J Pest Sci (2004) 77: 57–63
DOI 10.1007/s10340-003-0030-5

ORIGINAL ARTICLE

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Abundance and distribution of *Xylosandrus germanus* (Blandford 1894) (Coleoptera, Scolytidae) in Belgium: new observations and an attempt to outline its range

Received: 1 September 2003 / Published online: 15 January 2004

Abstract In Belgium, the current distribution and abundance of *Xylosandrus germanus* (Coleoptera, Scolytidae), a relatively new species to the Belgian fauna, is poorly known. Therefore, data on the range and population levels of this ambrosia beetle, on a regional and local scale respectively, are presented. Based on those results, the beetles' range is discussed. Among the analysed biotic and abiotic factors that could influence the species' settlement and population levels, climatic ones, and temperature in particular, seem to exert a crucial influence.

Keywords *Xylosandrus germanus* · Scolytidae · Belgium · Forest pest

Introduction

Accidentally introduced in Europe about 50 years ago, *Xylosandrus germanus* (Blandford 1894) originates from eastern Asia. In Belgium, it was first recorded in 1994 in the central part of the country, 10 km north-east of Brussels (Bruge 1995). One year later, the beetle was observed in the Forêt de Soignes (Decelle 1995), a 4,000 ha beech (*Fagus sylvatica*) stand located in the south of Brussels. According to Bruge (1995), the presence of *X. germanus* near the Belgian capital probably reflected its relatively wide distribution in the country. Since that time, however, new information on the distribution and abundance of *X. germanus* in Belgium has been clearly missing.

According to several authors (Maksymov 1987; Bruge 1995), *X. germanus* is a secondary pest in Europe, only attacking physiologically weakened trees. In this region, however, the economic importance of the species recently increased. During the last 20 years, damage caused by *X. germanus* was reported on *Fagus* spp., *Quercus* spp. (Maksymov 1987), *Juglans regia* (Stergulc et al. 1999; Faccoli 2000), *Picea abies*, *Pinus sylvestris* and *Abies alba* (Graf and Manser 1996, 2000). Many tree species are thus susceptible to be attacked by this beetle. Accordingly, considering the decline affecting several of the most common tree species present in western Europe (e.g. Nageleisen 1994) and their subsequent sensitivity to insect and fungus attacks, some authors consider *X. germanus* as a potential pest in Belgian forests (Grégoire 2002, personal communication).

Consequently, even if it does not appear to be a major threat in Belgium, biogeographical data on *X. germanus* are of practical interest for forest managers. Here, we present additional information on the regional distribution and on the local abundance of this species in Belgium. We also relate these data to biotic and abiotic factors potentially governing the settlement of *X. germanus* populations, in order to identify the factors underlying our observations.

Materials and methods

Abundance of *X. germanus* in the Forêt de Soignes

Free-hanging unbaited flight barrier traps are particularly suitable to objectively assess the composition and structure of scolytid communities (Martikainen et al. 1999), notably because the captures are not dependent on the bait type, nor on its release rate. Eight of these traps were set in two stands of the Forêt de Soignes (sites 6 and 6′ in Table 1 and Fig. 1), about 7 km apart, from March to September 2002. In each stand, the sampling device consists of four traps set on each of two 100 m long perpendicular transepts crossing in the middle of each other. The traps were made of two perpendicular

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Table 1 List of sites where *Xylosandrus germanus* has been recently observed in Belgium

Reference in Fig. 1	Name of the forest (nearest town or village*)	Altitude (m)	Stand composition	Population level of *X. germanus*	Data collected by
1	Wijnendalebos (Torhout)	25	Mixed hardwood forest	Unknown	Versteirt in 2000
2	Beiaardbos (Ronse)	50	Mixed hardwood forest dominated by beech trees	High	Versteirt in 2000
3	Forêt domaniale de Stambruges	70	Mixed hardwood / softwood forest dominated by beech trees	High	Henin in 2001
4	Bois de Baudour (Mons)	100	Mixed hardwood forest	Unknown	N. Huart in 2002
5	Bois d'Enghien (Silly)	110	Mixed hardwood forest dominated by beech trees	High	Henin in 2001
6 and 6′	Forêt de Soignes (Brussels)	115	Mixed hardwood forest dominated by beech trees	High	Henin in 2002
7	Meerdaalwoud (Leuven)	80	Mixed hardwood forest dominated by oak trees	High	Versteirt in 1999
8	Rodebos (Sint-Agatha-Rode)	40	Mixed hardwood forest	Unknown	Versteirt in 2000
9	Bois de Bu (Gembloux)	170	Mixed hardwood forest	Unknown	Henin in 2003
10	Kolmont (Tongeren)	105	Mixed hardwood forest dominated by beech trees	Unknown	Versteirt in 1999
11	Bois de la Princelle (Solre-sur-Sambre)	190	Mixed hardwood forest dominated by beech trees	Unknown	Henin in 2001
12	Bois de Châtelet	200	Mixed hardwood forest	Unknown	Henin in 2001
13	Forêt de Marche-les-Dames	180	Mixed hardwood forest dominated by beech trees	Unknown	Henin in 2001
14	Bois d'Ohey	260	Mixed harwood / softwood forest dominated by beech trees	Unknown	Henin in 2001
15	Bois de la Vequée (Boncelles)	240	Young beech stand	Unknown	Henin in 2001
16	Bois de Pinsonchamp (Hamoir)	240	Young beech stand	Unknown	Henin in 2001
17 and 17′	La Gileppe (Goé)	340	Mixed harwood / softwood forest	Unknown	Resp. Y. Thieren in 2000 and Henin in 2001
18	Mülenbusch (Raeren)	320	Mixed hardwood forest dominated by oak trees	High	Henin in 2002
19	Bois de Renonceau (Florenne)	300	Mixed hardwood forest dominated by beech trees	Unknown	Henin in 2001
20	Bois de Cerfontaine	270	Mixed hardwood forest dominated by beech trees	Unknown	Henin in 2001
21	Bois Rousseau (Virelle)	260	Mixed hardwood forest dominated by beech trees	Unknown	Henin in 2001
22	Bois de Matignolles (Treignes)	240	Mixed hardwood forest dominated by beech trees	Unknown	Henin in 2001
23	Fosse-Piraux (Oignies-en-Thiérarche)	360	Mixed hardwood forest dominated by beech trees	Unknown	Henin in 2001
24	Fond des Vaux (Rochefort)	240	Mixed harwood / softwood forest dominated by beech trees	Unknown	Henin in 2001
25	Banalbois (Wavreille)	220	Mixed harwood / softwood forest dominated by beech trees	Unknown	Henin in 2001
26	Bois de Bestin (Wellin)	400	Mixed hardwood forest dominated by beech trees	Low	Henin in 2001
27	Forêt de Saint-Hubert	350	Mixed hardwood forest dominated by beech trees	Low	Henin in 2001
28	Bois de Walinsart (Williers, France)	320	Mixed hardwood forest dominated by beech trees	Unknown	Henin in 2001
29	Trimetrichet (Saint-Léger)	300	Mixed hardwood forest dominated by beech trees	Unknown	Henin in 2002

*When not in the forest name

Plexiglas panels 40×60 cm high and hung 1.5 m above ground level. Catches were checked monthly.

Distribution of *X. germanus* in Belgium

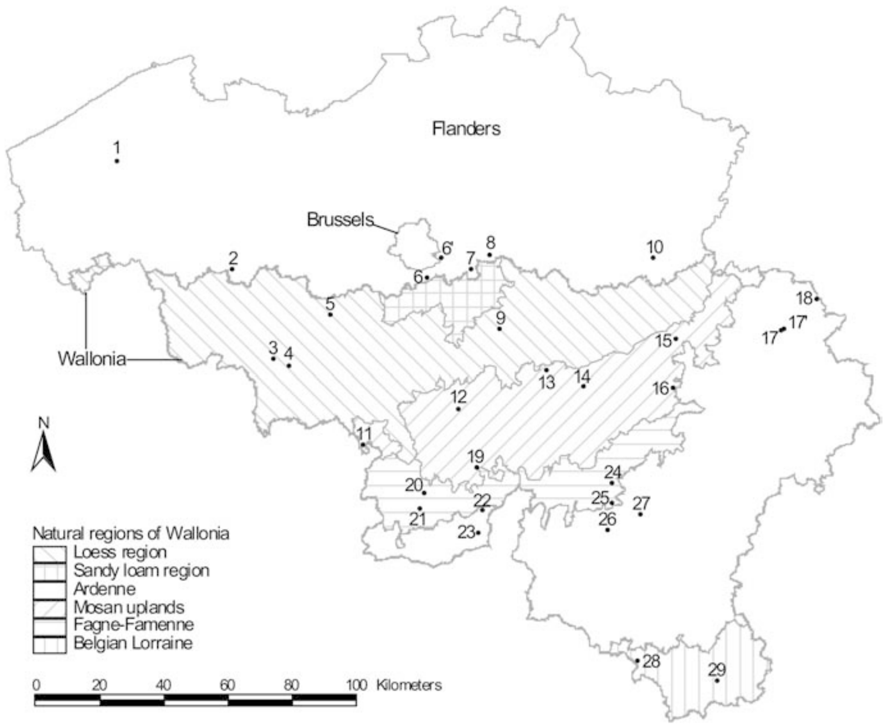
Information on the beetles' distribution in Belgium was gathered from representative entomological collections (Royal Belgian Institute for Natural Sciences, University of Gembloux), enquiries sent to amateur coleopterologists, and the unpublished results of several studies in which the authors have participated.

Results and discussion

Abundance of *X. germanus* in the Forêt de Soignes

The captures revealed that in both sampled parts of the forest *X. germanus* is now the most abundant scolytid. With 93 and 70 individuals caught in stand 6 and 6′

Fig. 1 Location of 29 stands where *Xylosandrus germanus* has been recently recorded in Belgium



respectively, *X. germanus* represented 37 and 47% of the captures (the total number of scolytids that were caught is 251 and 149 respectively). These data concern only one year of observations and, as scolytid population levels may show high year-to-year variations, our results evidently need to be confirmed by other surveys. Nevertheless, in the samples collected with ethanol-baited traps for a study realised in 2001 (Gregoire et al 2001), *X. germanus* was also the most abundant scolytid in the Forêt de Soignes. In this forest, according to our captures, its main potential competitors (among scolytids) are *Taphrorychus bicolor* (Herbst 1793), *Trypodendron domesticum* (L.), *Trypodendron signatum* (Fabricius 1787), *Ernopocerus fagi* (Fabricius 1778), *Xyleborus saxeseni* (Ratzeburg 1837) and *Xyleborus dispar* (Fabricius 1792); all these native species occasionally or usually breed in beech wood in the early stages of decay (Balachowsky 1949), the main resource exploited by *X. germanus* in the Forêt de Soignes. The predominance of this exotic species is thus remarkable. Indeed, some of the indigenous species are specialised on a particular type of substrate; e.g. *Ernopocerus fagi* only colonises branches less than 8 cm in diameter (Lekander et al. 1977). This specialisation contributes to the ecological isolation of the native species. Altogether, however, the native species exploit resources belonging to all diameter categories (from smaller branches to larger trunks). In spite of a niche overlap with several of the native species, *X. germanus* apparently does not suffer seriously from competition with the native scotylids, since in the Forêt de Soignes it can be found on all types of substrates: stumps, small branches, limbs and logs (although elements less than 10 cm in diameter are preferentially colonised, Bruges 1995; personal observations.). Accordingly, Zach et al. (2001) report a negligible effect of log diameter on *X. germanus* densities in bole diameter ranges of 19–33 and 33–38 cm. This relative non-dependence on resource size attests to the competitiveness of *X. germanus* with regard to indigenous bark and ambrosia beetles.

Distribution of *X. germanus* in Belgium

Sites where *X. germanus* was recently caught are listed in Table 1. This table also presents some characteristics of the stands where the beetles were captured. In Table 1, the population level is given only when the sampling method allowed its assessment (several unbaited or ethanol-baited window traps). Otherwise, it is considered as unknown. Population levels were considered ‘‘high’’ when several tens of individuals were present in the captures.

The location of the observation sites is reported in Fig. 1.

As shown in Fig. 1, *X. germanus* was caught all over southern Flanders (no information was collected for northern Flanders) and in all the natural regions of Wallonia.

It should be noted that the sampling effort (number of sampled stands) has been much higher in Wallonia and in the Forêt de Soignes than in Flanders. In particular, in the first region, a large-scale survey was undertaken in 2001 in order to collect information on the range of some beech-damaging scolytid species (Henin et al. 2003b). On this occasion, a network of 172 ethanol-baited traps (highly efficient in the capture of *X. germanus*) had been set up throughout Walloon beech forests ($G_{\mathrm{beech}} > 66\%$). The trap network was distributed among the six Walloon natural regions proportionally to their beech forest cover (Henin et al. 2003a). Because of this proportionality, 128 of the traps were located in the Ardenne. Although the availability of weakened beech trees (i.e. suitable breeding material) was very high in this region in 2001, only a few *X. germanus* individuals were captured there. Huart et al. (2003) also report the scarcity of *X. germanus* in the Ardenne. So far, the reasons why the beetle is meeting such difficulty with settling in this region are not fully understood (De Proft 2003, personal communication).

First, like most scolytid species, *X. germanus* has remarkable spreading capabilities. In the years following its introduction in the USA, it spread at a rate of several tens of kilometres per year (based on the data reported by Bruge 1995). In the early 1950s, its initial spreading rate was similar in Germany. In several areas relatively close to the Ardenne (i.e. within 100 km or closer), *X. germanus* is now well established (i.e. "populations are abundant enough to prevent extinction", Liebhold et al. 1995). Apart from the sandy loam region and loess region, where it may be locally predominant, *X. germanus* is also very abundant in Rheinland-Pfalz and Nordrhein-Westfalen (western Germany) (Bruge 1995; Kleinevoss et al. 1996; Köhler 1996, 2000). The small region that is the Ardenne is thus surrounded with regions where *X. germanus* is firmly settled. If suitable for settlement, the Ardenne (or some parts of it) should thus have been rapidly colonised by *X. germanus*.

Furthermore, *X. germanus* is highly polyphagous. It is able to breed in the most common hardwood (*Quercus* spp. and *Fagus* spp.) and softwood (*Picea abies* and *Pinus sylvestris*) tree species present in the Ardenne (and in Belgium in general). Therefore, resource availability does not seem to be a limiting factor to the spread of *X. germanus* in the Ardenne, the region that exhibits the highest rate of forest cover in Belgium.

It seems reasonable to state that the indigenous potential competitors of *X. germanus* do not exert heavy pressure on its populations in beech substrate in the Forêt de Soignes (cf. Sect. 3.1). In this particular case, according to Hutchinson's conception of the ecological niche (in Begon et al. 1996), it could be assumed that the native competitors do not substantially restrict *X. germanus*' fundamental niche. Zach et al. (2001) and Haase et al. (1998) also report the predominance of *X. germanus* respectively on Norway spruce near Köln and on oak (*Quercus petraea*) near Montabaur (western Germany). Thus, as on beech wood substrates in the Forêt de Soignes, the indigenous xylophagous entomofauna associated with oak and Norway spruce in the early stages of decay does not seem to exert a strong impact on *X. germanus* populations in western Germany. Since the specific compositions of scolytid communities in Belgium and western Germany do not exhibit deep differences, at least concerning the dominant species (Balachowsky 1949), it is likely that interspecific competition has little influence on *X. germanus* populations in beech, oak and spruce stands in these regions. Since these tree species are highly available in the Ardenne, interspecific competition cannot be put forward to explain the scarcity of *X. germanus* in this region.

Neither the isolation of the Ardenne nor the availability of suitable resources within this region is responsible for the low population levels of *X. germanus*. Several arguments lead us to think that interspecific competition exerted by native species has little impact on *X. germanus* populations on several of the most common tree species present in this region (beech, oak, Norway spruce). Finally, being an exotic species in Europe, *X. germanus* populations escape the majority, if not the totality of their natural enemies. Although it is possible that some disease, predator, parasitoïd, parasite or entomopathogenic fungi could have been introduced in Europe with *X. germanus*, it would be very surprising that this is the reason for the beetle's absence in the Ardenne, when such factors do not seem to have significant effect on its population levels in other Belgian natural regions. The same argument could be invoked regarding indigenous oligo- and polyphagous predators and parasitoïds. Furthermore, generally speaking, natural enemies are incapable of completely eradicating their host or prey over an area as large as the Ardenne.

According to Bruge (1995), *X. germanus* has never been observed above 500 m (a.s.l.) in Europe. Considering this elevation limit, the expected range of *X. germanus* in Wallonia should be that represented in Fig. 2. As shown by our surveys and enquiries, the actual range of *X. germanus* is smaller, particularly in the Ardenne. In order to illustrate this, the sites located in the Ardenne and where no *X. germanus* were captured as part of the survey of Henin et al. (2003b) are indicated in Fig. 2. Because of the methodology of this survey, the absence of *X. germanus* in the captures taken in a given site does not necessarily imply that the beetle was not present there (for more details see Henin et al. 2003a). Nevertheless, when several traps were present in a relatively small area (as in southern Ardenne), the absence of the beetle in all traps could be considered as significant evidence of its absence in the area. Hence, the elevation limit of 500 m is thus not relevant in Belgium and, according to our data, *X. germanus* does not appear to be able to settle as a permanent population above approximately 350 m (even if spreading individuals may be caught sporadically at higher elevation). As shown in Fig. 3, this implies that the major part of the Ardenne and a part of the Belgian Lorraine are to be considered unsuitable for a permanent settlement of *X. germanus*.

It is remarkable to note that these regions almost perfectly correspond to a climatic entity, and thus to an ecological territory. Indeed, owing to Belgium's small size, local climatic parameters within the territory, particularly temperature, are highly correlated with the altitude (Dufrêne and Legendre 1991). Therefore, the

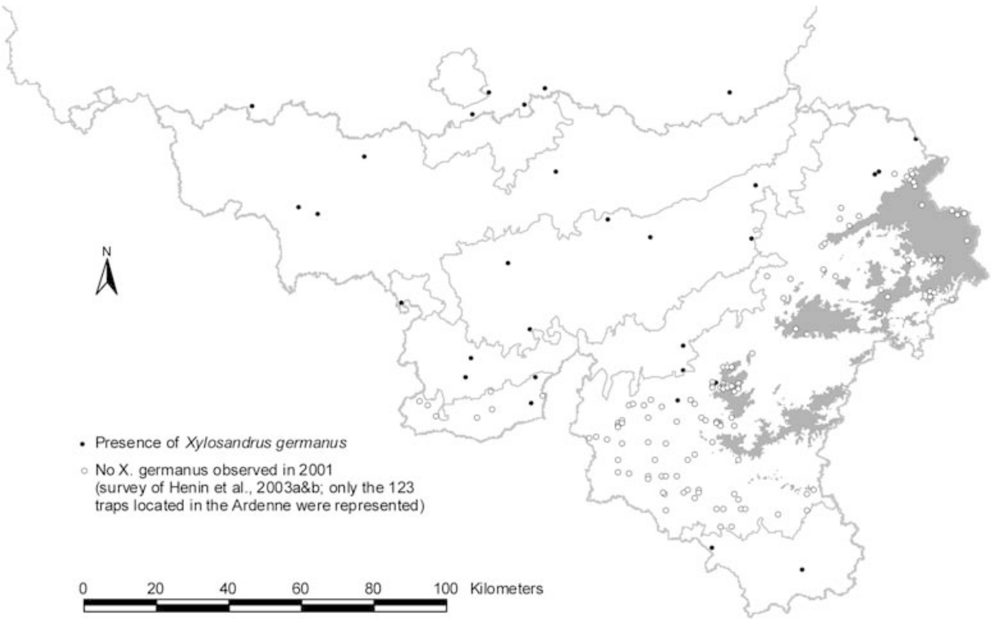


Fig. 2 Expected range of *X. germanus* in Wallonia (*clear zones*), considering the regions above 500 m elevation (*in grey*) unsuitable for a permanent settlement

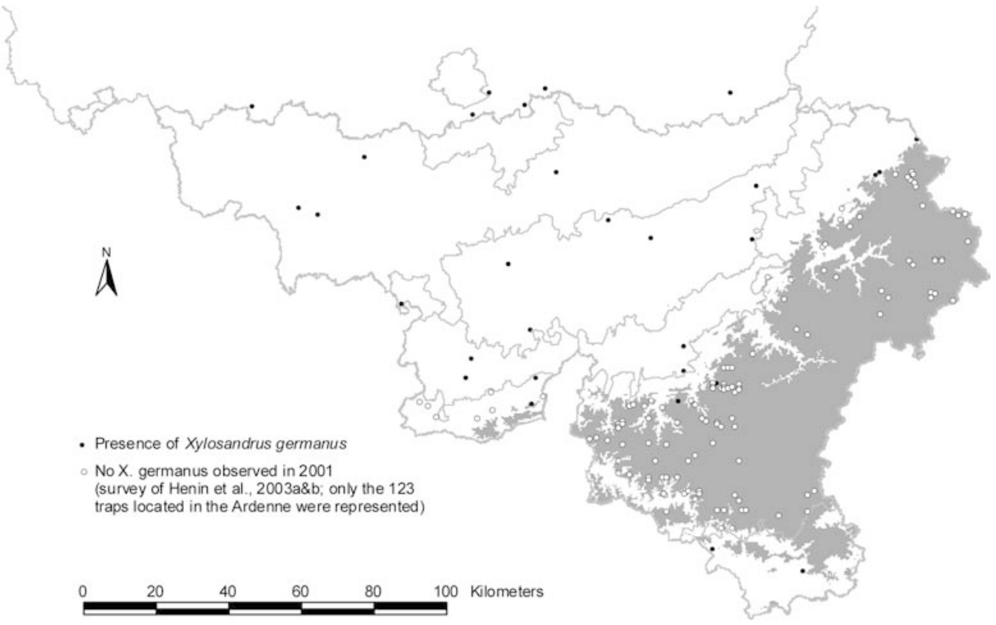


Fig. 3 Observed range of *X. germanus* in Wallonia (*clear zones*), considering the regions above 350 m elevation (*in grey*) unsuitable for a permanent settlement

annual rainfall and temperature patterns of the Ardenne and part of Belgian Lorraine differ from those in other Belgian natural regions. In the former regions, mean and minimal temperatures are lower and rainfall is more abundant. That is one of the reasons why, according to De Sloover and Dufrêne (1998), the Ardenne constitutes a biogeographical territory.

Temperature has been identified as the dominant abiotic factor directly affecting the range of herbivorous insects. In temperate regions, the main effect of temperature is to influence winter survival (Bale et al. 2002). Accordingly, the crucial influence of minimum temperatures on the range of many organisms has been demonstrated (Dajoz 1985), notably in bark beetles (Ungerer et al. 1999). Taking into account the origin of the species and especially its temperature optimum (approximately 30°C, Heidenreich in Bruge 1995), it is thus likely that minimal winter temperatures are the principal parameter governing *X. germanus*' range in Belgium. The presence of *X. germanus* in Flanders, which is situated at higher latitude but at lower elevation than the Ardenne, corroborates the crucial influence of temperature on *X. germanus*' range in Belgium. According to Bruge (1995), temperature regime also explains why the beetle is univoltine in Europe, whereas it is bivoltine in northern America.

Conclusion

X. germanus appears established in some Belgian natural regions. Because of its bioecological characteristics and competitiveness regarding native species, it has the potential to affect the diversity (i.e. richness and equitability) of the scolytid communities in the colonised areas. Indeed, as reported in many insect taxa, notably Formicidae (Bond and Slingsby 1984; Porter and Savignano 1990; Cole et al. 1992) and Coccinelidae (Elliot et al. 1996), the introduction of such an invasive species may have disastrous effect on indigenous biocenoses (Mack et al. 2000). Besides, biological invasions are considered as one of the most significant threats to the maintenance of natural forest ecosystems world-wide, and to forest exploitation (Liebhold et al. 1995; Allen and Humble 2002). Apart from economic considerations, the presence of *X. germanus* in Belgian forests could thus become a problem from a conservation viewpoint.

Data related to *X. germanus*' range and population levels could also be considered as worrying. Indeed, in a context of global climate change, the predicted rise in temperature will favour insect development and winter survival (Evans et al. 2002). Changes have already been observed in the distribution of native European butterfly populations, with their northern ranges extended (Evans et al. 2002). The same authors and others (e.g. Harrigton et al. 2001) highlight the effects of global warming on exotic pests, of which many are likely to benefit from the increase of minimal temperatures in the regions where they have been introduced. *X. germanus*' range is likely to be extended to regions like the Ardenne that seem at present unsuitable for permanent settlement. Among bark beetles, such a range shift is expected for two North American *Dendroctonus* spp. notably (Williams and Liebhold 2002). An increase in *X. germanus* population levels and an extension of its range could thus be observed in the near future throughout Belgian and western European forests. In that case, a subsequent increase of the economic impact of this invasive species is likely in these regions.

Acknowledgements We are particularly indebted to Mrs Félix, Messrs R. Deledicque, G. Miessen, M. Rouard and R. Van den Heuvel for kindly cooperating with our enquiry and to Mr N. Huart and Y. Thieren for allowing us to mention their observations. We also sincerely acknowledge Dr P. Fayt, O. Huart, Dr E. Branquart and Prof. C. Gaspar for their comments on the manuscript, as well as F. and J. Barber for improving the language. This research, realised in the context of the Xylobios research program, was enabled by financial support of the Federal Office for Scientific, Technical and Cultural Affairs, Brussels.

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