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ORIGINAL ARTICLE

Current status and first detection of *Xylosandrus germanus* (Coleoptera: Curculionidae: Scolytinae) in live trees in the Iberian Peninsula

Josep M. Riba-Flinch[1] | **Anna Garreta**[2] | **Anna Aymamí**[2] | **Belén Lumbierres**[3] | **Hugo Mas**[4] | **Diego Gallego**[5,6]

[1]Plant Pathologist and Consulting Arborist, Tossa de Mar, Spain

[2]Secció d'Agricultura i Sanitat Vegetal, Departament d'Acció Climàtica, Alimentació i Agenda Rural, Generalitat de Catalunya, Tarragona, Spain

[3]Laboratori d'Agricultura i Sanitat Vegetal, Departament d'Acció Climàtica, Alimentació i Agenda Rural, Generalitat de Catalunya, Lleida, Spain

[4]Laboratori de Sanitat Forestal. CIEF. VAERSA-Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica (Generalitat Valenciana), Quart de Poblet (València), Spain

[5]Department of Ecology, University of Alicante, Alicante, Spain

[6]Sanidad Agrícola Econex S.L., Murcia, Spain

Correspondence
Diego Gallego, Department of Ecology, University of Alicante, Alicante, Spain.
Email: diego.gallego@ua.es

Abstract

The black stem borer *Xylosandrus germanus* (Blandford, 1894) (Coleoptera: Curculionidae: Scolytinae) is a species native to Eastern Asia that has invaded 24 countries worldwide, including 21 European countries, the USA, Canada and New Zealand. On the Iberian Peninsula it was recorded for the first time in traps placed in the Basque Country (Northern Spain) in 2003, but its host plants were unknown. In the present work, three populations of *X. germanus* are recorded in the east of Spain in Girona, Tarragona and Valencia provinces (Automomous Community of Catalonia, and Valencia, respectively). Specimens were collected in traps and on host plants, showing a wider distribution range now including the east and north-east of the Iberian Peninsula. Infested carob trees (*Ceratonia siliqua*) were found in agricultural and urban green areas in Tarragona. *Ceratonia siliqua* is therefore reported here as a new host of *X. germanus.*

KEYWORDS
ambrosia beetles, *Ceratonia siliqua*, Girona, invasive species, Tarragona, Valencia, Xyleborini

Situation actuelle et première détection de *Xylosandrus germanus* (Coleoptera: Curculionidae: Scolytinae) dans des arbres vivants de la péninsule Ibérique

Le petit scolyte noir du Japon *Xylosandrus germanus* (Blandford, 1894) (Coleoptera: Curculionidae : Scolytinae) est une espèce indigène d'Asie orientale qui a infesté 24 pays dans le monde, dont 21 pays européens, les États-Unis, le Canada et la Nouvelle-Zélande. Dans la péninsule Ibérique, il a été signalé pour la première fois, dans des pièges placés dans la communauté autonome du Pays basque (nord-ouest de l'Espagne) en 2003, mais ses plantes-hôtes y sont inconnues. Cet article décrit trois populations de *X. germanus* signalées dans les provinces de Girona, Tarragona et Valencia (communauté autonome de Catalogne et communauté valencienne, respectivement). Des spécimens ont été collectés dans des pièges et sur des plantes-hôtes, montrant une répartition géographique plus vaste incluant désormais l'est et le nord-est de la péninsule Ibérique. Des caroubiers (*Ceratonia siliqua*) infestés ont été trouvés dans des espaces verts de

zones urbaines et agricoles à Tarragona. *C. siliqua* est donc signalé dans cet article comme un nouvel hôte de *X. germanus*.

Текущий статус и первое обнаружение *Xylosandrus germanus* (Coleoptera: Curculionidae: Scolytinae) на живых деревьях на Пиренейском полуострове

Короед *Xylosandrus germanus* (Blandford, 1894) (Coleoptera: Curculionidae: Scolytinae) происходит из Восточной Азии, но его инвазионный ареал охватывает 24 страны мира, включая 21 европейскую страну, США, Канаду и Новую Зеландию. На Пиренейском полуострове он был впервые зарегистрирован в ловушках, расставленных в Стране Басков (Северная Испания) в 2003 году, но его растения-хозяева были неизвестны. В настоящей работе три популяции *X. germanus* зарегистрированы в испанских провинциях Жирона, Таррагона и Валенсия. Образцы были собраны в ловушках и на растениях-хозяевах, что свидетельствует о расширении ареала вида, который теперь включает восток и северо-восток Пиренейского полуострова. Заселенные рожковые деревья (*Ceratonia siliqua*) были обнаружены в сельскохозяйственных и городских зеленых зонах Таррагоны. Таким образом, *C. siliqua* является новым растением-хозяином *X. germanus*

1 | INTRODUCTION

Biological invasion is a natural process that has allowed many species to expand their native geographic range (Guo, 2006). Once a geographic frontier disappears, the movement of species from both sides of the border to the new territories causes new species interactions. Thus, new relationships such as predation, competition, parasitism, competitive exclusion and niche displacement can occur, resulting in the evolution of some species and the extinction of others (Ricciardi, 2007). Global trade and climate change weaken the effect of borders and facilitate the movement of invasive species worldwide. Consequently, the frequency of biological invasions has increased in recent decades (Gentili et al., 2021) and they are a significant threat to the biodiversity of the invaded territories.

Some coleopteran species of the *Xylosandrus* genus, as well as other species from the Xyleborini tribe, have high invasive ability (Gallego et al., 2020; Jordal et al., 2001). New records of *Xylosandrus* spp., such as *X. crassiusculus* (Motschulsky, 1866), *X. compactus* (Eichhoff, 1875) and *X. germanus* (Blandford, 1894), have increased in Europe in the last decade (EPPO, 2020, 2021a, 2021b, 2021c, 2021d).

Xylosandrus crassiusculus was first detected in Europe in Italy (2003) and some years later in France (2014), Spain (2016), Slovenia (2017) and Malta (2021) (EPPO, 2021d; Gallego et al., 2017).

In 2010, *X. compactus* was detected for the first time in Europe in Campania and Toscana, Italy (Francardi et al., 2012; Garonna et al., 2012; Pennacchio et al., 2012). The first detection in France was reported in the Alpes Maritimes region in 2015 (Roques et al., 2019). In October 2019, attacks by *X. compactus* were detected on twigs and branches up to 10 cm in diameter of a carob tree (*Ceratonia siliqua*) in a private garden in Calvià (Mallorca, Balearic Islands). This was the first record for Spain (EPPO, 2020; Leza et al., 2020). This species was previously detected in other European countries: Italy, France, Monaco and Greece (CABI, 2021a; EPPO, 2021b). In August 2020, *X. compactus* was recorded for the first time on the Iberian Peninsula (Banyoles, Girona province, North-East Spain), attacking twigs of *Laurus nobilis* (Riba-Flinch et al., 2021). Moreover, attacks of *X. compactus* were also reported on carob trees and hazelnuts (*Corylus avellana*) in Salou (Tarragona), 180 km south of Banyoles (EPPO, 2021a).

The first record of *X. germanus* in Europe was in Germany (Darmstadt, on *Quercus* and *Fagus*) in 1951, probably introduced because of the high quantity of timber exports after World War II. However, other authors indicate that this species could have been introduced to Germany much earlier with imports of *Quercus* wood from Japan, during the 1907–1914 and 1919–1929 periods (Galko et al., 2019; Wichmann, 1957). *Xylosandrus germanus* is native to Eastern China, the Korean Peninsula, Japan, Taiwan and Vietnam (CABI, 2021b; EPPO, 2021c).

Between 1980 and 2000 *X. germanus* was recorded in Switzerland (1984, near Basel, on *Fagus* trunks), France (1984, eastern part), Austria (1992, Feldkirch and Rankweil), Italy (1992, in Lombardia, in *Juglans* crops), Belgium (1994, near Brussels), European Russia (1995, North-West Caucasus), Sweden (1996, Nybro, by trapping) and Poland (1998, Wolin island).

The spread of *X. germanus* accelerated after 2000 (Bouget & Noblecourt, 2005; Galko et al., 2019), being recorded in Slovenia (2000, Nova Gorica, on

Castanea), Spain (2003, Basque Country, only in traps and host plants unknown), Hungary (2005, on *Quercus* and *Tilia* logs), the United Kingdom (2008, South-East England), Croatia (2009, in *Quercus* stand), Czechia (2007, Moravia), the Netherlands (2008), Romania (2009, western part, in *Quercus* and *Fagus* forest), Slovakia (2010, Duchonka, in a *Quercus* stand, by trapping), Denmark (2012, Lolland Island), Turkey (2011, in *Actinidia* orchards, by trapping), Ukraine (2012, Uzhgorod, caught in flight) and European Russia (2015, Kaliningrad) (Björklund & Boberg, 2017; Galko et al., 2019; Hauptman et al., 2019; Mandelshtam, 2001; Nazarenko & Gontarenko, 2014).

Currently, *X. germanus*, outside its native area of Eastern Asia, is present in Europe (21 countries), North America (35 states of USA and six Canadian provinces) and Oceania (New Zealand) (CABI, 2021b; EPPO, 2021c; Gugliuzzo et al., 2021). The introduction of this species in North America and Europe is most likely associated with trading and the movement of infested timber, wood products or untreated solid wood packaging (Bruge, 1995; Inward, 2018), as well as with the movement and commerce of infested live ornamental/agricultural plants (Björklund & Boberg, 2017). These were also the most likely pathways for the introduction of *X. crassiusculus* into the EU (EFSA et al., 2020) and *X. compactus* into Spain (Riba-Flinch et al., 2021).

Xylosandrus germanus attacks are focused on weakened and stressed trees. This species is attracted to ethanol, the most common volatile released by stressed plants (Inward, 2018; Ranger et al., 2021; Ruzzier et al., 2021). Worldwide, their attacks are often found in association with other ambrosia beetles, such as *Trypodendron*, *Xyleborinus*, *Xylosandrus* and *Xyleborus* species (Hauptman et al., 2019; Inward, 2018). In Europe, *X. germanus* is considered a secondary pest and attacks seem to be focused on forest areas (natural or commercial forests), but also on harvested trees and logs, as well as flood-stressed plants. However, in North America, the most important attacks occur on fruit tree crops and ornamental nurseries, and *X. germanus* is considered one of the most economically damaging ambrosia beetle species (Dzurenko et al., 2021; Galko et al., 2019; Gugliuzzo et al., 2021; Hauptman et al., 2019; Inward, 2018; Ruzzier et al., 2021). Similar to *X. crassiusculus*, *X. germanus* rarely attacks healthy trees, and if this occurs plants are weakly colonized (Ranger et al., 2015). However, *X. compactus* can attack apparently healthy trees that are not suffering physiological stress (Chong et al., 2009).

Xylosandrus germanus is considered highly polyphagous, with more than 200 host species recorded, belonging to 52 families, and with a preference for deciduous over coniferous hosts (Inward, 2018). It seems that there is a preference to attack trees with thin bark (Ranger et al., 2016). In Europe, attacks of *X. germanus* have been recorded on forest species (in natural and commercial forests, attacking both deciduous and coniferous woody plants), especially on logs of *Carpinus betulus*, *Castanea sativa*, *Fagus sylvatica*, *Quercus* spp., *Tilia* spp. and *Ulmus* spp., and also conifers (*Picea abies*, *Pinus sylvestris*, *Abies alba*) (Galko et al., 2019). However, some attacks have also been recorded in crops, such as *Juglans regia* plantations in Italy, *Actinidia deliciosa* and *Corylus avellana* plantations in Turkey, and *Vitis vinifera* plantations in Germany and Italy (Galko et al., 2019; Ruzzier et al., 2021). Nageleisen et al. (2015) and Inward (2018) mention that some of the most important hosts in Europe belong to *Abies*, *Acer*, *Alnus*, *Betula*, *Camellia sinensis*, *Carpinus*, *Carya*, *Castanea*, *Cornus*, *Fagus sylvatica*, *Fraxinus*, *Juglans nigra*, *J. regia*, *Magnolia*, *Picea*, *Pinus*, *Populus*, *Prunus*, *Pseudotsuga menziesii*, *Quercus*, *Salix*, *Ulmus glabra* and *Vitis vinifera*. Galko (2013) indicates that the host range in the invaded areas (USA, Europe) includes many species from *Quercus*, *Fagus*, *Acer*, *Alnus*, *Betula*, *Buxus*, *Carpinus*, *Corylus*, *Juglans*, *Robinia*, *Ulmus* and conifers (*Picea*, *Pinus*, *Abies*). In previous works, other host species are reported, such as Pfeffer (1994), who records attacks on *Fagus sylvatica*, *Picea abies*, *Pinus densiflora* and *P. pentaphylla* from Western Europe; and Schott (1994), who recorded attacks on *Alnus* spp., *Betula* spp., *Carpinus betulus*, *Castanea sativa*, *Fraxinus* spp., *Picea* spp., *Pinus sylvestris*, *Populus* spp., *Pseudotsuga menziesii*, *Quercus* spp., *Salix* spp. and *Ulmus glabra* from Alsace region (France).

Several publications have shown evidence of the spread of *X. germanus, X. crassiusculus* and *X. compactus* in recent years in Europe, especially in France and Italy (Barnouin et al., 2020; CABI, 2021a; Contarini et al., 2020; DACC, 2021; Dzurenko et al., 2021; EPPO, 2021b; Faccoli, 2021; Gallego et al., 2020; Gugliuzzo et al., 2021; Riba-Flinch et al., 2021; Roques et al., 2019). The European Life SAMFIX project (www.lifesamfix.eu/the-project), which started in June 2018, studies the expansion pathways and develops detection protocols, as well as containment and eradication measures, for these species in Italy, France and Spain. In December 2020, after the recording of *X. compactus* in Catalonia (EPPO, 2021a; Riba-Flinch et al., 2021), the Plant Health Service of the Department of Climate Action, Food and Rural Agenda (DACC) of the Regional Government (Generalitat of Catalonia) implemented a reinforcement surveillance programme for *Xylosandrus* species in Catalonia (North-East Spain) to assess the extension of invasion of the genus *Xylosandrus*. In addition, specimens of *Xylosandrus* were captured in the early detection network named 'Red de Alerta Temprana' (RAT), which is a network of traps, installed in ports and in surrounding forests, implemented by the Regional Government of Valencia since 2017, focused on the early detection of exotic insects.

The aim of the present work was to show the new records of *X. germanus* in the east and north-east of the Iberian Peninsula, as consequence of the actions of DACC surveillance and RAT monitoring in 2021.

2 | MATERIALS AND METHODS

The DACC surveillance programme was carried out in the areas where *X. compactus* was detected in 2020 to investigate the extent of the invaded area for this species in Tarragona and Girona provinces (Catalonia). From December 2020 to autumn 2021, plants were visually inspected for suspicious signs of damage (exudates, holes or shoot and twig dieback) and, if symptoms were observed, sampled by cutting affected shoots and branches to obtain adult insect samples. In spring 2021, eight cross-vane traps (Crosstrap® mini, Econex, Spain) were placed in Vila-seca (Tarragona province) and Platja d'Aro (Girona province) (Table 1). Traps were baited with an ethanol dispenser (ultrahigh release rate of 1.5 g per day at 20°C), and a dispenser of (−)-alpha-pinene (release rate of 30 mg per day at 20°C) (Econex, Spain). In Vila-seca, four traps were placed in carob and hazelnut crops, and the remaining two traps were placed in urban green areas. In Platja d'Aro, traps were placed in a forest with *Pinus pinea*, *Quercus ilex*, *Quercus suber*, *Quercus pubescens* and *Robinia pseudoacacia*. Traps were surveyed biweekly and lures were replaced according to the manufacturer's instructions. Captured insects were preserved in 70% ethanol and deposited in the DACC and personal collections of the authors.

The RAT network is composed of 16 traps placed in ports, surrounding forests and areas with a high concentration of fresh wood industries in the Valencia, Castellon and Alicante provinces. In particular, it includes a trapping point at the port of Gandía, in Valencia province. The RAT network also uses the same cross-vane traps, baited with the same ethanol and (−)-alpha-pinene dispensers, plus a dispenser with a blend of ipsdienol, ipsenol and *cis*-verbenol, containing 300 mg of each component, with a 1.5 mg/day release rate at 20°C (Econex, Spain). Since 2017, traps have been installed each year in April and surveyed monthly until the end of November.

Morphological identification of collected Xyleborini beetles was carried out using the following taxonomic keys: Faccoli (2008), Dole and Cognato (2010), Hulcr and Smith (2010) and Gallego et al. (2017), as well as by direct comparisons with specimens from the personal collections of the authors. Although *X. germanus* and *X. compactus* are very similar, *X. germanus* is clearly differentiated by its larger size (2.0–2.4 mm) and by the absence of setae in the elytra declivity striae, while *X. compactus* has setae in the striae and interstriae, and it is smaller, at 1.4–1.9 mm in length (Dole & Cognato, 2010; Faccoli, 2008). The identification of insects captured at the port of Gandìa was done by the Forest Health Laboratory of Valencia Region and confirmed by the National Reference Laboratory of Entomology by morphological and molecular methods.

3 | RESULTS

In Tarragona province, during the DACC surveillance on 10 December 2020, suspicious damage was observed on an ornamental carob tree located in an urban green area in Vila-seca. This tree had several thin branches (10–15 mm in diameter) showing dieback and wilting leaves still attached. On these branches, perforation holes were observed on the bark. Both species, *X. compactus* and *X. germanus*, were collected together, attacking thin branches of the same carob tree (Figure 1). Samples collected on 3 May 2021 had *X. compactus* on twigs and branches, while *X. germanus* was only found in branches (Table 2).

Since March 2021, surveys and samples from carob trees have intensified, both in agricultural crops and in urban green areas, with a special focus on Tarragona province (municipalities of Vila-seca, Salou and Riudoms). On 3 May, during a survey in an urban green area in Vila-seca, a multi-stemmed carob tree (from 70 to 133 cm in trunk circumference) showed several dead twigs (less than 1 cm diameter) in the lower part of the crown that revealed *X. compactus* attacks (Figure 2a). In this same tree, multiple perforation holes with exudates were also observed in branches with diameters ranging from 1 to 22 cm (Figure 2b). Both *X. compactus* and *X. germanus* specimens emerged from branch pieces in the laboratory (Table 2) from samples taken in Vila-seca Tarragona.

Between spring and autumn of 2021, nine specimens of *X. germanus* were captured in the RAT trap surrounding the forest of the port of Gandía. Different surveys were carried out to identify potential host plants during spring, summer and autumn in 2021, but no damage or symptoms compatible with attacks of this species were observed. Therefore, the host plants of *X. germanus* in Gandía remain unknown.

The map of *X. germanus* occurrences on the Iberian Peninsula (Figure 3) shows the previous records of the

TABLE 1 Crossvane traps installed in Catalan and Valencia provinces

Installation date	Site	Coordinates	Province	Number of traps
April 2021	Vila-seca	41.091°N, 1.145°E	Tarragona	6
May 2021	Platja d'Aro	41.810°N, 3.051°E	Girona	2
April 2021	Gandía	38.993°N, 0.152°E	Valencia	1

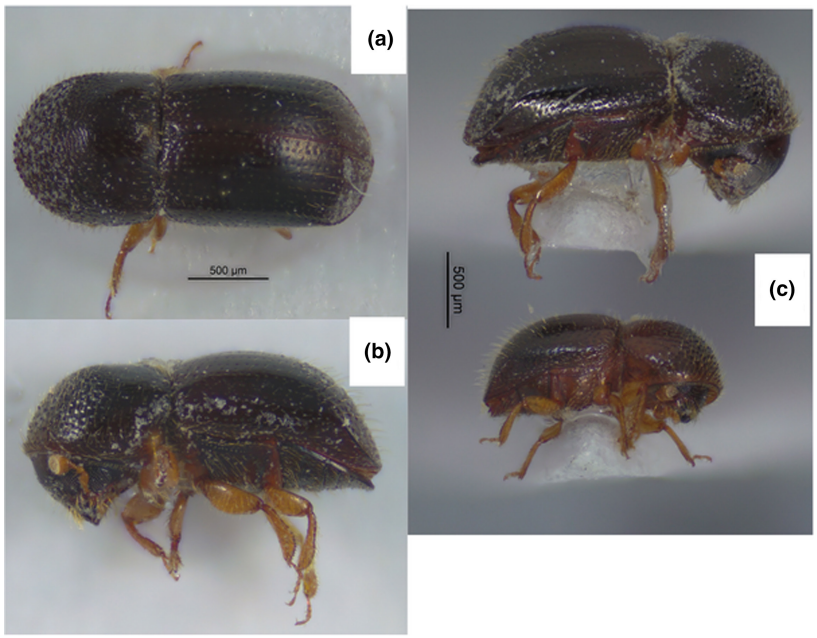

FIGURE 1 (a) Dorsal view of *Xylosandrus germanus*. (b) Lateral view of *X. germanus*. (c) Size and habitus comparison between *X. germanus* (upper; 2.0–2.4 mm) and *Xylosandrus compactus* (lower; 1.4–1.9 mm)

TABLE 2 Species and specimens of *Xylosandrus* collected by direct collection or trapped in baited traps

Sampling date	Site	Method	Host portion	Species[a]
10 December 2020	Vila-seca (Tarragona)	Direct collection of attacked host material	Branches	*X. compactus* *X. germanus*
3 May 2021	Vila-seca (Tarragona)	Direct collection of attacked host material	Twigs and branches	*X. compactus*
			Branches	*X. compactus* *X. germanus*
12 April 2021	Vila-seca (Tarragona)	Baited traps	—	*X. compactus* (1) *X. germanus* (2)
10 June 2021	Platja d'Aro (Girona)	Baited traps	—	*X. compactus* (5) *X. germanus* (17)
02 June to 21 September 2021	Gandía (Valencia)	Baited traps	—	*X. germanus* (9)

[a]The number of captured specimens in baited traps is shown in brackets. Specimens emerging from tree host pieces were not counted.

species in four localities of Basque Country and the new locations in the east and north-east of the Iberian Peninsula.

4 | DISCUSSION

Prior to the present work, the known distribution of *X. germanus* in the Iberian Peninsula was restricted to the Basque Country (Northern Spain; Goldarazena et al., 2014; López et al., 2007). However, our results suggest that the range of this species has extended widely towards east and north-east of the Iberian Peninsula. It was first recorded in Vila-seca, Tarragona, in December 2020, and later in Platja d'Aro, Girona, and Gandía, Valencia, both in June 2021 (Figure 3). In summer 2018, *X. germanus* was collected in the Circeo National Park (Tyrrhenian Sea coast, Lazio, Italy) in trapping networks of the SAMFIX European Life Project, which aimed to capture *X. compactus* and *X. crassiusculus* (Contarini et al., 2020; SAMFIX, 2021). Apparently, these three *Xylosandrus* species occur in the same ecosystem of Mediterranean maquis, mainly composed of non-deciduous trees such as *Q. ilex*, *C. siliqua* and *Arbutus unedo*. Our results indicate that *X. germanus* is also able to establish in urban and agricultural environments. It should be noted that in all these locations, *X. germanus* has been detected as a consequence of a non-targeted survey for other *Xylosandrus* or Scolytinae species.

The presence of *X. germanus* in Europe has been known since 1951 and the species has shown a great potential for spreading and establishing in new areas, as well as in new ecosystems, such as the Mediterranean maquis or urban environments. However, there are

FIGURE 2 (a) Affected carob tree in Vila-seca (Tarragona; 3-August-2021), with *Xylosandrus compactus* attacks on twigs and branches and *Xylosandrus germanus* attacks on branches. (b) Fresh exudations on a branch (50–70 mm diameter; 3 August 2021, Vila-seca), from which some *X. germanus* were collected. (c) Active colonies of *X. germanus*, showing the brood gallery on the external xylem, with larvae, pupae and new adults, and the dark brown-black staining of the wood by the fungal infection (branch with 65 mm diameter; 5 August 2021, Vila-seca).

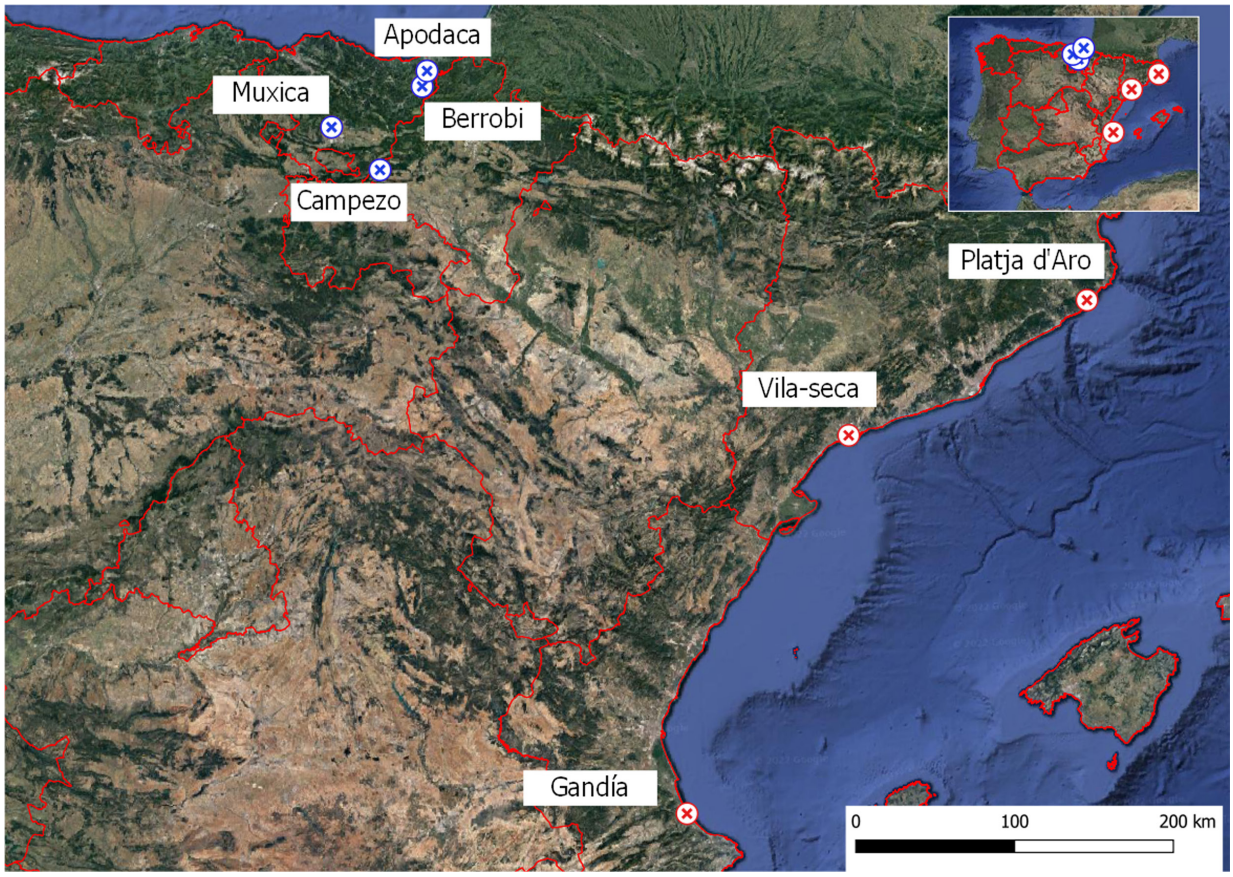

FIGURE 3 Records of *Xylosandrus germanus* on the Iberian Peninsula. The four cites from the Basque Country (blue crosses) were reported in López et al. (2007) and Goldarazena et al. (2014). The new ones (red crosses) are from Vila-seca (Tarragona, December 2020), Platja d'Aro (Girona, May 2021) and Gandìa (Valencia, June–September 2021).

few reports of significant economic or environmental impacts of this species (Björklund & Boberg, 2017; Inward, 2018). In several European countries, captures of *X. germanus* in traps have reached values of 45–80% of captured Scolytinae, much higher than the other *Xylosandrus* species or other Xyleborini or Scolytinae.

This could be a potential threat to the native populations of bark and ambrosia beetles (Björklund & Boberg, 2017; Hauptman et al., 2019).

Our work presents the first host record of *X. germanus* for the Iberian Peninsula, the carob tree *C. siliqua*. Although *X. germanus* had already been occasionally captured in traps baited with attractants in Spain, this work reveals that it can successfully develop in carob trees (Figure 2c), thus enlarging its known host plant list. As with the other congeneric and invasive species, *X. crassiusculus* and *X. compactus*, *X. germanus* has spread widely across the European territory, possibly helped by live plant commerce and the timber trade. One of the goals of the SAMFIX European Life Project is to elucidate the origin of invasive populations by molecular techniques (SAMFIX, 2021). Several specimens of *X. germanus* collected from these new locations in Tarragona, Girona and Valencia will be sent to the SAMFIX team for analysis.

Exotic species of *Xylosandrus* are silently spreading over wide territories aided by climate change and globalization (Dzurenko et al., 2022; Gallego et al., 2020; Urvois et al., 2021). New detections are usually random events, linked to other non-targeted activities or citizen science. The RAT network has been demonstrated to be an effective tool for early detection and alert. Consolidation of common early alert systems and implementation of effective and standardized policy measures for live plant and timber commerce will be necessary to reduce the risk of new invasions or spread of introduced alien Xyleborini in Europe.

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ORCID

Josep M. Riba-Flinch https://orcid.org/0000-0003-3147-0737
Anna Garreta https://orcid.org/0000-0001-8984-3730
Anna Aymamí https://orcid.org/0000-0002-6679-8364
Belén Lumbierres https://orcid.org/0000-0001-5695-2607
Hugo Mas https://orcid.org/0000-0002-7158-0204
Diego Gallego https://orcid.org/0000-0002-9258-0238

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