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Cucujus cinnaberinus (Cucujidae) is rapidly colonising Northern Belgium

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Abstract

Till ten years ago, *Cucujus cinnaberinus* (Scopoli, 1763) was largely restricted to Eastern Europe and Scandinavia and likely extinct in entire Western Europe. In 2014, the first observation was done in Belgium. Since 2017, large populations have been found spreading quickly throughout Flanders. Currently, the species has spread over large areas in Flanders but is not yet reported from Wallonia. Here, we report on the spreading distribution and habitat preference in Flanders as well as proposing a standardised data sampling for future monitoring.

Keywords: Habitat Directive species, flat bark beetle, saproxylic beetle

Samenvatting

Tot tien jaar terug was *Cucujus cinnaberinus* (Scopoli, 1763) hoofdzakelijk beperkt tot Oostelijk Europa en Scandinavië en wellicht uitgestorven in heel Westelijk Europa. In 2014, werd de eerste observatie gedaan in België. Sinds 2017 worden grote populaties gevonden die zich snel verspreiden doorheen Vlaanderen. Momenteel heeft de soort zich verspreid over een groot deel van Vlaanderen maar werd nog niet gerapporteerd in Wallonië. Hier rapporteren we over de toenemende verspreiding en habitat voorkeur in Vlaanderen. Daarnaast stellen we ook een standaard protocol voor data inzameling bij verdere monitoring.

Résumé

Jusqu'il y a dix ans, *Cucujus cinnaberinus* (Scopoli, 1763) était largement limité à l'Europe de l'Est et à la Scandinavie et probablement éteint dans toute l'Europe occidentale. En 2014, la première observation a été faite en Belgique. Depuis 2017, de grandes populations se propagent rapidement dans toute la Flandre. Actuellement, l'espèce s'est répandue sur de vastes étendues en Flandre mais n'est pas encore signalée en Wallonie. Ici, nous rendons compte de l'expansion géographique et de la préférence d'habitat en Flandre et proposons un protocole d'échantillonnage de données standardisé pour un suivi futur.

Introduction

The Cucujidae or Flat bark beetles is a small family represented by 8 species in Europe belonging to the genera *Cucujus* (4) and *Pediacus* (4) (THOMAS 2011; GUTOWSKI *et al*., 2014; BONACCI *et al*., 2012). In Belgium, *Pediacus depressus* (Herbst, 1797) and *Pediacus dermestoides* (Fabricius, 1792) have been known to occur while *Cucujus cinnaberinus* (Scopoli, 1763) has colonised rather recently (CRÈVECOEUR *et al*., 2017). The Cucujidae are recognised as extremely flat, often brown or red, beetles living as saproxylic insects under the bark.

Larvae of *Cucujus cinnaberinus* live under the bark of recently died trees where they feed on a combination of fungal hyphae, decomposing bark fibers and animal products, the latter originating from predation as well as carrion (HORÁK, 2011; PRIKRYL *et al*., 2012). The species depends on sufficient amounts of dead wood with large diameters (HORÁK *et al*., 2010; ECKELT *et al*., 2014; VREZEC *et al*., 2017). *Cucujus cinnaberinus* has been included in Annex II of the European Habitats Directive meaning that member states must outline protected areas for this species, report on the conservation status and measures taken for this species.

For a long time, *C. cinnaberinus* was mainly found in Scandinavia, Central and Eastern Europe (HORÁK *et al*., 2008, 2010). It also occurred in Western Europe but it is known from only a few old records (Spain: HORÁK *et al*., 2008, 2010 and Italy: MAZZEI *et al*., 2011). Up to ten years ago the most western populations were in Austria, Bavaria and Norway (HORÁK *et al*., 2008). Since then the species increased over Central-Europe, becoming more common especially in river valleys (e.g. ECKELT *et al*., 2014). Starting from 2002, the population in southeast Bavaria spread to other locations in Bavaria (www.colkat.de). In 2003, the first record was found in the western part of Germany, namely Baden-Württemberg (REIBNITZ, 2008). Since then no in-between populations have been found which seems to confirm that the species colonized this area over a large distance. Since 2012, the species was found in adjacent areas in Hessen (Ginshei Gustavsburg, Nonnenaue and Großen Goldgrund: SCHAFFRATH, 2014, in 2016 in Rheinland-Pfalz (www.colkat.de) and in 2017 in Nordrhein-Westfalen (THOMAES *et al*., in press). This population is connected to the colonization in the Netherlands, Belgium and France.

In North-Germany, a sudden colonisation started in Mecklenburg-Vorpommern (2009, www.colkat.de) and later in Brandenburg (2014: ESSER & MAINDA, 2016; MAINDA & WENDLANDT, 2019), in Schleswig-Holstein (2016: HORREN & TOLKIEHN, 2016) and finally in Sachsen-Anhalt (BÄSE, 2018). Also, in Austria, the species increased significantly and colonized many new federal states (ECKELT *et al*., 2014). In 2009, the species was rediscovered in Italy (since 1960: MAZZEI *et al*., 2011). In the French Alsace region, the species is being found along the Rhine since 2014 (FUCHS *et al*., 2014).

In the Netherlands, the species was discovered in 2012 in the valley of the Dommel, only a few kilometres from the Belgian border (COLIJN & NOORDIJK, 2012). The species strongly spread in the Netherlands since then and colonized the Warmbeek (NOORDIJK *et al*., 2017b), Groene Woud, Bergsche Maas and Zuid-Limburg (NOORDIJK *et al*., 2017a) and finally reached Gelderland (NOORDIJK *et al*., 2018).

After the discovery of the species in the Netherlands, we started searching for this species in the Belgian parts of the Dommel and Warmbeek valley, adjacent to the Dutch sites. Two adults were found in the Warmbeek valley in 2014. But it took until 2017 before we could find more evidence of its presence, as at that time it had established populations in the Belgian part of the Warmbeek valley and other areas (CRÈVECOEUR *et al*., 2017).

Since then, the species has been monitored more structurally in Flanders (Northern Belgium). Here, we report on this monitoring and the habitat used by the species.

Material and methods

Study species

Adults of *C. cinnaberinus* are 11 to 15 mm long. The head and thorax are shiny red at the dorsal side, while the elytra are matte red. The head has strongly pronounced temples giving the head a triangular habitus and making the head wider than the thorax. The thorax has a somewhat square form. The legs, antennae, eyes and mandibles are black as well as the entire underside of the beetle. The tarsi are dark brown (Fig. 1). The related East European *Cucujus haematodes* Erichson, 1845 has red mandibles, a more rounded thorax and a more uniform red colour at dorsal side.

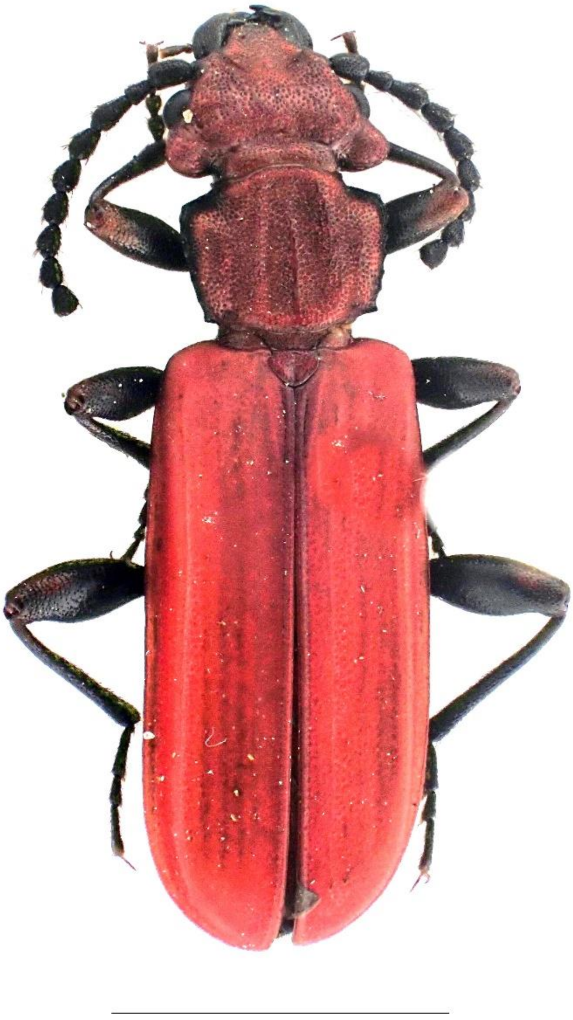

Fig. 1. Habitus of *Cucujus cinnaberinus*, ex larva on 7.iii.2017, De Warande, Hamont-Achel, Belgium, leg. A. Thomaes, scale bar 5 mm. © Frederik De Wint.

The larvae of *C. cinnaberinus* are 20–26 mm long and 3–3.25 mm wide and flattened. They are yellow to orange in colour. The last (eighth) segment has 4 cerci (urogomphi) (Fig. 2). The larger middle cerci are curved at the base while the apexes remain nearly parallel. The last segment is of similar length as the other segments while the last segment of larvae of *Pyrochroa* spp. (which have a similar habitat) are a bit more than twice as long as the other segments.

Furthermore, *Pyrochroa* spp. larvae are paler and bear two straight cerci. *Schizotus pectinicornis* has a slightly elongated last segment and 2 strongly curved cerci with apexes not parallel. Larvae of *Pediacus* spp. are white, the last segment is about three times the length of the other segments and the cerci are fused to a Y-shaped spine. Larvae of *C. cinnaberinus* and *C. haematodes* are less easy to distinguish, but the last is only known from Eastern Europe. In *C. cinnaberinus*, the frontal suture (dorsal view of the head) has a bell-shaped form and the base forms an obtuse angle (> 90°) with the body line. In *C. haematodes*, the frontal suture is fluke shaped and the base makes an orthogonal angle. A spine placed on the large inner cerci is placed below the base of the cerci in *C. cinnaberinus* and at the base in *C. haematodes* (Fig. 2, GUTOWSKI *et al*., 2014).

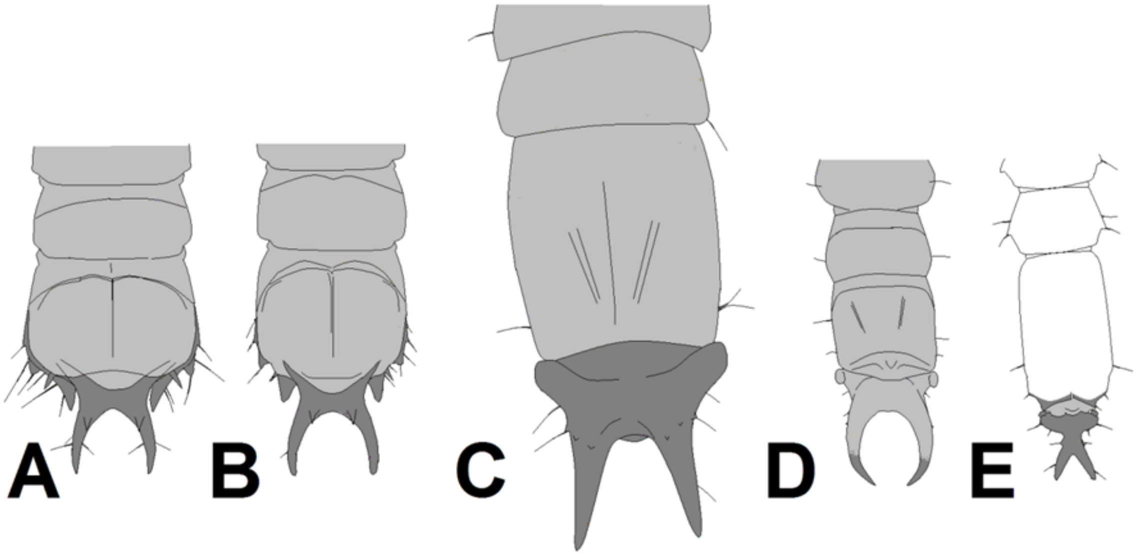

Fig. 2. Last larval segments of A, *Cucujus cinnaberinus*; B, *C. haematodes*; C, *Pyrochroa coccinea;* D, *Schizotus pectinicornis* and E, *Pediacus* spp. (A and B after GUTOWSKI *et al*., 2014).

Species monitoring

In the initial years, sites were visited rather ad hoc, based on expected appearance and suitability of the habitat. In the course of several internships and thesis projects, a standardised monitoring evolved. Finally, a well-defined monitoring protocol was worked out (THOMAES *et al*., 2019). For this a map with potential habitat was made for Flanders, defined as high green vegetation from the Lidar greenmap of Flanders (AGIV, 2012) within 50 m buffered wetlands (DECLEER *et al*., 2016: code 50 to 81 and 120). This resulted in 1087 ha of potential habitat in Flanders (0.08% of the surface). Secondly, we calculated the amount of potential habitat within protected areas (nature reserves as well as other areas managed by the Agency for Nature and Forest) for each utm 1×1 km square unit. In each of the 36 Flemish ecodistricts, the squares with the highest area of potential habitat within protected areas were selected for monitoring, leading to 49 squares that will be monitored in the future.

To monitor a square, three to five locations (stands) are selected. In each stand, maximally three suitable trees are studied. Suitable trees died two to three years ago, preferably have a rough bark and large diameter (> 40 cm) and stand on moist to wet soils. The bark is still well attached and under the bark a red to brownish coloration is present.

Field work was mainly done in winter but larvae can be found year-round. Bark is removed with a claw hammer and the fibrous material under the bark is studied carefully. The bark is removed over about 2 m of the trunk and half of the circumference. However, to minimalize impact, we stop removing the bark as soon as *C. cinnaberinus* is found.

From each tree, the following data is gathered: coordinates, site, observer, date, tree species, circumference at the place of investigation, position (standing, lying, or hanging), number of larvae/adults of *C. cinnaberinus* present and area investigated (calculated as an oval with length and width of the debarked area). Hanging trees are trees that have fallen but are not touching the ground as they lean on other standing or fallen trees or on their branches. Some characteristics were only noted initially such as bark cover, canopy closure and co-existence with *Pyrochroa* spp. and rhizomorphs of *Armillaria* spp. However, it was soon clear that in order to find the species, degree of bark cover needs to be high (at least on the part of the log that is investigated) and co-existence with rhizomorphs and *Pyrochroa* spp. can occur but there is no requirement neither. The species occurs under both open and closed canopies (which can be quite dynamic in such stands and sometimes it is difficult to assess during winter).

Besides these initial monitoring efforts, accidental findings have been reported and a few specimens have been found in various traps. This has resulted in data from 132 sites studies (including initial studies, accidental findings and various traps) and additional data from 471 single tree investigations (not included in the site data) by combining data from the authors and waarnemingen.be (Natuurpunt & Stichting Natuurinformatie, 2020). Tree characteristics explaining presence and absence were analysed by Chi^2 analysis in R4.0.2.

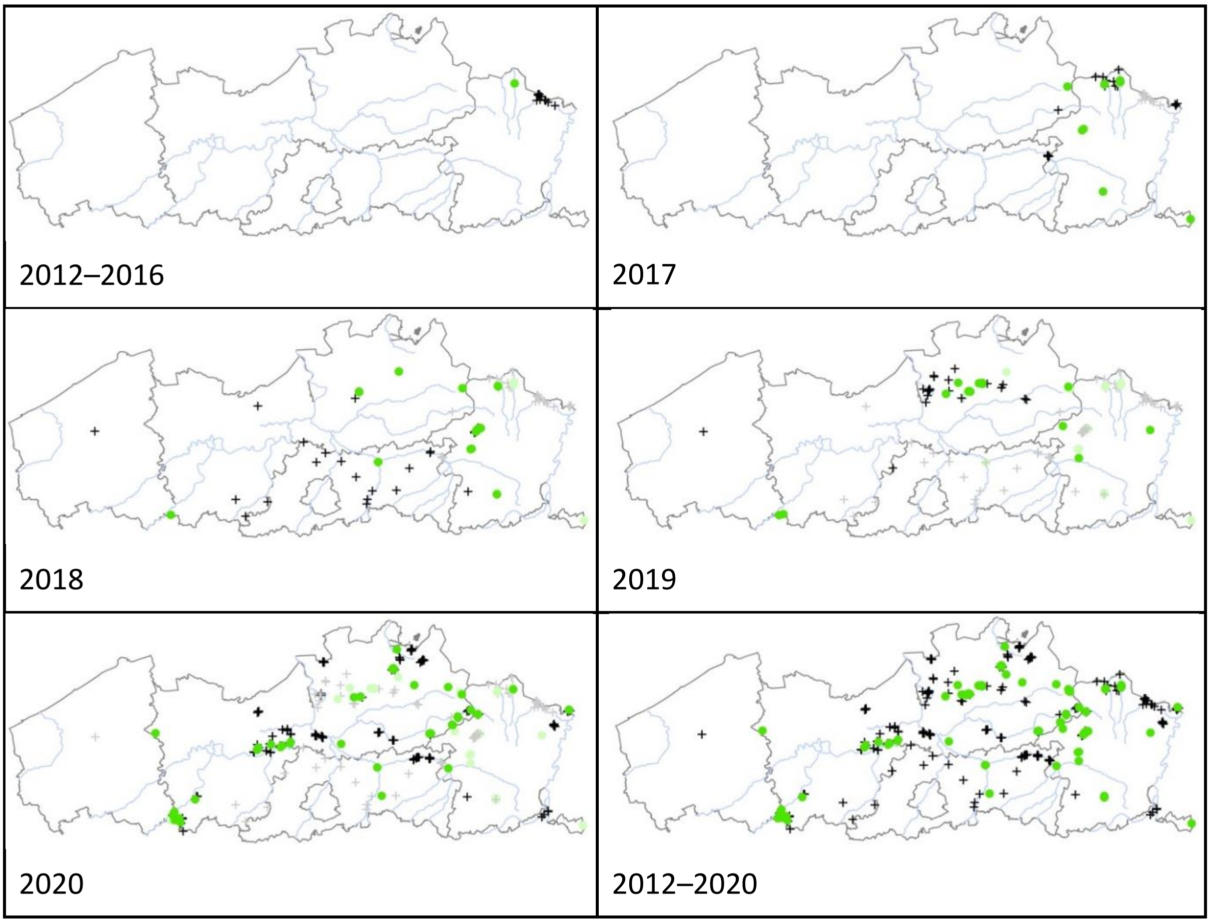

Fig. 3. Presences (green dots) and absences (black + crosses) of *Cucujus cinnaberinus* during the consecutive years of study. The records of the previous years are added as pale green dots and grey crosses.

Statistics

Presence/absence data of *C. cinnaberinus* at tree level was compared with tree species (grouped as in Fig. 5), circumference classes and position of the tree by a Chi²-analysis. This test statistic is designed to compare two categorical variables, Chi² represents the value of the calculated test statistic, df represents the degrees of freedom (the number of categories – 1) and p represents the possibility that the observed pattern results from a random distribution. If p is smaller than 0.05 (5%) than a random distribution is assumed unlikely and a non-random distribution (in this case a species preference) can be considered significant.

Results

Currently, the species has been found in all Flemish provinces (Fig. 3). In province West Flanders, the species has only been found at one site yet but its presence needs further investigation here. After the discovery of this species in the Netherlands in 2012, we tried to find the species in adjacent areas in the northeast of province Limburg and finally two specimens were found in 2014 in the valley of the Warmbeek. The species was not found again till 2017, when already large numbers of larvae seemed present along the Warmbeek. The same year, the species was also found in several other sites in provinces Limburg and Antwerp. In 2018, the species was looked for systematically in province Flemish Brabant leading to one observation (MARCHAND, 2018) and habitat preferences were studied in the nature reserve of Zwarte Beek (LAMMERANT, 2018). The species was also discovered in province East Flanders and some additional sites in Antwerp and Limburg. In 2019, a region in the centre of Antwerp was systematically investigated (KARIUKI, 2019) leading to the discovery of the species at several new sites. Finally, in 2020, the remaining areas of Antwerp as well as the valley of the Scheldt in East Flanders were investigated with again newly discovered populations (DAKA, 2020). Dead wood beetles are generally well studied in Flanders which can be illustrated by a map of observations of *Pyrochroa* spp. larva (Fig. 4). This map can help to interpret the colonization of *C. cinnaberinus* in Flanders.

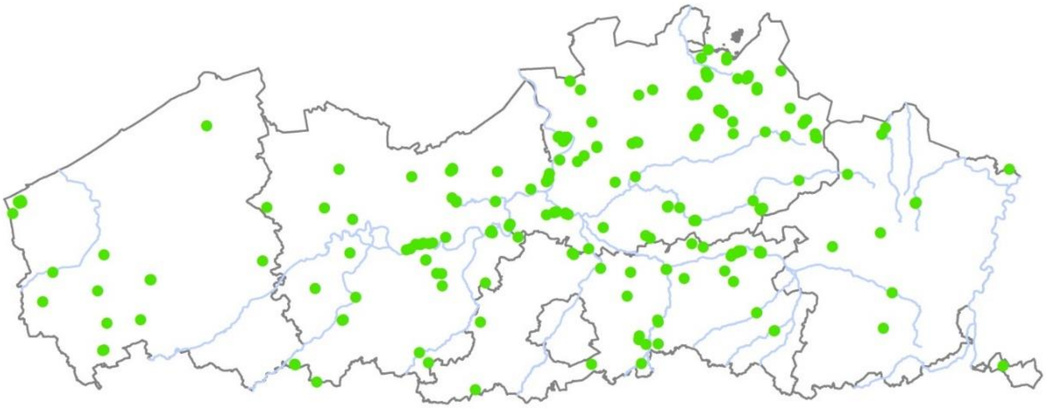

Fig. 4. Observations of larva of *Pyrochroa* spp. between 01.i.2015 and 19.iii.2020 based on waarnemingen.be (NATUURPUNT & STICHTING NATUURINFORMATIE, 2020, n=275).

From 474 trees and logs detailed measurements were noted, including 78 trees for which the presence of *C. cinnaberinus* was confirmed. Trees investigated included *Populus* (n=343), *Quercus* (51), *Pinus* (22), *Alnus* (19) and *Salix* (18) besides *Abies*, *Acer*, *Betula*, *Fagus*, *Fraxinus*, *Larix*, *Picea*, *Prunus* and *Tilia* (with all less than 10 trees investigated per tree species). The presence of the species differs significantly for tree species (Chi²: 19.164, df: 6, p: 0.00389). In *Populus*, the species is significantly more present than in *Quercus* (Chi²: 7.2056, df: 1, p: 0.007268) but not more than in *Pinus* (Chi²: 0.27595, df: 1, p: 0.5994, Fig. 5). In this study, the species hasn't been found on *Salix* and *Alnus* but these trees are still underrepresented in the sample.

The circumference varied from 15 to 340 cm (n=449). There is a clear trend of increasing presence with increasing size of the tree up to 200 cm circumference (Fig. 6). The species is significantly more present in stems with a circumference above 100 cm compared to smaller trees (Chi²: 5.4524, df: 1, p: 0.01954). For very large trees, the trend seems to gradually decline again but this group is represented by lesser trees as well (generating larger uncertainties). As the tree species differ in circumference, the absence on *Alnus* and *Salix* might be explained by the lower circumference in our dataset (mean ±s.e. 50 ±5 cm and max. of 104 cm and 71 ±8 cm, max. 160 cm respectively). Moreover, the *Populus* trees include the highest circumferences (129 ±3 cm, max. 340 cm) which could explain the preference for this tree species.

The position of nearly all trees was noted and nearly half were lying trees (n=232), next to standing (n=134) and hanging (n=105) trees. The presence differs between positions (Chi²: 6.7612, df: 2, p: 0.03403) and is significantly lower in hanging trees (Chi²: 5.017, df:1, p: 0.0251) but not significantly higher in standing trees (Chi²: 2.663, df:1, p: 0.1027). Standing trees in our dataset have a higher circumference (mean ±s.e. 154 ±6 cm and max. 340 cm) compared to hanging (104 ±6 cm, max. 260 cm) and lying (102 ±3 cm, max. 280 cm) trees. The higher presence of the species in standing trees might thus be related to the higher circumference.

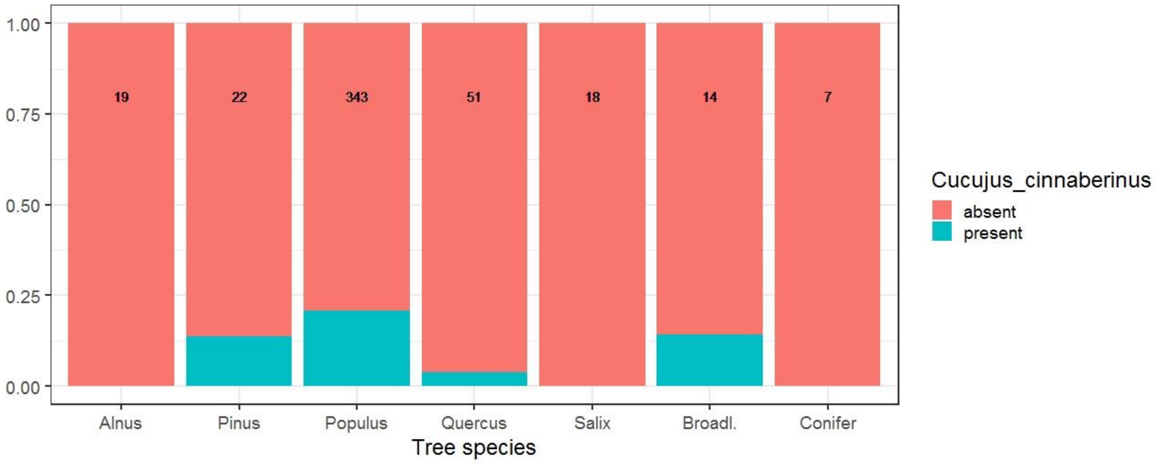

Fig. 5. Presence and absence of *Cucujus cinnaberinus* in different tree species with number of trees investigated (n) plotted on the bars.

The length of the tree or log investigated was only recorded for 68 trees or logs and varied from 2.4 to 27 m. These data are too limited to allow for further analysis.

For 375 trees, the density of the specimens was calculated as number of specimens per area investigated but this included only 39 trees with presence of *C. cinnaberinus* (mean ±s.e. 14.9±2.8 /m² for trees with presence).

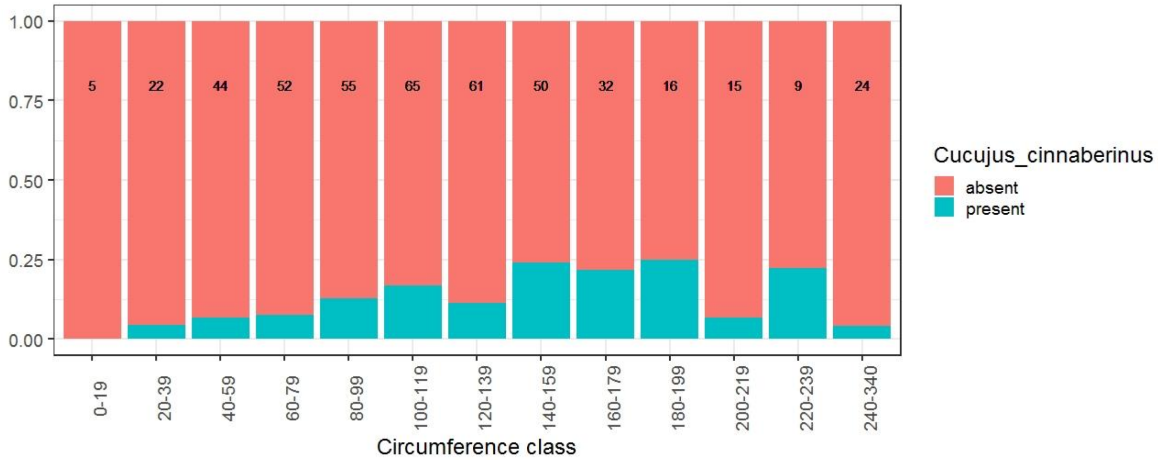

Fig. 6. Presence and absence of *Cucujus cinnaberinus* in different trees grouped by diameter class with number of trees investigated (n) plotted on the bars.

Larvae were found much more often than adult beetles. From the tree data, the species was present in 72 occasions including only 6 observations with adult beetles (sometimes co-occurring with larvae). For the other (location based) observations, there are 19 observations which include adults out of 53 positive observations. This higher value for this last category is explained as this category includes all accidental findings of the beetle as well as beetles found in traps.

Discussion

Cucujus cinnaberinus has colonised a large part of Flanders in a short period of time. The species was extinct in the few known localities from Western Europe and not reported from Belgium before 2014. The study in Flanders seems to limb behind the colonisation so no actual proof of the colonisation process can be presented. However, the observations of *Pyrochroa* sp. larvae from the same period in the entire region show that volunteers look and report larvae under the bark. As these records did not include records from *C. cinnaberinus*, this can be considered indirect evidence of their former absence and steady colonisation. Still the species hasn't been found in Wallonia despite various attempts to search for it. It is unclear what can be the reason. Likely, one reason is that the preferred habitat, old poplar plantations taken out of management, is less present than in Flanders. Secondly, the research is less intense but possibly also other factors are important such as the lower amount of alluvial areas.

The main habitat in Flanders seems to be former managed poplar plantations. Many of these forests were planted in the second half of the last century on drained soils in alluvial areas by converting former meadow and alluvial forests. In the last three decades a growing number of these areas have been bought by the Agency for Nature and Forest and by Nature NGOs and maintained as unmanaged nature reserves. Under these circumstances, these areas quickly evolve to sites with large amounts of thick dead wood. Furthermore, stopping the maintenance of the original drainage systems helped to restore the wet character of these sites often facilitating the dying of poplar trees. Nearly all observations have been done in sites characterized by: 1) high amounts of thick dead wood and 2) moist to wet soils (cfr. BUSSLER, 2002; HORÁK *et al*., 2010; ECKELT *et al*., 2014; VREZEC *et al*., 2017; GOCZAŁ & ROSSA, 2017) so we believe these two elements are key to the species habitat. These two requirements were also lacking in most alluvial forests in large parts of Western Europe till three decades ago as most sites were drained and hardly any dead trees were left in the forest, explaining the absence of *C. cinnaberinus* in former days. Several observations show a less typical habitat with limited amounts of dead wood or on drier sites but these observations seem to be related to nearby large suitable areas and should thus be interpreted as temporary stepping stones.

A preference was found for a large tree diameter which is in line with many previous studies (GOCZAŁ & ROSSA, 2017; VREZEC *et al.*, 2017; BEŁCIK *et al.*, 2019). We also found a preference for poplar trees but this might be related to their larger diameter rather than the tree species itself. The current data set is not large enough to disentangle these effects properly. Previous studies found the species in more than 18 different tree species (see THOMAES & MARCHAND, 2019 for an overview). Also other studies found a preference for certain tree species but the preferred tree species seem to differ regionally (BUSSLER, 2002; MAZZEI *et al.*, 2011; ECKELT *et al.*, 2014; BRANDMAYR *et al.*, 2016; VREZEC *et al.*, 2017), likely explained by the local availability of thick dead trees (besides a preference for thick bark: HORÁK *et al.*, 2010; VREZEC *et al.*, 2017) rather than a preference for the tree species itself. We also found a lower preference for hanging trees compared to standing and lying trees but in general no preference is assumed and only ESSER & MAINDA (2016) mention a preference for lying trees.

We think the species will likely remain present in currently colonised areas in Western Europe and will likely spread further at least in the Northwest European lowlands. Consequently, we estimate the species will colonize most of Flanders and likely also Wallonia. However, the high requirements for fresh dead wood mean that the species will mainly be limited to reserves or other unmanaged areas (e.g. key habitats in larger managed forests) and thus remains a good indicator of high amounts of dead wood in alluvial areas. We strongly advise managers to choose for a natural succession from planted forest to natural habitat. Alternatively, managers sometimes cut down the non-native trees as initial management realising the unmanaged reserve. This is however detrimental for many species dependent on a certain forest structure and dead wood. Furthermore, especially on alluvial soils the harvest can compact the soil and be problematic for the soil dwelling fauna (e.g. KOIVULA *et al.*, 2002; JOHANSSON *et al.*, 2016; NAGY *et al.*, 2016).

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