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Rapid Communication

Continued eastward spread of the invasive ambrosia beetle *Cyclorhipidion bodoanum* (Reitter, 1913) in Europe and its distribution in the world

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Abstract

Ambrosia beetles, including *Cyclorhipidion bodoanum*, are frequently introduced into new areas through the international trade of wood and wood products. *Cyclorhipidion bodoanum* is native to eastern Siberia, the Korean Peninsula, Northeast China, Southeast Asia, and Japan but has been introduced into North America, and Europe. In Europe, it was first discovered in 1960 in Alsace, France, from where it has slowly spread to the north, southeast, and east. In 2020, *C. bodoanum* was captured in an ethanol-baited insect trap in the Bohemian Massif in the western Czech Republic. The locality is covered by a forest of well-spaced oak trees of various ages, a typical habitat for this beetle. The capture of *C. bodoanum* in the Bohemian Massif, which is geographically isolated from the rest of Central Europe, confirms that the species is spreading east. The species probably spread naturally from Germany, but the period of establishment is difficult to estimate. Although the spread seems to be slow i.e. the beetle required about 60 years to spread from the borders of France and Switzerland to Bohemia, *C. bodoanum* may have spread more quickly but remained undetected in the newly invaded areas.

Key words: biological invasions, oak forest, pest, Scolytinae

Introduction

Cyclorhipidion bodoanum (Reitter, 1913) belongs to the "ambrosia" group of bark beetles. Members of this group have developed symbiotic relationships with fungi and are sometimes referred to as "fungus-farmers". The term "ambrosia beetle" is an ecological classification describing the larval and adult habit of feeding on mutualistic fungi in woody host tissue. Ambrosia beetles includes species in both the Scolytinae and in the distantly related Platypodidae. The ambrosia fungi are transported by the adult beetles in specialised structures (mycangia) or on the body surface; as the beetle tunnels into the host, they deposit the fungus on the gallery walls (Kirkendall et al. 2015).

Ambrosia beetles are frequently introduced into new areas through the international trade in wood and wood products (Brockerhoff and Liebhold 2017). When novel species of host trees are encountered by the beetles, the

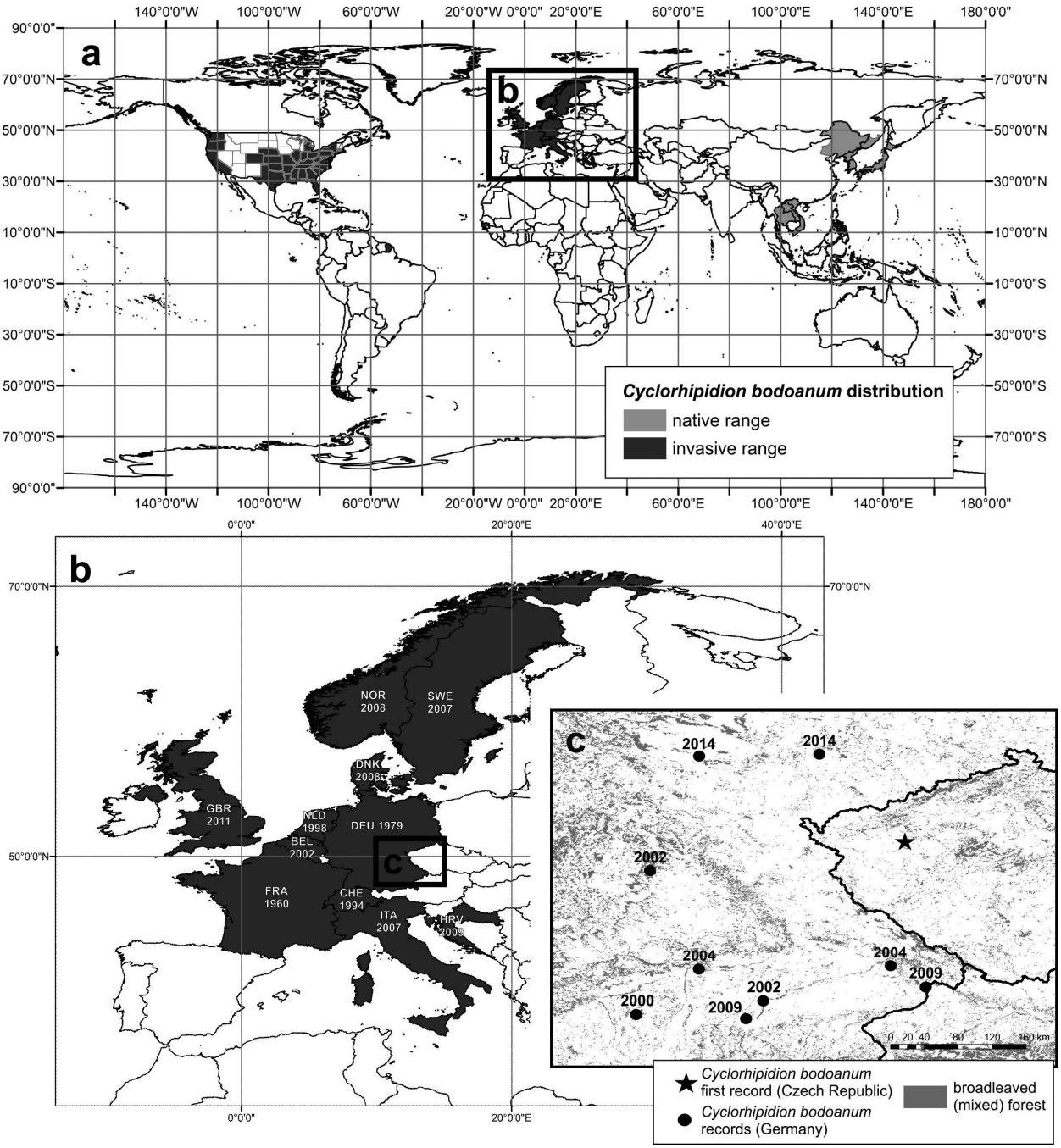

Figure 1. Distribution of *Cyclorhipidion bodoanum* throughout the world (a) with the years of its discovery in European countries (b) and in German localities near the Czech locality (indicated by a star) of the current study (c).

trees can be "naïve" and susceptible to attack, enabling previously harmless scolytine species to become damaging, or the ambrosia fungi to become pathogenic (Kirkendall and Faccoli 2010; Mayers et al. 2015). Although 30 non-native bark beetles are registered in Europe (Alonso-Zarazaga et al. 2017; Dodelin and Saurat 2017; Dodelin 2018), we know relatively little about their spread and recent distribution.

Cyclorhipidion bodoanum is native to eastern Siberia (Figure 1), where it was first described as *Xyleborus bodoanus* (Reitter, 1913) and then as *X. punctulatus* (Kurentsov, 1948). It is also widespread in the Korean Peninsula

Figure 2. The protected area of Vladař where a Theysohn® trap was suspended. Photographs of the forest interior in spring (top) and in autumn (bottom). Photographs by Přemysl Tájek.

and Northeast China (Reitter 1913; Park et al. 2020), in Southeast Asia and Taiwan (Beaver et al. 2014; Smith et al. 2020) and in Japan, where it was reported as *Xyleborus misatoensis* (Nobuchi, 1981) (Smith et al. 2020).

The beetle was also introduced into North America (Figure 1), where it was described as *Xyleborus californicus* (Wood, 1975), before being synonymised and moved into the genus *Cyclorhipidion* by Knížek (2011). The male of *C. bodoanum* was misidentified and described as *Xyleborus peregrinus* Eggers, 1944 (Bense and Schott 1998).

Cyclorhipidion bodoanum has been introduced into Europe (Wood 1975; Vandenberg et al. 2000; Kirkendall and Faccoli 2010; Gomez et al. 2018; Sanchez et al. 2020) and is now established and widespread in Western Europe (Figure 1; Kirkendall and Faccoli 2010; Alonso-Zarazaga et al. 2017).

The aim of the work was (i) to report the spread of C. *bodoanum* into a geographically isolated part of Central Europe and (ii) to review its recent worldwide distribution.

Materials and methods

In 2020, an ethanol-baited Theysohn® insect trap was deployed in the Vladař Nature Reserve (Figure 2) near the town of Žlutice (50.0755; 13.2094)

in the Bohemian Massif (Czech Republic). The highest peak in the locality is 693 m a.s.l., and the trap was placed at 605 m a.s.l.

The locality lies in a rain shadow and has a relatively warm and very dry climate (Tolasz 2007). The southern slopes of Vladař support deciduous trees, which grow in Hercynian oak groves, dry acidophilous oak groves, and gravel forests of the *Tilio-Acerion* association (Figure 2).

The trap was suspended from a rope tied between two trees, with the trap base approximately 150 cm above the ground. The 96% ethanol in the trap was contained in a 50-ml polypropylene screw-top container that had four 3-mm-diameter holes in its lid; the ethanol was released from the trap at a rate of approximately 200 mg/day at 15 °C.

The ethanol bait was placed in the trap at the beginning of April. Beetles were collected from the trap every 2 weeks, and the lure and preservative fluid was changed. The collected insects were transferred to 96% ethanol, and two specimens were identified as *C. bodoanum* by the second author.

Results and discussion

In Europe, *C. bodoanum* was first discovered in 1960 in Alsace, France (Schott 2004). It was subsequently discovered in Germany in 1979 (Schott 2004), Switzerland in 1994 (Sanchez et al. 2020), the Netherlands in 1998 (Vorst et al. 2008), Belgium in 2002 (Henin and Nageleisen 2005), Italy in 2007 (Audisio et al. 2008), Sweden in 2007 (Lindelöw 2012), Denmark in 2008 (Pedersen et al. 2010), Norway in 2008 (Kvamme and Lindelöw 2014), Croatia in 2009 (Donji Lozac, 31 July 2009, Åke Lindelöw lgt., coll., Miloš Knížek det.) (Knížek 2011), and Britain in 2011 (Telfer 2019) (Figure 1). As indicated in the previous sentence, the beetle has been spreading to the east and north, and findings in other countries can therefore be expected. It does not appear to have been introduced to Spain or Portugal and is still advancing only from the west to the east and the north.

The species was also mentioned from Austria (Alonso-Zarazaga et al. 2017), but there are no official records in that country (Kirkendall and Faccoli 2010; Holzschuh *pers. comm.*; Zábranský *pers. comm.*). Its occurrence in Austria must be confirmed, although its spread to that country is very likely.

In the current study, two specimens of *C. bodoanum* (Figure 3) were collected from the Vladař Nature Reserve in the Bohemian Massif (Figure 2) on 15 April 2020. The morphological characteristics of these specimens correspond with those of the species. The collected specimens are about 2 mm long (the body length of the species ranges from 1.93 to 2.30 mm (Hoebeke et al. 2018; Knížek *pers. obs.*) and are pale yellow-brown in colour (Figure 3). From a dorsal view, the heads of the specimens are concealed under the pronotum. The basal half of the pronotum is semi-dull, shagreened, and very finely punctated (Figure 3). The frontal part is declivous, tuberculate, with a finely granulate frontal margin. The punctation of elytra is dense, without distinct striae; the postero-lateral margins of the elytral declivity,

Figure 3. Dorsal and lateral photographs of a *Cyclorhipidion bodoanum* female collected in the Vladař locality (the Czech Republic). Photographs by Zbyněk Kejval.

to the elytral apex, are rounded; the whole elytra is covered with dense pubescence, which becomes longer posteriorly; the elytral declivity is dull, flattened, and not impressed between interstriae 1 and 3; the declivital strial punctations are large, shallow, and distinct, with reticulate interior surfaces, and are separated by less than their diameter; the denticles on declivital interstriae 1 and 3 are small and more or less uniform in size.

Cyclorhipidion bodoanum is a polyphagous species that is typically associated with Fagaceae and especially *Quercus* (Wood 1982; McPherson et al. 2008; Blaschke and Bussler 2012), but has also been reported from walnut trees (*Juglans* sp.) (Seybold et al. 2016), chestnut trees (*Castanea*) (Bussler and Immler 2007), and *Pinus* (Pinaceae) and *Populus* trees (Salicaceae) (Lightle et al. 2007). It is usually found on weakened or stressed hosts and attacks trunks > 10 cm in diameter (Brin et al. 2011). *C. bodoanum* prefers forests with well-spaced trees (Bouget et al. 2013) or parks dominated by oak (Lee et al. 2019). The latter characteristics are descriptive of the current study's locality, which is an oak forest with well-spaced trees of various ages (Figure 2).

Cyclorhipidion bodoanum is a secondary pest (Lassauce et al. 2012) but increasing levels of damage from this and other ambrosia beetles can be expected because climate change will likely result in more frequent drought stress and "windblows" and increases in the number of beetle generations per year (Wainhouse and Inward 2016). A warmer, wetter climate is a good predictor of the establishment of exotic ambrosia beetles, probably because such conditions favour the growth of their symbiotic fungi (Marini et al.

2011). *Cyclorhipidion bodoanum* is a carrier of the fungus *Geosmithia morbida* M. Kolařík, Freeland, C. Utley & Tisserat, 2010, which causes a canker disease on walnut (*Juglans* sp.) (Moore et al. 2019), and also of the fungi *Mucor racemosus* f. *racemosus* Fresen., 1850, *Hypocrea lixii* Pat., 1891, *Trichoderma viride* Pers., 1794, *Pleosporaceae* sp. (McPherson et al. 2013), and *Sporothrix stenoceras* (Robak) Z.W. de Beer, T.A. Duong & M.J. Wingf., 2016 (Gebhardt et al. 2005).

McPherson et al. (2008) note that *C. bodoanum* attacks *Quercus* trees previously attacked by pathogenic fungi, resulting in the spread of decay fungi and increased tree mortality. Because *C. bodoanum* attacks relatively thick wood, economic damage may occur (Grégoire et al. 2001). On the other hand, it prefers open, non-commercial oak forests, and extensive damage to commercial forests therefore seems unlikely.

Cyclorhipidion bodoanum was probably introduced into Continental Europe and Britain with timber products or perhaps sapling trees (Schott 2004; Lee et al. 2019). The beetle has spread from its places of introduction (Bouget and Noblecourt 2005), and the finding in the Bohemian Massif, which is geographically isolated by border mountains (Ore Mts., Giant Mts. and Bohemian Forest) from the rest of Central Europe (Chytrý 2012), confirms its continued spread to the east. The species probably spread naturally to the Czech Republic from Germany, but the unintentional introduction by humans could not be also excluded (Figure 1; Table S2). Year of establishment in the Bohemian Massif is difficult to estimate. The beetle seems to spread only slowly, e.g., it required about 60 years to spread from the borders of France and Switzerland to Bohemia. However, the spread may have been faster if the beetle was simply overlooked for long periods.

It is possible that *C. bodoanum* appeared in Bohemia only recently. Although we do not have a single monitoring program for the spread of invasive species, there are number of approaches for monitoring saproxylic species. We have recently summarized the detection of *Xylosandrus germanus* (Blandford, 1894) in dozens of field searches that used hundreds of barrier traps in the Czech Republic (Fiala et al. 2020); all of the scientists involved in the experiments were experts in bark beetles and failed to detect *C. bodoanum*. We therefore speculate that *C. bodoanum* appeared in the Czech Republic only recently.

As noted earlier, invasive bark beetles are being spread by global trade, with huge movements of wood products, live plants, and unprocessed wood occurring between continents (Brockerhoff and Liebhold 2017). Individuals on new continents are first introduced in ports and airports (Haack 2001; Loreto 2015) and from there they can spread across the continents. In the USA, the spread of *C. bodoanum* began on the west coast of California and then stopped at the edge of the Rocky Mountains as a geographical barrier (Liebhold and Tobin 2008). Another wave of spread in the USA began in the ports of Texas and continued toward the east coast

(Figure 1; Table S1). In Europe, proliferation was initially limited to western countries, but after the creation of the European Union (which accelerated trade and abolished tariffs on all products including wooden products) and the fall of the "Iron Curtain", the spread of bark beetles gained momentum (Roques et al. 2016).

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Supplementary material

The following supplementary material is available for this article:

Table S1. Years when *Cyclorhipidion bodoanum* was discovered in the USA.

Table S2. Years when *Cyclorhipidion bodoanum* was discovered in the Germany, near of the border with the Czech Republic.

Appendix 1. References to Table S1.

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