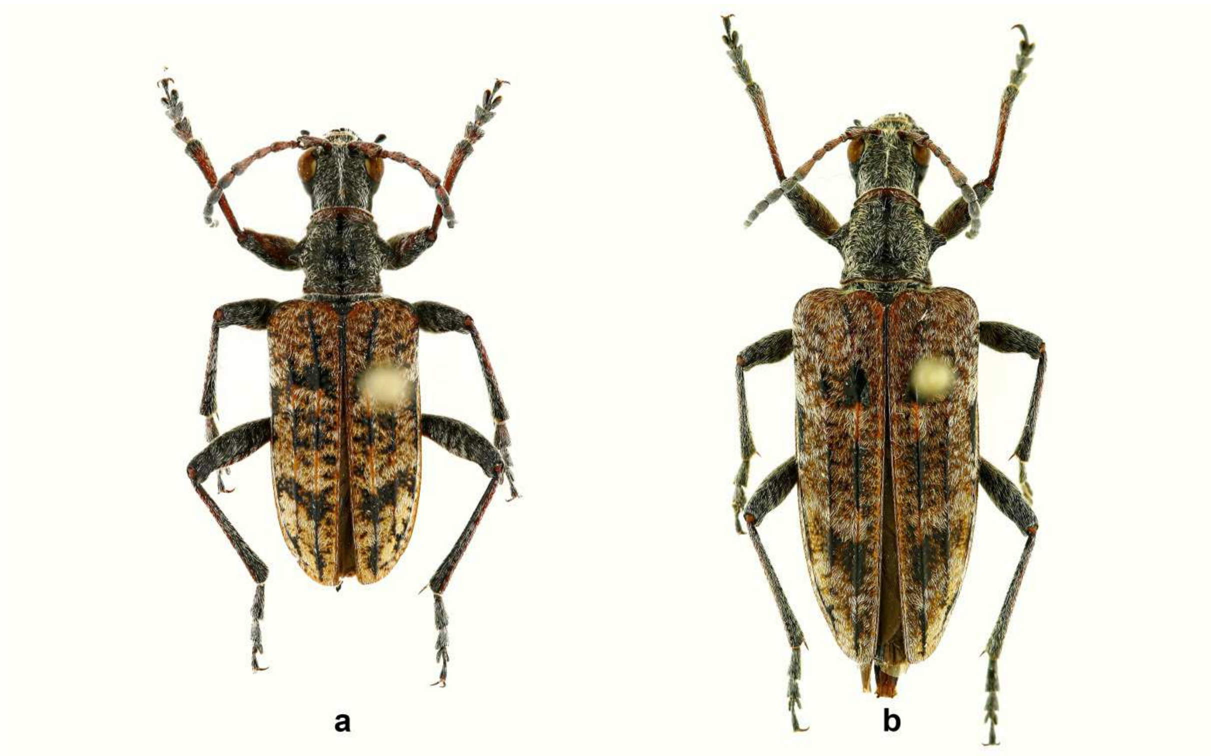


Fig. 4. *Rhagium inquisitor* (Linnaeus, 1758), habitus, dorsal view. a: male, 13 mm, b: female, 18.5 mm (pictures: S. Hanot) (size measured from the clypeus to the apex of the elytra).

Arhopalus rusticus (Linnaeus, 1758) (Spondylidinae) and *Spondylis buprestoides* (Linnaeus, 1758) (Spondylidinae), comprised 92.6% of the captures. These three species are considered to be attracted to the components of the Galloprotect Pack, therefore their distribution and life history will be described more thoroughly than other species.

Rhagium inquisitor was the most frequently captured cerambycid, comprising 64.1% of the total captured with a total of 175 specimens (2013: 15; 2014: 160). This species was most frequently captured in Trap 4 (Chemin du tir aux Pigeons) with 79 specimens, and its population likely peaked prior to the initiation of sampling (Fig. 3). *Rhagium inquisitor* (Fig. 4) is very common and widely distributed throughout most of Europe, becoming rare or absent in some southern countries (SAMA, 2002). The larvae feed, develop and eventually pupate in the subcortical tissues of conifers (*Pinus*, *Abies*, *Picea*, *Cedrus*, *Larix*), but are occasionally recorded in deciduous trees (*Betula*, *Fagus* and *Quercus*) (BENSE, 1995; BERGER, 2012). Adults overwinter under the bark in an oval cell composed of vegetal fibres and emerge in the spring to begin a flight period from March to July (MUYLAERT, 1990; BENSE, 1995; SAMA, 2002; BERGER, 2012). Adults are diurnal and fly or run on the trunks exposed to the sun, rarely on flowers (BENSE, 1995; SAMA, 2002; ALLEMAND *et al*., 2009, GOUVERNEUR & GUÉRARD 2011; BERGER, 2012). In 2013, the trapping period was initiated too late in the season (18 June) to capture the peak population flight period in this forest, while higher numbers of *R. inquisitor* were captured in 2014 due to sampling earlier in the season exhibiting flight activity trends corresponding to published records (Fig. 3).

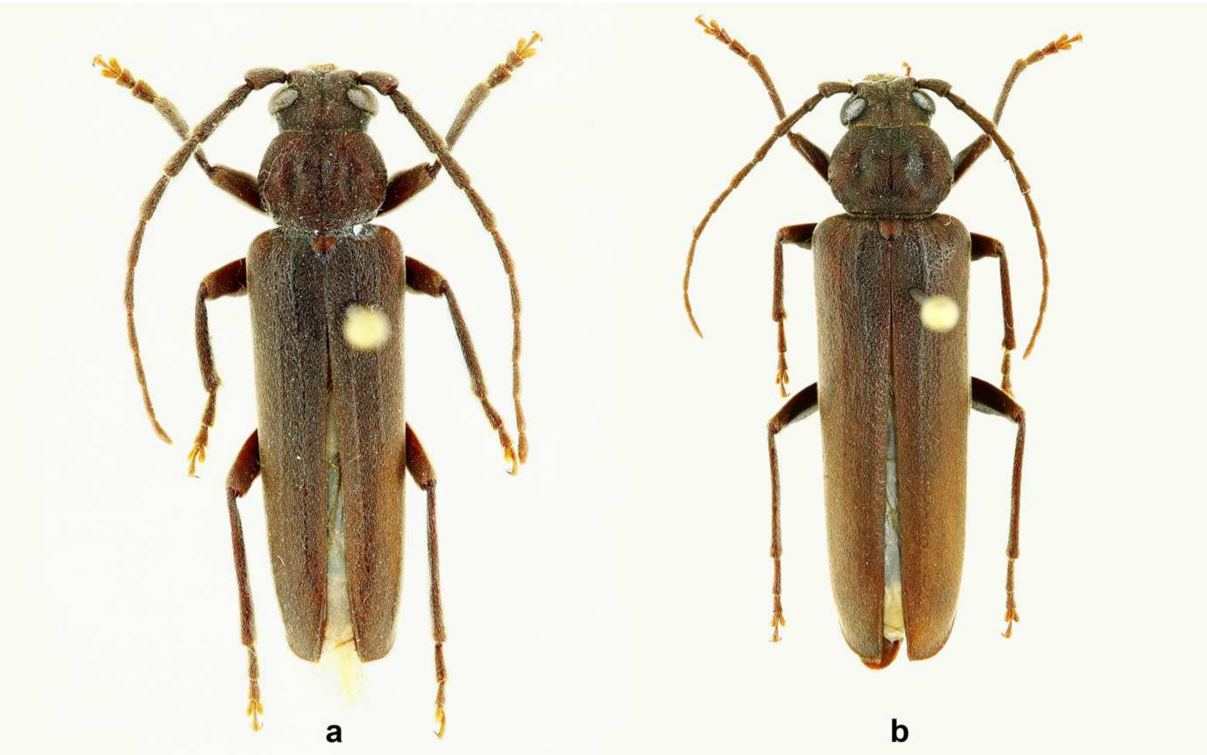


Fig. 5. *Arhopalus rusticus* (Linnaeus, 1758), habitus, dorsal view. a: male, 18.5 mm, b: female, 24 mm (pictures: S. Hanot).

Arhopalus rusticus (Fig. 5) was the second most frequently captured cerambycid comprising 19.0% of the total captured with 52 specimens (2013: 39; 2014: 13) and was most frequently captured in Trap 3 (Sentier de Grasdelle). This species is widespread throughout Europe from Fennoscandia to Sicily, and from France to Russia and European Kazakhstan (SAMA, 2002). In Belgium, *A. rusticus* was formerly restricted to Kempen (Lameere, 1894), but is now well distributed throughout the country (WARZÉE & DRUMONT, 2004; DRUMONT *et al.*, 2011) where it is primarily associated with *Pinus* species and less frequently with *Abies*, *Picea* and *Larix*. Eggs are laid on freshly killed fallen or standing trunks, stumps, and large branches (SAMA, 2002; WARZÉE & DRUMONT, 2004). Larvae first feed under the

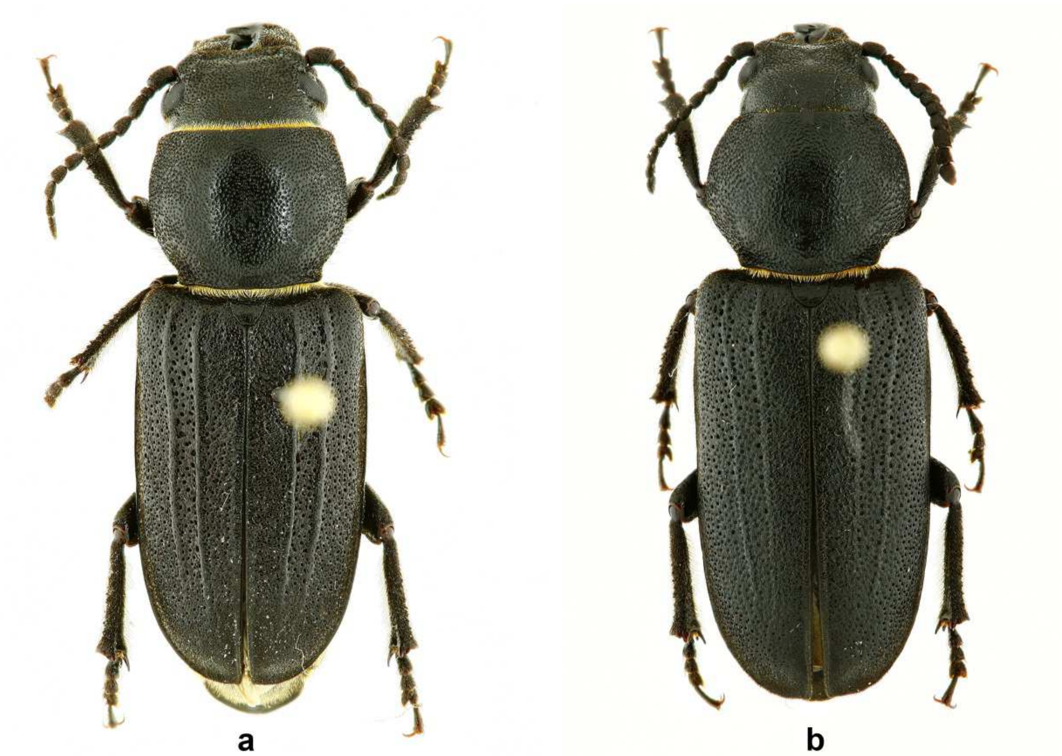


Fig. 6. *Spondylis buprestoides* (Linnaeus, 1758), habitus, dorsal view. a: male, 19 mm, b: female, 20 mm (pictures: S. Hanot).

bark and move into the sapwood as they mature (BENSE, 1995). Contrary to *R. inquisitor*, adults of *A. rusticus* are nocturnal, sometimes attracted to the light, and hide by day under the bark of dead standing trees or under fallen branches. Adults are active from June to September (MUYLAERT, 1990; BENSE, 1995; VINCENT, 1998; SAMA, 2002; ALLEMAND *et al*., 2009; BERGER, 2012), corresponding to our data, which shows peak population captures around 1 August in 2013 and 6 August in 2014 (Fig. 3). In spite of the extended sampling period in 2014, much fewer specimens of *A. rusticus* were captured than in 2013.

Spondylis buprestoides (Fig. 6) comprised 9.5% of the total captured with 26 specimens (2013: 19; 2014: 7) and was most frequently captured in Trap 2 (Sentiers des Vallons des Chiens) in 2013. This species is also widespread throughout Europe but becomes more localized in southern Europe. It is associated with predominantly *Pinus* species, rarely on *Abies*, *Picea*, *Cryptomeria*, *Chamaecyparis*, where larvae develop in dead roots, thick branches, stumps and large fallen trunks (BENSE, 1995; BERGER, 2012). Adults are mostly crepuscular (MUYLAERT, 1990; BENSE, 1995; SAMA, 2002) and sometimes attracted by light (VINCENT, 1998; SAMA, 2002; ALLEMAND *et al.*, 2009), but can be also seen flying in full sun around felled pine trunks (ALLEMAND *et al*., 2009, GOUVERNEUR & GUÉRARD, 2011; BERGER, 2012). Their flight period extends from May to August (SAMA, 2002; BERGER, 2012) and rarely to September (VINCENT, 1998), corresponding with the peak population captures around 14 August in 2013. In spite of the extended sampling period in 2014, fewer *S. buprestoides* were captured and showed no seasonal trend (Fig. 3).

The remaining six species: *Rhagium mordax* (Fig. 7), *Rutpela maculata* (Fig. 8), *Stenurella melanura*, *Clytus arietis*, *Pogonocherus hispidus* (Fig. 9), and *Pogonocherus hispidulus* (Fig. 10) were captured infrequently, comprising only 7.4% of the total captures in 2013 and 2014 (Table 1), and were likely incidental captures or present in very low densities. Most of these species are polyphagous on dead or rotting deciduous trees as larvae, while adults visit flowers or simply fly within the coniferous stands where the traps were deployed.

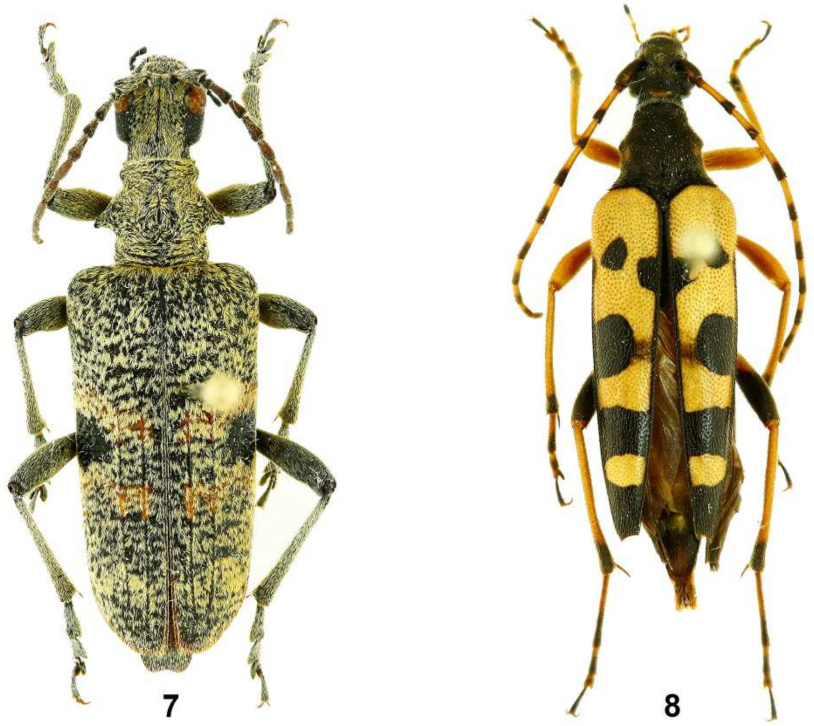


Fig. 7. *Rhagium mordax* (De Geer, 1775), habitus, dorsal view, 20.5 mm (picture: S. Hanot).
Fig. 8. *Rutpela maculata* (Poda, 1761), habitus, dorsal view, 17 mm (picture: S. Hanot).

Fig. 9. *Pogonocherus hispidus* (Linnaeus, 1758), habitus, dorsal view, 4.5 mm (picture: S. Hanot).
Fig. 10. *Pogonocherus hispidulus* (Piller & Mitterpacher, 1783), habitus, dorsal view, 8 mm (picture: S. Hanot).

Discussion

Rhagium inquisitor, *Arhopalus rusticus* and *Spondylis buprestoides* were collected in each of the four traps in 2013 and 2014 (Table 1) suggesting a homogenous distribution within the coniferous stands sampled in the Sonian forest. Two species, *A. rusticus* and *S. buprestoides*, were considered rare in Belgium based on examination of collections at the RBINS since the 1830's and of several Belgian private collections (110 and 131 records respectively in Belgium until 2013 (DRUMONT *et al.,* 2011 - accession date 20.2.2015)). Our data suggests that these species have stable populations within the Sonian Forest and their current status in Belgium is a reflection of their life habits (crepuscular and nocturnal) and trapping systems utilized for their detection. There was also annual variation in the number of cerambycids captured. Captures of *R. inquisitor* were higher in 2014 than 2013 likely due to the expansion of the sampling period into the spring and early summer when *R. inquisitor* adults emerge and their activity is higher. This species is a typical example of species range expansion into Belgium facilitated by the increase in coniferous plantations during the past century. Population densities have been increasing based on records before 1950 (17 records), from 1950-1980 (28 records) and after 1980 (112 records) (DRUMONT *et al.*, 2011), similar to the trend in the "île de France" region in France (VINCENT, 1998).

Both *A. rusticus* and *S. buprestoides* adults are active in the summer, however, both species were captured in lower numbers in 2014 than 2013 in spite of this extended sampling period. It is unknown if the variation in their densities are an effect of the availability of suitable hosts or environmental factors, but it is more probable that this variability is an artefact of the voltinism of the species: *A. rusticus* requires 2-3 years per generation (BENSE, 1995; BERGER, 2012) while *S. buprestoides* requires several years (BENSE, 1995), commonly 3-4, to reach adulthood. By comparison, *R. inquisitor* only requires 2 years (BENSE, 1995).

Insects that occupy the same guild often utilize similar olfactory cues to locate suitable habitats and hosts, therefore, a monitoring system that employs multiple volatile sources of attraction will likely attract a range of species within that habitat. No other Lamiinae species other than *Monochamus* have been shown to be attracted to monochamol (PAJARES *et al.*, 2010; TEALE *et al.*, 2011), consequently the attraction of the predominant cerambycids captured in this study is likely due to the other components in the Galloprotect Pack lure. Most cerambycids specialize on host material in a specific physiological condition (LINSLEY, 1959; HANKS, 1999), therefore rapid host location and assessment is likely mediated by changes in host chemical composition (ALLISON *et al.*, 2004; FAN *et al.*, 2007). Woodborers infesting dying conifers are attracted to host odours (PHILLIPS *et al.*, 1988), such as *S. buprestoides*, which are attracted to resin volatiles of freshly cut trees (ALLEMAND *et al.*, 2009; GOUVERNEUR & GUÉRARD, 2011; BERGER, 2012). All three main species in this study colonize the basal area of the stem of weak and dying conifers, preferring Scots pine, *P. sylvestris*. The attraction of wood-borers and bark beetles to their pheromones and other attractive host compounds is often synergized by α-pinene (MILLER, 2006; ALLISON *et al.*, 2012), the predominant monoterpene in pines (SMITH, 2000) and the most attractive individual monoterpene to woodborers (IKEDA *et al.*, 1986; CHÉNIER & PHILOGÈNE, 1989). The two Spondylidinae species, *A. rusticus* and *S. buprestoides*, are attracted to α-pinene alone or in combination with ethanol (MILLER, 2006; JURC *et al.*, 2012).

Coniferous wood borers often colonize the same hosts as coniferous bark beetles (DAHLSTEN & STEPHEN, 1974; STEPHEN & DAHLSTEN, 1976). The kairomonal response of woodborers to bark beetle pheromones is an adaptive measure to host seeking, facilitating multiple relationships. Co-habiting woodborers and bark beetles undergo resource competition within the host (COULSON *et al.*, 1976), yet, bark beetles are usually first to arrive at a susceptible host, thereby facilitating commensalism by expanding the resource base for woodborers (FLAMM *et al.*, 1989). Woodborer larvae also perform intraguild predation on bark beetle larvae, receiving an additional nutritional resource (DODDS *et al.*, 2001). Pheromones from the *Ips* genus, such as ipsenol and ipsdienol, are more attractive than those of *Dendroctonus* (MAYER & MCLAUGHLIN, 1991; ALLISON *et al.*, 2003; SEYBOLD & VANDERWEL, 2003), and ipsenol has been shown to be the most attractive to *M. galloprovincialis* (PAJARES *et al.*, 2004; IBEAS *et al.*, 2007). Several specimens of *A. rusticus* have been captured at the base of standing spruce trunks recently mass attacked by *Ips typographus* (Linnaeus, 1758) (WARZÉE & DRUMONT, 2004), of which methyl butenol and ipsenol are essential pheromone components (VITÉ *et al.*, 1972; BAKKE *et al.*, 1977). The Lepturinae species, *R. inquisitor*, is attracted to the combination of quaternary lure including ethanol, α-pinene, ipsenol and ipsdienol more than binary lures consisting of only ethanol and α-pinene (ALLISON *et al.*, 2003; MILLER *et al.*, 2011). This species also had the greatest response to bottle traps baited with Pheroprax, racemic ipsdienol and exo-brevicomin (WARZÉE & DRUMONT, 2004). The ability of cerambycids to respond to both bark beetle pheromones and host volatiles could minimize energy spent in foraging to locate hosts, exposure to natural enemies, and other biologically important activities in presence/absence of mass attack of primary and secondary bark beetles (ALLISON *et al.*, 2001).

Although no *Monochamus* species were captured in the Sonian Forest and *Pinus* species constitutes a very minor component, a risk of PWN introduction remains possible. The PWN has a co-evolutionary history with *Monochamus* species, and *Monochamus* is considered the only true vector of PWN. However, PWN has been found on other conifer-infesting species in Cerambycidae and Curculionidae. These interactions are likely due to their co-habitation with *Monochamus* or colonizing a tree infected by PWN. In the U.S.A., 88% of *A. rusticus* beetles contained no PWN (LINIT *et al.*, 1983) and the remainder had less than 300 nematodes. A survey in Spain found no PWN on captured *A. rusticus* or *R. inquisitor* beetles, but a few specimens of related species, *Arhopalus ferus* and *Rhagium bifasciatum*, were found carrying PWN (ROBERTSON *et al.*, 2008), and both species have been recorded in Belgium (DRUMONT *et al.*, 2011). This same survey showed PWN under the elytra of *S. buprestoides*, and furthermore, in Japan *S. buprestoides* has been found carrying PWN (KOBAYASHI *et al.*, 1984) but the extent to which it contributes to its spread is unknown. In most cases, the amount of PWN present on the insect was not determined, therefore it remains unknown if these alternate potential vectors present a threat. Although timber infested by these species has little commercial value due to feeding damage by larvae or introduction of fungi, these insects are decomposers and play a beneficial role in the natural functioning of the forest ecosystem. However, monitoring for potential PWN contamination and their vectors should continue at some level and our study provides support for the use of the Crosstrap and Galloprotect Pack for effective detection of multiple species of conifer-inhabiting bark and wood-boring beetles in Belgium which could potentially carry PWN.

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References

ALLEMAND R, DAZLMON J., PUPIER R., ROZIER Y. & MARENGO V., 2009. - *Coléoptères de Rhône-Alpes - Cerambycidae*. Musée des Confluences, 351 pp.

ALLISON J.D., BORDEN J.H., MCINTOSH R.L., DE GROOT P. & GRIES R., 2001. - Kairomonal response by four *Monochamus* species (Coleoptera: Cerambycidae) to bark beetle pheromones. *Journal of Chemical Ecology*, 27: 633-646.

ALLISON J.D., MOREWOOD W.D., BORDEN J.H., HEIN K.E. & WILSON I.M., 2003. - Differential bio-activity of *Ips* and *Dendroctonus* pheromone components for *Monochamus clamator* and *M. scutellatus* (Coleoptera: Cerambycidae). *Environmental Entomology*, 32: 23-30.

ALLISON J.D., BORDEN J.H. & SEYBOLD S.J., 2004. - A review of the chemical ecology of the Cerambycidae (Coleoptera). *Chemoecology*, 14: 123-150.

ALLISON J.D., MCKENNEY J.L., MILLAR J.G., MCELFRESH J.S., MITCHELL R.F. & HANKS L.M., 2012. - Response of the woodborers *Monochamus carolinensis* and *Monochamus titillator* (Coleoptera: Cerambycidae) to known cerambycid pheromones in the presence and absence of the host plant volatile α-pinene. *Environmental Entomology*, 41: 1587-1596.

ALVAREZ G., ETXEBESTE I., SÁNCHEZ E., GALLEGO D. & PAJARES J.A., 2013. - Effective traps for live trapping of PWN vectors *Monochamus* spp. *In:* SCHRÖDER, T. (ed.), Pine Wilt Disease Conference 2013, pp. 14-16, Braunschweig, ISSN: 1866-590X.

BAKKE A., FRĂYEN P. & SKATTEBĂL L., 1977. - Field response to a new pheromone compound isolated from *Ips typographus*. *Die Naturwissenschaften*, 64: 98-99.

BENSE U., 1995. - *Longhorn Beetles. Illustrated key to the Cerambycidae and Vesperidae of Europe*. Weikersheim, Margraf Verlag, 512 pp.

BERGDAHL D.R., 1988. - Impact of pinewood nematode in North America. *Journal of Nematology,* 20: 260-265.

BERGER P., 2012. - *Coléoptères Cerambycidae de la Faune de France continentale et de Corse*. Edition de l’Association Roussillonnaise d’Entomologie, 664 pp.

BONIFÁCIO L., PRAIAS F. & SOUSA E., 2012. - Trapping *Monochamus galloprovincialis* (Coleoptera: Cerambycidae), vector of the pine wood nematode, with pine allelochemicals, in Portugal. *Silva Lusitana,* 20: 39-53.

CHÉNIER J.V.R. & PHILOGÈNE B.J.R., 1989. - Field responses of certain forest Coleoptera to conifer monoterpenes and ethanol. *Journal of Chemical Ecology*, 15: 1729-1745.

COULSON R.N., MAYYASI A.M., FOLTZ J.L. & HAIN F.P., 1976. - Interspecific competition between *Monochamus titillator* and *Dendroctonus frontalis*. *Environmental Entomology*, 5: 235-247.

DAHLSTEN D.L. & STEPHEN F.M., 1974. - Natural enemies and insect associates of the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae), in sugar pine. *The Canadian Entomologist*, 106: 1211-1217.

DODDS K.J., GRABER C. & STEPHEN F.M., 2001. - Facultative intraguild predation by larval Cerambycidae (Coleoptera) on bark beetle larvae (Coleoptera: Scolytidae). *Environmental Entomology*, 30: 17-22.

DRUMONT A., KERKHOF S. & GROOTAERT P., 2011. - Saproxylic beetles from Belgium, online distribution maps of species (Coleoptera) (http://projects.biodiversity.be/beetles/).

DWINELL L.D. & NICKLE W.R., 1989. - An overview of the pine wood nematode ban in North America. *General Technical Report SE-55*. USDA Forest Service, Southeast Forest Experimental Station, Asheville, NC., 13 pp.

FAN J., SUN J. & SHI J., 2007. - Attraction of the Japanese pine sawyer, *Monochamus alternatus*, to volatiles from stressed host in China. *Annals of Forest Science*, 64: 67-71.

FIERKE M.K., SKABEIKIS D.D., MILLAR J.G., TEALE S.A., MCELFRESH J.S. & HANKS L.M., 2012. - Identification of a male-produced aggregation pheromone for *Monochamus scutellatus* scutellatus and an attractant for the congener *Monochamus notatus* (Coleoptera: Cerambycidae). *Journal of Economic Entomology*, 105: 2029-2034.

FLAMM R.O., COULSON R.N., BECKLEY P., PULLEY P.E. & WAGNER T.L., 1989. - Maintenance of a phloem-inhabiting guild. *Environmental Entomology*, 18: 381-387.

FVO: Food and Veterinary Office, 2008. - Final report of a mission carried out in Portugal from 02 June to 06 June 2008 in order to assess the implementation of Commission decision 2006/133/EC and the national eradication programme for *Bursaphelenchus xylophilus* (Pine wood nematode). DG SANCO/2008/7991-MR-Final.

GODEFROID S. & KOEDAM N., 2003. - Distribution pattern of the flora in a peri-urban forest: an effect of the city–forest ecotone. *Landscape and Urban Planning*, 65: 169-185.

GOUVERNEUR X. & GUÉRARD P., 2011. - Les longicornes armoricains. Invertébrés armoricains. *Les Cahiers du GRETIA*, 7: 1-224.

HANKS L.M., PAINE T.D., MILLAR J.G., CAMPBELL C.D. & SCHUCH U.K., 1999. - Water relations of host trees and resistance to the phloem boring beetle *Phoracantha semipunctata* F. (Coleoptera: Cerambycidae). *Oecologia*, 119: 400-407.

HUMBLE L.M. & ALLEN E.A., 2006. - Forest biosecurity: alien invasive species and vectored organisms. *Canadian Journal of Plant Pathology*, 28: S256-S269.

IBEAS F., GALLEGO D., DIEZ J.J. & PAJARES J.A., 2007. - An operative kairomonal lure for managing pine sawyer beetle *Monochamus galloprovincialis* (Coleoptera: Cerymbycidae). *Journal of Applied Entomology*, 131: 13-20.

IKEDA T., YAMANE A., ENDA N., ODA K., MAKIHARA H., ITO K. & OKOCHI I., 1986. - Attractiveness of volatile components of felled pine trees for *Monochamus alternatus* (Coleoptera: Cerambycidae). *Journal of Japanese Forest Society*, 68: 15-19 (in Japanese).

JURC M., BOJOVIC S., FERNÁNDEZ M.F. & JURC D., 2012. - The attraction of cerambycids and other xylophagous beetles, potential vectors of *Bursaphelenchus xylophilus*, to semio-chemicals in Slovenia. *Phytoparasitica*, 40: 337-349.

KOBAYASHI F., YAMANE A. & IKEDA T., 1984. - The Japanese pine sawyer beetle as the vector of pine wilt disease. *Annual Review of Entomology*, 29: 115-135.

LAMEERE A., 1894. - Révision du catalogue des Longicornes de la Belgique. *Annales de la Société Entomologique de Belgique*, 38: 294-309.

LINIT M.J., KONDO E. & SMITH M.T., 1983. - Insects associated with the pinewood nematode, *Bursaphelenchus xylophilus* (Nematoda: Aphelenchoididae), in Missouri. *Environmental Entomology*, 12: 467-470.

LINIT M.J., 1988. - Nematode-vector relationships in the pine wilt disease system. *Journal of Nematology*, 20: 227-235.

LINSLEY E.G., 1959. - Ecology of Cerambycidae. *Annual Review of Entomology*, 4: 99-138.

MAYER S. & MCLAUGHLIN J.R., 1991. - *Handbook of insect pheromones and sex attractants*. USA, Florida, Boca Raton: CRC Press. 1083 pp.

MILLER D.R., 2006. - Ethanol and (-)-α-pinene: attractant kairomone for some large wood-boring beetles in southeastern USA. *Journal of Chemical Ecology*, 32: 779-794.

MILLER D.R., ASARO C., CROWE C.M. & DUERR D.A., 2011. - Bark beetle pheromones and pine volatiles: attractant kairomone lure blend for longhorn beetles (Cerambycidae) in pine stands of the southeastern United States. *Journal of Economic Entomology*, 104: 1245-1257.

MOTA M., BRAASCH H., BRAVO M.A., PENAS A.C., BURGERMEISTER W., METGE K. & SOUSA E., 1999. - First report of *Bursaphelenchus xylophilus* in Portugal and in Europe. *Nematology*, 1: 727-734.

MUYLAERT A., 1990. - *Faune de Belgique – Longicornes (Cerambycidae)*. Version française traduite par G. Coulon. Institut royal des Sciences naturelles de Belgique, Rue Vautier, Bruxelles, 139 pp.

NAVES P.M., CAMACHO S., DE SOUSA E.M. & QUARTAU J.A., 2007. - Transmission of the pine wood nematode *Bursaphelenchus xylophilus* through feeding activity of *Monochamus galloprovincialis* (Col., Cerambycidae). *Journal of Applied Entomology*, 131: 21-25.

PAJARES J.A., IBEAS F., DÍEZ J.J. & GALLEGO D., 2004. - Attractive responses by *Monochamus galloprovincialis* (Col., Cerambycidae) to host and bark beetle semiochemicals. *Journal of Applied Entomology*, 128: 633-638.

PAJARES J.A., ALVAREZ G., IBEAS F., GALLEGO D., HALL D.R. & FARMAN D.I., 2010. - Identification and field activity of a male-produced aggregation pheromone in the pine sawyer beetle, *Monochamus galloprovincialis*. *Journal of Chemical Ecology*, 36: 570-583.

PHILLIPS T.W., WILKENING A.J., ATKINSON T.H., NATION J.L., WILKINSON R.C. & FOLTZ J.L., 1988. - Synergism of turpentine and ethanol as attractants for certain pine-infesting beetles (Coleoptera). *Environmental Entomology*, 17: 456-462.

ROBERTSON L., GARCÍA-ÁLVAREZ A., ARCOS S.C., DÍEZ-ROJO M.A., MANSILLA J.P., MARTINEZ C., ESCUER M.L., CASTESANA L., NOTARIO A., BELLO A. & ARIAS M., 2008. - Potential insect vectors of *Bursaphelenchus* spp.(Nematoda: Parasitaphelenchidae) in Spanish pine forests. *In*: *Pine Wilt Disease: A Worldwide Threat to Forest Ecosystems* (pp. 221-234). Springer Netherlands. 428 pp.

SAMA G., 2002. - *Atlas of the Cerambycidae of Europe and the Mediterranean area. Volume 1*. Nekladatelstvi Kabourek, Zlin, 173 pp.

SEYBOLD S. J., & VANDERWEL D., 2003. - Biosynthesis and endocrine regulation of pheromone production in the Coleoptera. In: *Insect Pheromone Biochemistry and Molecular Biology*, (pp. 137-200). Academic Press. 768 pp.

SMITH R.H., 2000. - Xylem monoterpenes of pines: distribution, variation, genetics, function. *USDA General Technical Report PSW-GTR-177*, Albany, CA. 454 pp.

STEINER G. & BUHRER E.M., 1934. - *Aphelenchoides xylophilus* n. sp., a nematode associated with bluestain and other fungi in timber. *Journal of Agricultural Research*, 48: 949-51.

STEPHEN F.M. & DAHLSTEN D.L., 1976. - The arrival sequence of the arthropod complex following attack by *Dendroctonus brevicomis* (Coleoptera: Scolytidae) in ponderosa pine. *The Canadian Entomologist*, 108: 283-304.

TEALE S.A., WICKHAM J.D., ZHANG F., SU J., CHEN Y., XIAO W., HANKS L.M. & MILLAR J.G., 2011. - A male-produced aggregation pheromone of *Monochamus alternatus* (Coleoptera: Cerambycidae), a major vector of pine wood nematode. *Journal of Economic Entomology*, 104: 1592-1598.

TOGASHI K. & JIKUMARU, S., 2007. - Evolutionary change in a pine wilt system following the invasion of Japan by the pinewood nematode, *Bursaphelenchus xylophilus*. *Ecological Research*, 22: 862-868.

VINCENT R., 1998. - *Catalogue des Coléoptères de l'Ile de France – Fascicule VII: Cerambycidae*. Supplément au Bulletin de Liaison de l'ACOREP, No 32. Association des coléoptéristes de la région Parisienne (ACOREP), 108 pp.

VITÉ J.P., BAKKE A. & RENWICK J.A., 1972. - Pheromones in *Ips* (Coleoptera: Scolytidae): occurrence and production. *The Canadian Entomologist*, 104: 1967-1975.

WARZÉE N. & DRUMONT A., 2004. - Contribution à l'étude des longicornes de l'Ardenne avec la découverte d'une nouvelle espèce pour la Belgique: *Acanthocinus griseus* (Fabricius) (Coloptera, Cerambycidae). *Lambillionea*, CIV, 1: 45-57.

ZHAO L., MOTA M., VIEIRA P., BUTCHER R.A., & SUN J., 2014. - Interspecific communication between pinewood nematode, its insect vector, and associated microbes. *Trends in Parasitology*, 30: 299-308.